

# Protecting Organic Seed Integrity

The Organic Farmer's Handbook to GE Avoidance and Testing



Organic Seed Growers and Trade Association  
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# Protecting Organic Seed Integrity: *The Organic Farmer's Handbook to GE Avoidance and Testing*

## ORGANIC SEED GROWERS AND TRADE ASSOCIATION

*The Organic Seed Growers and Trade Association (OSGATA) is a national non-profit membership organization committed to protecting, promoting, and developing the organic seed trade and its growers, thereby assuring that the organic community has access to excellent quality organic seed, free of GE contaminants and adapted to the diverse needs of local organic agriculture.*



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## Executive Summary

The agricultural landscape of the United States includes a breadth of different growing practices, often broken down into these three basic categories: organic, conventional, and genetically engineered (otherwise known as genetically modified, transgenic, or biotech). While genetically engineered (GE) crops are often discussed for their widespread adoption in certain commodity sectors, the organic sector, between 1995 and 2011, has been steadily on the rise [15]. Sales for organic products totaled \$81.3 billion in 2012, and a growth rate of 14% is anticipated, within the organic sector, between 2013 and 2018 [24].

Growth in the organic industry, in large part, reflects consumer demand. Consumers are also the driving force behind in-country GE labeling efforts, with a March 2013 *Huffington Post* poll finding 82% of Americans supporting mandatory labeling [91].

While mounting consumer support bodes well for the organic industry, the loose regulatory framework concerning the coexistence of these differing agricultural practices is a direct threat to organics [27]. Often relegated to the sidelines as specialty crops, the organic interests are not front and center in the debate of how the differing agricultural sectors can exist and prosper side-by-side. Instead the onus is put on organic and non-GE farmers to maintain seed and crops free of GE genetics [73].

**Organic crops grown with GE contaminated seed will inevitably yield a contaminated crop. GE contamination, however trace, is unacceptable.**

The very definition of organic, as regulated by the USDA National Organic Program (NOP), prohibits GE practice and deems it an excluded method [27]. Contamination of organic crops by GE crops—whether via cross-pollination or inadvertent seed commingling within the supply chain—can, and has, resulted in market-determined economic losses for individual farmers, as well as losses in consumer confidence. Future ripple effects could irreparably tarnish the organic brand as a whole.

The organic seed industry is at the same time especially vulnerable to transgenic contamination and also a crucial link to reducing contamination. Organic seed, which by definition is free of GE genes and other contaminants, is one of the foundations of organic agriculture. Organic crops grown with GE contaminated seed will inevitably yield a contaminated crop. GE contamination, however trace, is unacceptable.

While compromised organic seed integrity has broad-reaching impacts on the viability of organic farms and the credibility of organic products, contamination also presents liability issues. Organic farmers face threat of patent litigation due to contamination [4].

Seed is produced in fields and thus is subject to, even in the best cases,

potential contamination from various sources. In order to limit GE presence in organic seed, growers need to become educated about best practices for contamination avoidance.

This handbook provides a one-stop tool to help farmers, as well as seed handlers and seed companies, to maintain genetic purity in organic seed and organic food crops.

It offers pertinent guidance on seed contamination avoidance for the following at-risk crops (those with USDA-approved GE counterparts currently in commercial production): corn, soybean, cotton, alfalfa, papaya, canola (*Brassica napus* and *B. rapa*), sugarbeet, and squash (*Cucurbita pepo*). Crop-specific testing protocols have also been assessed as testing is critical for early detection of contaminated seed lots, to prevent further dispersal through trade channels.

Recommendations for avoidance and testing have been synthesized through an assessment of international literature, as well as solicited input from organic farmers, seed company professionals, and seed breeders familiar with isolation and purity concerns.

Through this analysis, we have outlined avoidance strategies and testing practices based on both crop specifics and scale of production.

While specifics are geared to crops currently at-risk, the process for determining best management practices remains the same for other crops and is helpful in assessing risk management for potential future GE crop releases. The impact of GE field trials on contamination risk is also addressed.

In addition, sections of the handbook are dedicated to economic burdens and farmer liability concerns.

Maintaining seed integrity will ensure that organic farmers and consumers have access to organic products, now and in the future.

# PART ONE

## Introduction

### What is the Risk?

To establish the importance of protecting organic seed integrity, it is critical to understand the climate of risk in which organic seed crops are grown. Independent of which production system a farmer chooses—whether organic, conventional (non-GE), GE, or a composite enterprise system—the widespread adoption of GE crops in the landscape of commercial agriculture will affect their farm operation [70].

Since the first approval of GE crops for the American marketplace in 1994, GE crops have grown to become part of the agricultural mainstream. In 2011, American farmers planted 170 million acres of GE corn, soybeans, cotton, canola, sugarbeets, alfalfa, papaya and squash—with the latter two crops accounting for minor acreage. That is nearly 270,000 square miles, or the approximate size of the state of Texas. In 2011, GE crops comprised: 88% of the field corn, 94% of soybeans, 95% of sugarbeets, and 90% of cotton planted in the U.S. [55].

Most of these crops contain genes that provide the individual plant with resistance to pests, such as Bt corn with resistance to corn earworm or root worm, or resistance to herbicides, like Roundup Ready™ soybeans with resistance to glyphosate [55, 70]. These crops can contain single GE traits or multiple traits. The latter are referred to as stacked [55].

In the process of genetic engineering, scientists use molecular techniques in the laboratory to: isolate a gene from one organism (or specific variety of organism), engineer the gene for expression in a different organism using recombinant DNA methods, and transfer the gene to the new organism or variety. This gene produces a new protein, that is responsible for the novel GE trait. Because the gene has integrated into the nuclear DNA and become part of the germ line, it is also transferred to its offspring. For example, a second



generation Bt corn plant will also express the Bt trait [55].

Classical breeding (also known as conventional or traditional breeding) is different from genetic engineering in that it uses traditional methods of hybridization and selection to recombine genetic variation from different varieties within a species, or among closely related species. The methods utilized in plant breeding are effective in manipulating traits in the context of an organism's interaction with its environment. In this way, classical plant breeding designs a plant to evolve with its stressors and allows for its genes to achieve adaptation naturally, with expression at many levels. Genetic engineering swaps this multifaceted, whole-systems approach for manipulation of one to a few genes [82].

Hundreds of other novel GE traits, from drought tolerance to higher vitamin concentrations, are in the laboratory and field test stages, but have not been, and may never be, commercialized in the U.S. [55]. Prior to commercialization, GE crops are typically field tested for several years in open environments, allowing for additional opportunities for cross-pollination and/or seed mixing [66].

Concerned organic seed growers wishing to buffer their seed crops from potential contamination sources are disadvantaged here, as many of the GE crops in the trial stage are considered confidential business information.

**Widespread GE production, coupled with the fact that GE traits will pass to offspring, poses a threat to coexistence between the disparate farming sectors within a global agricultural context.**

A public database, Information Systems for Biotechnology (ISB), provides basic USDA records on field trials. Farmers can search the information and find out what GE crops are being grown in their respective state, and the acreage, but the exact trial locations are not provided [66].

Between 1987 and 2012, some 10,000-15,000 field trials have undergone USDA's regulatory process [55, 66]. Of those genetic traits listed on the

USDA's public record, over 5,000 apply to just three crops: corn, soybean, and canola [66]. Some crops deregulated but not commercially in production at this time include: wheat, rice, chicory, carnation, potato, tomato, and creeping bentgrass [45].

Widespread GE production, coupled with the fact that GE traits will pass to offspring, poses a threat to coexistence between the disparate farming sectors within a global agricultural context.

Many consumers wishing to avoid GE foods have turned to the organic label. Under the federal standards, genetic engineering is an excluded method in organic production systems. Organic certification is process-based: growers cannot knowingly use excluded methods and must practice avoidance principles, but are not necessarily required to test for GE content prior to achieving certification. Organic products will therefore only contain GE

ingredients as contamination and not by design.

Some manufacturers have started to voluntarily label products as GE-free, and at least one third-party product verification program has implemented a program of traceability and testing. However, no government system currently exists to vet or enforce the accuracy of independent label claims or seed purity [55].

Perhaps additional regulatory oversight is not far off. Starting in the fall of 2012, the National Organic Standards Board (NOSB)'s Ad Hoc GMO Subcommittee has invited public comment on the issues of seed purity to determine a framework for maintaining organic seed integrity.

## **GE Contamination is Real**

GE crops have quickly become a major feature in the American landscape since the deregulation and commercial acceptance of the first GE crop in 1994. The biology of gene flow is undeniable: pollen and seeds move beyond farmers' fields, via natural and human-aided processes. There is no exception for crops that are genetically engineered.

According to a 2005 report on GE contamination, 39 countries across five continents had been affected by GE contamination since that inaugural planting year. This is nearly twice the number of countries with approved plantings of GE crops at that time. Most of the incidents were associated with corn, soybean, canola, and cotton. Other incidents were related to GE crops still in the field trial stage including: grass, plum, and rice [44].

In a 2006 presentation, Mike Gumina, of Pioneer Hi-Bred International, discussed the predicted presence of GE material in non-GE corn crops based on the market penetration of GE crops within a geographic area. At 50% market penetration of a GE crop, the predicted rate of contamination to non-GE crops within that area is approximately 0.21%. Gumina projected that market penetration could reach 80% in some areas by 2016; at 80% penetration the predicted GE contamination rate is 0.33%. These numbers reflect single gene outcrossing and will be higher in regards to stacked GE crops. In regions of the country with high GE market saturation, it may become impossible to maintain genetic purity in organic seed [74].

One of the best documented examples of GE genes moving in unintentional ways is the case of StarLink corn. This GE variety was approved for animal consumption but ended up in processed products destined for dinner tables across America, causing a national recall in 2000 [65]. By then, Starlink genetics were widespread in the U.S. corn seed supply, persisting there for the following three years. Seeking to avoid a recurrent introduction within the nation's food supply, the USDA initiated a buy-back program targeting the contaminated corn seed. In 2001, the U.S. government announced it would spend around \$20 million on recovering the rogue seed [32].

While concrete data on GE contamination is limited, evidence that it can occur in unsuspected ways is accumulating. Take, for instance, the June 2013 discovery of a non-approved GE wheat in an Oregon wheat field, for which

testing had ceased in 2003. Just a few months later, in September 2013, a conventional alfalfa hay crop in Washington State underwent testing which confirmed GE contamination [41]. Glyphosate resistant bentgrass trialed on the Warm Springs Indian Reservation in Oregon and Canyon County, Idaho, is another example of GE genes escaping containment. The GE bentgrass in Idaho apparently jumped the Snake River to be found in Malheur County, Oregon [59,63,103].

The numbers that do exist should draw attention to what appears to be a precarious situation facing the world's organic food supply. Independent tests performed in 2003 and 2004 by the Union of Concerned Scientists on the traditional seed supply of corn, soybean, and canola, sourced from some of the largest seed companies in the country, showed pervasive GE contamination of seed resources. Data analysis of genetic tests conducted by two independent laboratories led them to extrapolate that seed contamination already existed within the range of 0.05 to 1.0 percent [66].

While the Union of Concerned Scientists study is ten years old, the data remains relevant—especially as many growers are disinclined to disclose information regarding GE contamination due to fear of market rejection, loss of consumer confidence, and legal jeopardy for unauthorized possession of patented seed technology.

## The Future of Organic

GE contamination within the organic seed sector is especially harmful to the organic industry. For that matter, GE contamination in conventional seed, which may be allowed in organic operations, is equally damaging. Pure uncontaminated seed is the base of the global food supply [66]. Once the integrity of organic seed has been compromised, the integrity of the entire organic system will follow [53]. Furthermore, the reproductive nature of seed negates the concept of low-level contamination. Plants grown from contaminated seed continue to act as avenues for release of contaminated genes [66].

**Pure uncontaminated seed is the base of the global food supply. Once the integrity of organic seed has been compromised, the integrity of the entire organic system will follow.**

Genetic engineering is an excluded method under the National Organic Program (NOP), as outlined in section 205.105. Many organic farmers shun GE technology on principle [27]. Likewise, consumers expect that organic foods will be free of GE contaminants [53, 66]. In fact, buying organic is often publicized as the only reliable method for avoiding GE products in the absence of adequate labeling. GE contamination strips the freedom of choice for farmers and consumers alike. It could also lead to monetary losses to organic growers as once higher price-fetching organic

products have to be diverted into the mainstream commodity sector (prices for organic products are usually higher than non-GE conventional products because of higher production costs). Perhaps even more devastating for growers is the potential loss of consumer confidence on an individual or industry-wide basis.

Unlike other defined seed contaminants (for example, presence of weed seed) there are currently no definite thresholds for GE presence in organic and non-GE seed [ 9, 27, 66]. Testing requirements to ensure that organic seed is free of genetic contaminants also do not exist. Rather, the NOP dictates production standards for certified organic crops rather than certifying the end product [27].

While the National Organic Standards Board (NOSB) recently established their Ad Hoc Committee on GMOs and Seed Purity to discuss such matters, the adoption of avoidance and testing protocols within the organic community cannot wait for regulatory oversight.

It is clear that organic farmers and purveyors of organic seed are concerned about contamination. In OSGATA's 2012 survey of organic seed growers, some respondents said they were declining to grow specific crops based on perceived risk of contamination [38].

Organic crops with deregulated GE counterparts have already been contaminated. A ten-year-old survey of organic farmers conducted by the Organic Farming Research Foundation (OFRF), found that 11% of the 17% of organic farmers testing their organic seed for transgenic content had positive results for contamination [70].

This data is reinforced by OSGATA member FEDCO Seeds, Inc. whose 2010 seed catalog outlines a zero tolerance policy on GE presence in seed lots and their resulting decision to drop varieties of sweet corn in 2008 and 2009 due to contamination [27].

OSGATA's 2012 survey also elicited various individual confidential responses detailing contamination, ranging from thousands of dollars of chard seed lost due to GE contamination to loss of established primary customers for corn [38].

Complicating the issue, organic seed integrity does not reside within the boundaries of any single nation. The global nature of the seed and food commodity trade ensures worldwide travel of GE traits. An international response is needed to adequately address the threat of potential continued GE contamination [44]. While there is presently no labeling or tolerance laws within the U.S., several countries have set tolerance levels pertaining to GE contamination of non-GE, including organic, foods. For example, the European Union has a 0.9% threshold for approved varieties and zero tolerance for non-approved varieties; Japan rejects food products with GE content above 5% [12, 27].

Our lack of in-country tolerance thresholds for GE works against the ability of organic farmers in the U.S. to compete in the current international marketplace. If farmers attempt to market crops that are not approved for export, or have adventitious presence above allowable levels, they face entire shipments being rejected by import countries [19, 46, 70].

Contamination of non-engineered seed stocks in the U.S. has further global

implications, beyond complicating our trade relationships. GE contamination can affect the seed resources and agricultural systems of developing countries. When we export contaminated seed to these nations, as either seeds for planting or as bulk products comprised of viable seeds, we run the risk of contributing to the spread of GE contamination. This is especially of concern in centers of crop diversity like Mexico, the ancestral home of corn [66]. Loss of regionally adapted varieties to GE contamination constitutes a monumental and irreplaceable loss of unique genetic diversity [96].

How do we mitigate future contamination in order to protect our shared genetic resources? OSGATA has adopted a policy on seed purity designed to be consistent with the expectations of genetic purity within the organic seed market, while also aiming to protect our genetic heritage for generations to come. OSGATA's Policy on Genetic Engineering, ratified by the membership, states that contamination of organic seed by GE seed constitutes irreparable harm to the organic seed industry by undermining the integrity of organic seed: *any detectable level is unacceptable.*

Some companies and governments are considering, or have considered, higher allowable thresholds of contamination [44]. Such considerations are harmful to the organic markets. International controversy over GE food, the increasing demand and continued growth in the organic market sector, and variable regulatory regimes across the globe beg for reliable sources of pure seed now and in the future [66].

To meet this increasing market demand, we must acknowledge that avoidance of GE contamination is a shared responsibility between growers of organic crops, non-GE conventional crops, and GE crops, as well as the GE seed technology owners. Best management practices designed to reduce the risk of contamination should be embraced by all agricultural sectors in order to ensure the integrity of organic seed [26]. The ease in which GE contamination can infiltrate the traditional seed supply puts unfair social responsibilities and unreasonable economic burdens on farmers wishing to avoid GE technology [66]. This is in addition to the risks of legal liability these growers face, as well as the potential loss of genetics and biodiversity [4, 96].

**OSGATA's Policy on Genetic Engineering, ratified by the membership, states that contamination of organic seed by GE seed constitutes irreparable harm to the organic seed industry by undermining the integrity of organic seed: any detectable level is unacceptable.**

## Contamination 101

### Clean Seed

Genetic contamination of organic seed can happen in any number of ways, from cross-pollination of crops in the field to commingling of seed at planting and



harvest, or during transport. Of the 88 documented cases of GE contamination worldwide recorded by Greenpeace from 1996-2005, 51% were cases of seed contamination (the other contamination cases involved human food and animal feed). Cross-pollination, followed by poor quality control, were cited as the main causes. Most of the contaminated seed was traced to North America [44].

Clean seed is *the* foundation for producing agricultural products that are free of GE contamination. Confidence in your seed source's integrity and knowing whether seed has been tested for adventitious presence is the absolute first step to avoidance [70].

In organic seed production, the importance of purchasing seed stock from a trusted source cannot be overstated. In the U.S., where large amounts of GE seed is planted, there has been little, if any, effort towards traceability and contamination avoidance from a regulatory standpoint [44]. As a result, organic growers and organic seed companies have long shouldered the burden of keeping the contaminants out.

Seed contamination can happen in various ways. First, GE seed can contaminate conventional seed lots before leaving the confines of the laboratory or greenhouse. GE tomato, zucchini, and corn seed have all previously entered into global distribution channels due to a combination of misidentification and insufficient quality control practices in the lab [44].

More often, inadvertent mixing occurs within the regular avenues of agriculture. Mixing can happen at planting if a farmer switches seed and does not properly clean seed planting equipment. Seeds can commingle during or after harvest in the combine or during harvest handling, in transport vehicles, and in cleaning, drying, and storage facilities [66].

In the U.S., commercial seed crops are often grown in the same region as commodity crops. As an example, corn and soybean seed are produced alongside field crops in Illinois and Iowa. Similarly, canola seed amounts to a sizeable harvest in North Dakota, the leading state for commodity crop



**Organic Floriani Flint Corn Seed.** Clean seed is the foundation for producing agricultural products that are free of GE contamination. Confidence in your seed source's integrity and knowing whether seed has been tested or not is critical to GE avoidance. Photo by Holli Cederholm.



production of canola [66].

Some seed companies have cited difficulty of producing pure seed in the U.S. as reason for relocation abroad [66]. For example, Pioneer Hi-Bred International has moved some seed production out of the U.S. into countries not growing GE crops [74].

Imported seed has its own issues regarding seed purity. Unsanctioned and potentially illegal large-scale plantings of GE crops and smaller unregulated field

**Utilizing highly trusted sources and appropriate testing for seed of at-risk crops is necessary to ensure seed integrity prior to planting**

trials have previously been discovered in Brazil (soybean), India (cotton), Romania (soybean), and elsewhere, and could lead to further contamination of neighboring and subsequent crops [44].

Utilizing highly trusted sources and appropriate testing for seed of at-risk crops is necessary to ensure seed integrity prior to planting [70].

## Gene Flow

Unfortunately, planting clean seed does not equate to a clean crop at harvest time. Every growing season offers an opportunity for GE contamination to occur under certain conditions. Clean seed does, however, eliminate the natural accumulation of GE traits within a crop when seeds are routinely saved and planted without selection [66].

Pollen flow is one source of GE contamination. If an organic crop is grown in proximity to a GE crop of the same species, neighboring transgenic pollen may result in cross-pollination and subsequent contamination [70]. Pollen movement is not limited to outcrossing crops and can occur, albeit to a lesser extent, in self-pollinating crops [63, 72].

Some small percentage of pollen may move long distances when conditions are favorable. Factors that affect pollen movement and longevity include temperature and humidity, direction and speed of wind for wind-pollinated crops, and presence and diversity of foraging insects for insect-pollinated crops. Due to the complexity of these factors, pollen can move in unpredictable and thus uncontrollable ways [31, 65]. A study tracking corn pollen found it present up to one mile above the earth, which confirms that long-range pollen transfer is virtually unavoidable. In this particular French study, viable corn pollen moved dozens of kilometers prior to settling [13].

Receptor crops within a given field are also producing pollen which will compete with foreign pollen for pollination landing sites on the stigmas of flowers. Accordingly, contamination will decrease in moving from the field's edge toward the center [92]. Typically, the smaller the field size, the greater the likelihood for receptivity from foreign pollen. If a larger GE field is situated nearby this could lead to higher rates of contamination [31].

Of course, in order for gene flow to occur via pollen, sexually compatible crops must be flowering at the same time in close proximity to one another.

While the distances in which specific pollens travel vary widely, the study of the viability of pollen is more precise: generally pollen survives just a few hours up to a couple of days [63]. High temperatures and low humidity will both shorten this window, as pollen is prone to drying out [63, 72]. Aside from pollen attributes, flower characteristics, wind, and density of pollinators all affect gene flow [83, 98].

Gene flow can occur in other ways apart from pollen, such as the dispersal of seeds or movement of vegetative growth. With perennial crops, like creeping bentgrass (still in the trial stage) and alfalfa, vegetative reproduction is a concern [63].

Viable seed is another likely avenue for contamination—whether through residual seed left in the field to germinate as future generations of volunteers or via commingling during transport or storage post-harvest [63, 65].

Mature seeds left in the field can be dispersed by natural means, including water, wind, and animals, and are a more persistent source of genetic material than pollen. Documents from Agriculture Canada have recently shown evidence of just this: Canada geese may be responsible for spreading viable GE wheat seeds from an experimental plot of the crop [87]. Seed movement via equipment and dispersal along roadways should also be considered. Characteristics pertaining to natural movement of seeds include seed size, dormancy, and average length of viability [63].

To reduce contributions to the seed bank, care should be taken during harvest and threshing. If threshing with a combine, the combine harvester should be properly adjusted and operated at the correct ground speed. Also, threshing should take place at the optimum harvest window. If too late, seeds will detach more easily and deposit in the soil [31].

Factors affecting the persistence of a seed bank include seed dormancy, soil temperature and moisture, as well as exposure to light. The potential amount of sprouting seed also depends on the amount of residual viable seed at the beginning [31]. If a crop is prone to seed head shattering, such as canola, it will contribute greater amounts [63].

Cultivation practices also affect the longevity of the seed bank. Seeds maintain dormancy longer at greater soil depths, so depleting the seed bank is best ensured by minimizing deep plowing. The seed bank can also be depleted through crop rotation and summer fallow [31].



**Turkey Red Heirloom Wheat.** One can assume that any crop with a GE counterpart, even in the field trial stage, is at-risk. Risks are especially high in terms of known commodity crops, i.e. wheat, which are trialed at higher rates. Photo by Bryce Stephens, Stephens Land and Cattle.

## Inadvertent Seed Mixing

It has long been assumed that gene flow through cross-pollination is the principal source of GE contamination, most widely affecting crops with high rates of outcrossing like corn and canola. However, the genetic contamination within traditional varieties of soybean and cotton, which are largely self-pollinating, confirms that seed mixing is indeed a critical cause of contamination [66].

There are many points within the production line for commingling to occur: at seeding and harvest, during transport and storage, and anywhere in between. Whereas pollen exchange is localized in relative proximity of the donor and receptor fields, seed holds the potential to span vast distances [28].



**Seeding Organic Cotton.** Shared planting equipment, combines, trucks, seed cleaners, and other equipment are all potential avenues for GE contamination via commingling. Photo by Sally Fox, Vreseis Limited.

Spread of contaminated seed can and does occur by human error. For example, the majority of GE contamination in Hawaiian papaya happens as a result of unaware tourists or shoppers purchasing unlabeled GE papaya and disposing of the seeds in a compost pile or along a roadside—inadvertently planting a GE papaya tree on or in close proximity of an organic farm [52].

Planting, harvest, cleaning, and transport all pose their own challenges [65]. Shared planting equipment, combines, trucks, seed cleaners, and other equipment yield adventitious presence in non-

GE crops through lack of adequate cleaning between uses. Grain transport and handling offer other opportunities for contamination [70]. On a larger scale, the existing commodity infrastructure was not designed to handle purity concerns hinged upon crop segregation when channeling grain and oilseeds to different destinations [66]. These trade channels consequently aid and abet the long-distance dispersal of transgenes [63]. Vigilance is thereby required throughout the entire lifecycle of a crop, seed to seed, and beyond, with follow-up into distribution channels.

To eliminate commingling, segregated dedicated systems for GE and non-GE grains are desirable. Otherwise, all equipment utilized for harvest, collection, cleaning, storage, and transportation must be carefully cleaned between lots [84].

Proper prior crop volunteer plant control in the field will also lessen adventitious presence at the harvest stage [63].

## The Politics of Avoidance

Clean seed, determined by adequate testing, is a must for maintaining organic seed integrity. Knowing what crops your neighbors are growing, along with their planting dates, is crucial to consider in determining a contamination avoidance strategy. Natural dispersal of pollen, mediated by wind and insects, is impossible to control. Depending on specific circumstances, isolation in time and/or space may be an appropriate measure. However, it is important to remember that the time of pollen shed is not absolute and gene flow may occur over considerable distances [63].

Some organic seed professionals advise doubling or tripling the minimum industry isolation standard when organic seed crops are being produced in the vicinity of GE crops of the same type [72].

Farmers utilizing GE technology are not mandated to disclose the location of their fields [54]. The responsibility is therefore left to individual growers wishing to maintain purity in organic and non-GE seed lines of at-risk crops to know their neighbors and their neighbors' crops, if trying to maintain isolation distances.

From 1987 to 2002, the USDA evaluated more than 8,000 field trials at more than 24,000 sites in most of the 50 states and U.S. territories [102]. Field trials included around 40 different GE food and feed crops with plantings ranging in size from a tenth of an acre to hundreds of acres, equating to a likely estimate of thousands of acres in undisclosed field trials over time. Many of these tests have been enacted in seed growing regions of the country, adding to their likelihood of acting as possible sources of contamination via gene flow [66].

One can assume that any crop with a GE counterpart, even in the field trial stage, is at-risk when GE fields are nearby [66]. Risks are especially high in terms of known commodity crops which are trialed at higher rates. The major crops trialed from 1987 to 2002 included: corn, soybeans, potatoes, tomatoes, cotton, tobacco, and wheat [102].

If a farmer's crop is deemed to be at-risk, the potential sources of contamination should be identified. The sources will vary according to farm location, scale, and particulars of cultivation. Unfortunately, a lack of transparency on an industry level hinders the process. Recognition of prospective GE contaminants must therefore start at the farm level. In talking with other growers in the area, individuals can ascertain knowledge pertaining to nearby GE acreage. However, this line of communication is complicated by absentee farmers and corporate-owned farms. Only once contamination points are identified can a grower begin to plan for best management with good growing practices [86].

**One can assume that any crop with a GE counterpart, even in the field trial stage, is at-risk when GE fields are nearby.**



## Genetic Testing

### An Overview

Testing for seed purity should happen at multiple points along the seed supply chain. Ideally seed is tested by the grower who produced the seed prior to sale and distribution by the seed company. Testing as early in the supply chain as possible makes the most economic sense. To illustrate, a grower who produces 1,000 pounds of seed and sells seed in 50-pound batches to 20 different seed companies can spend \$200 on testing the entire seed lot. To recoup costs, the grower can then add \$10 to the cost of each 50-pound bag. Otherwise the individual seed companies will each spend \$200 on testing, for a total of \$4,000 for that one seed lot.

Testing saved seed or purchased seed, if assurance cannot be obtained from the seed company that the seed lot tested clean, prior to planting will ensure a clean start. Testing saved seed prior to storage, post cleaning, will reduce the risk of storing a lot all winter, only to find it is contaminated at planting time [9].

The scale of an operation, as well as the level of reliance on shared equipment, may lend to different sampling points prior to sale. Each point of handling potentially creates another point of contamination. Testing at point of harvest may be sufficient for growers exclusively using their own equipment. Those sharing harvesting or cleaning equipment, storage facilities, or transportation may wish to test more frequently [9]. Without any such post-harvest testing, growers risk having their non-GE crops rejected in the marketplace or planting

**Testing for seed purity should happen at multiple points along the seed supply chain.**

their own crops with contaminated seed [70].

Due to the cost of testing, there is a likelihood that there will be growers and companies who do not test when they should. In order to track contamination, a formal testing regimen is necessary. All

private seed companies within the U.S. should be systematically testing their at-risk seed stocks for transgenic contamination. Breeder and foundation seed stocks are of particular concern [66].

Primarily, two groups of testing are currently used for detection of GE presence in most food and seed analysis: 1) immunosorbent assays, which analyze proteins, and 2) DNA analysis using polymerase chain reaction (or PCR) of selected transgenes. These tests are different in turnaround time, accuracy and precision, and administrative parameters (i.e. field vs. laboratory setting). Costs also vary [43, 95]. A third type based on a hemical color assay for the reporter gene beta-glucuronidase (GUS) is specific to papaya [56].

It is important to note that all genetic testing, whether protein or DNA, is limited in scope. Laboratories can only manufacture primers (used in PCR testing) for known DNA sequences, which are often referred to as transgenic events. Testing professionals only have access to DNA of deregulated, or

approved, GE crops and can therefore only test for those transgenic events [43, 66].

In other words, labs are not equipped with all primer sets necessary for assaying all GE events, especially GE crops and novel traits that are undergoing field assessments and have not been deregulated. Some crops in the field trial stage may be engineered with common promoters, such as P35S (a promoter for cauliflower mosaic virus) or T-NOS (a terminator sequence), that can be detected [66]. Others may be engineered with native promoters which regulate genes already found within an organism. These would not be detected when testing for known promoter sequences [57]. As a result, hundreds of events remain undetectable by PCR tests [66].

Special cases, like widespread contamination of traditional varieties of commodity crops with unapproved GE varieties, will lead to the availability of additional PCR tests. GE rice, which has not been approved for commercial production and remains relegated to field trials, is one such instance [21], as well as for other currently non-commercialized GE crops including flax, potato, and tobacco [48].

### Protein Analysis

Though different versions exist, all immuno-analysis tests utilize antibodies to identify specific proteins that genetically engineered DNA produce within a plant. The lateral flow strips (often called strip tests or dipsticks) are widespread in use among grain elevators as they are easy to use, relatively inexpensive, and yield qualitative results in as few as two to five minutes [95].

However, strip tests are not as accurate as ELISA (see below) or DNA PCR tests. Because they can be performed in the field, there is also a higher potential for human error. Furthermore, proteins are a product of the gene and have a tendency to vary in different environments. They are therefore not recommended as sufficient analysis for organic seed [57].

Enzyme-linked immunosorbent assays (ELISA) are the most accurate type of immunosorbent assay. ELISA are test kits, manufactured by various individual companies, and performed in a laboratory setting. They offer a higher degree of sensitivity in testing seed, grains, and leaves in comparison to strip tests, but are not as precise as DNA PCR tests. As ELISA are pre-packaged kits, the standard error likely varies between manufacturer and is often unknown [57]. ELISA takes longer than strip tests, averaging from two to four hours, but offers a level of quantitative analysis [95].

Both ELISA and strip tests are further limited in the range of proteins detected. Different events require individual testing for their presence. For example, a corn sample cannot be tested for all GE traits simultaneously and the same sample cannot be reused with different tests [57].

### DNA Analysis

Polymerase chain reaction (PCR) is the most sensitive, specific, and



reliable technology for identifying GE contamination. PCR tests are also the most costly. Although these tests take more time than protein assays (up to three days in some cases) PCR testing has nonetheless become the industry standard worldwide in GE detection [100].

PCR DNA testing provides qualitative, quantitative, and semi-quantitative analysis. Two different types of PCR testing are widely available: End-Point PCR and Real-Time PCR. End-Point PCR, which is qualitative, determines whether or not GE DNA is present in a sample. Real-Time PCR is used to provide a quantitative assessment of the level of engineered DNA present in a

**Polymerase chain reaction (PCR) is the most sensitive, specific, and reliable technology for identifying GE contamination.**

sample. Both types can be utilized circumstantially for semi-quantitative analysis, offering detection to a certain pre-defined level [43, 66]. A third type of PCR testing, digital PCR, is poised for widespread adoption by

testing laboratories due to even greater accuracy and precision in quantifying GE content at low levels [71].

With End-Point and Real-Time PCR, DNA is detected using primers, or primer pairs, which target particular sequences of DNA within a defined sample (i.e. a specific seed lot). Primers are short pieces of DNA synthesized to match DNA sequences at the beginning (the promoter) and end (the terminator) of the targeted genetically engineered DNA sequence (the coding sequence). The targeted DNA may be the entire GE gene, or just a section of it [66, 100].

Once the primers bind to the target DNA, DNA polymerase (a special DNA-replicating enzyme) multiplies copies of the target sequence in an iterative process that produces many copies. These allow for identification, through a DNA visualization process, and the rate of increase and number of copies allows for quantitative measurement. It is a complicated process which requires specific machinery operated by trained professionals in a laboratory environment [66].

PCR testing can be broad-spectrum or event-specific. The specificity of the assay depends on the targeted sequence, the specificity of the primers, and the stringency of the DNA amplification. Due to the nature of individualized testing plans, PCR testing costs are variable and tend to be rather expensive. Tests range in from cost \$75 to \$700 per sample, with prices increasing based on number of GE traits being tested. A common cost per individual PCR test is \$200 [57, 95].

### **GUS Testing**

GUS testing is used for GE detection of papaya tissue. The assay works by detecting the beta-glucuronidase protein, which is a bacterial enzyme synthesized by GE papaya as a result of the engineering process. Beta-glucuronidase does not occur naturally in non-GE papaya and is therefore

indicative of GE [22].

The GUS assay consists of soaking tissue from young papaya leaves, or seed embryos removed from their black seed coats, in a solution containing a blue dye bonded to glucuronic acid. If beta-glucuronidase is present in the papaya tissue, it will cleave the bond of the glucuronic acid, resulting in the release of the blue dye. A non-GE sample will not change color [22].

## Individualized Testing Plans

### Proper Sampling

Even though genetic testing is refined, there is still a chance for error. The sources of error generally fall into one of three categories: sampling, sample preparation, and analytical method [84]. The chance of error is thereby minimized through choosing an appropriate testing plan, including proper sampling procedures [80].

Testing a sample that is representative of the seed lot in question is critical for correct results [43]. A seed lot can consist of an entire harvest from a particular field, or just a portion of a single shipment to a buyer. In considering lot parameters, potential points of contamination should be addressed. For instance, including field sections with different spatial proximity to a known source of contaminating drift could influence the amount of contamination detected [9].

**Testing a sample that is representative of the seed lot in question is critical to correct results.**

No matter how the seed lot is designated, the sample is a subset that must embody the level of impurity that exists within it. This is achieved through random sampling: a technique ensuring that each seed has the same chance of being included for testing [80]. From a practical standpoint random sampling is difficult. Systematic sampling, the process of sampling at known and equal intervals, is easier to achieve and is assumed to be a reasonable substitute [84].

Scale further affects practicality of sampling techniques. With small lots of seed, a grower can simply mix their entire harvest, forming a homogenous composite, and randomly remove a scoop with the correct number of seeds needed for testing. This “one-scoop” can then be designated as a representative seed lot [80].

Larger growers need different sampling tactics. Their plans should be chosen based on the spatial arrangement of the seeds and their accessibility [80].

Probe sampling is one common method. It can be applied when a harvest is contained in a large open vessel, like a truck. To take a sample, the surface of the seed container is divided into an invisible grid. A probe is used to extract a sample from each square of the grid; these samples are then combined to form a composite from which to extract the seed lot [80].

Another method can be utilized for larger seed lots housed in closed

containers, like silos or the cargo hold of a ship. This systematic sampling technique requires a continuous seed flow generated by the filling or emptying of a container. To ensure a representative lot, the seed is sampled, or extracted, from the continuous flow at regular pre-determined intervals (like once every five minutes). The sample is removed either manually or with a diverter type sampling device. Again, the seeds should be mixed into a composite prior to testing [80, 84].

### Appropriate Sample Size

Knowing your testing objectives beforehand will help ensure a successful testing plan. Qualitative testing may be appropriate for indicating whether or not GE contamination has occurred, but will not reflect the extent of the contamination. Quantitative testing can, conversely, determine the extent [9].

When choosing an individual testing plan, a tolerance threshold should be determined. OSGATA's Policy on Genetic Engineering, approved by the OSGATA membership, states that *any* detectable level is unacceptable. While a zero-tolerance purity standard constitutes a higher rate of producer risk, OSGATA's membership believes that contamination of organic seed by GE seed constitutes irreparable harm to the organic seed industry by undermining the integrity of organic seed.

Theoretically, a true zero percent contamination result would be best ensured by testing individual seeds in a seed lot rather than combining seeds into a composite test [80]. Testing every seed in a lot individually would produce results with the absolute lowest margin of error. In assaying individual seeds, the exact proportion of GE to non-GE seeds can be determined. For example, testing one hundred individual soybean seeds would determine if 1 out of 100 seeds (1%) were contaminated with a significantly reduced error rate [57].

Unfortunately, this type of test procedure would be prohibitively expensive and not practical because the test itself is destructive by nature and destroys the seed [80].

Alternatively, seeds can be tested as a composite. For this, they are ground together into a homogeneous flour [80]. This is the testing norm.

Within the organic seed industry there is an on-going discussion regarding the ideal sample size. The recommended seed count for testing is difficult to standardize. As a general rule, testing for lower levels of contamination within a composite sample requires a larger sample size. For zero tolerance, taking the largest sample possible is recommended in USDA's Grain Inspection Handbook [84]. This is especially important if there is a high degree of variability within the seed lot [9]. Importantly, a single contaminated corn seed present in a 1,000 seed sample could very well result in 5-10% GE contamination in as little as one generation [57].

Again, identifying testing objectives upfront will also help individuals determine the appropriate sample size for their needs. It depends on what information an individual is trying to ascertain as well as the size of the crop in question [34, 84].

Generally, two questions arise when determining an appropriate testing

plan. 1) Can any GE content be detected in a given representative sample? 2) What amount of GE content can be detected in a given representative sample? The limit of detection (LOD) and the limit of quantification (LOQ) have different thresholds. LOD is the lowest presence of genetic material that can be detected. LOQ is the lowest amount of genetic material that can be quantified. Generally speaking, the standard LOQ in PCR testing is 0.1%; this can be pushed to 0.05% in ideal conditions. However, the LOD for PCR is often stated as 0.01% [34].

It is important to note that a testing plan really boils down to statistics and that the statistical approach differs when asking if there is any GE contamination detectable as opposed to measuring the amount of contamination present.

In terms of LOD, the probability of a PCR test detecting a single GE seed in a 3,000 seed sample is 95%. In other words, there is a 95% chance that if a 3,000 seed sample tests negative, there will be less than 0.1% GE presence in that particular sample. However, this leaves the small probability (5%) that GE content may remain undetected. The likelihood of detection increases to 99% when the sample size is increased to 10,000 seeds [34].

LOQ has different probabilities. In trying to quantify the level of contamination in a 10,000 seed lot, there is an 88% chance that the GE content will be accurately measured below 0.2%. With a 3,000 seed sample, the probability decreases to 61% [34].

These percentages represent sampling error alone and do not account for any analytical error. When trying to test for low levels of GE contamination, i.e. 0.01%, analytical error can be as much as  $\pm 30$  to 50%. The new wave of PCR testing, digital PCR, decreases this potential analytical error to  $\pm 10\%$  for an LOC of 0.01% [34].

Other considerations in sample preparation include aiming to reduce the risk of false positives and false negatives. A false positive is when a sample tests positive for contamination, when the real result is negative; a false negative is the opposite error reading [80].

Rogue seeds within a sample, like a few GE corn kernels in a soybean lot, will be detected and might contribute to a false positive result [66]. Likewise, the paper or cotton bags containing the organic seed sample for testing can skew results. One lab ran swab samples of incoming bags, probably made out of GE cotton or lined with a GE corn-derived product, and ran PCR tests resulting in contamination as high as 1.4% [57]. Internal laboratory errors can also occur if dust from one sample mixes with another [80]. Competence and integrity are important considerations to choosing a trusted testing provider.

**A testing plan really boils down to statistics and that the statistical approach differs when asking if there is any GE contamination detectable as opposed to measuring the amount of contamination present.**

### Crop Specific Considerations

In creating a testing plan, it is also important to consider that different crops



require different approaches to sampling: a papaya tree is either GE or not, while an ear of corn consists of individual pollination events and therefore can be comprised of a mix of GE and non-GE kernels [50]. The number of potential GE contaminants also varies between crops. Some cultivars are engineered to express multiple, or stacked, traits. In those cases, reliable results may be best achieved via testing individual seeds [9].

Most testing companies dictate specifics, including recommended minimum amount of seed per crop and which tests to employ, to ensure accurate results [48].

### Testing Appropriate to Scale

Different scales of agriculture may result in different testing programs. A larger sample size will provide results that are more protective of affected farmers and seed producers. A 10,000 seed sample may not always be feasible depending on an individual grower's scale. For a small grower of specialty vegetable seed, even a 3,000 seed sample could constitute the majority of a harvest.

Small-scale growers might modify their testing plans to be appropriate to their own business models. Again, statistics can help determine different

courses of action. A 3,000 seed sample will offer a 95% confidence level in detecting GE content to 0.1%. A 1,000 seed sample offers a 63% confidence level, and a 300 seed composite sample will yield a 26% confidence level [34].

Growers that want higher assurance but cannot spare larger quantities of seed may opt to test live plant tissue rather than seed. Instead of testing the seed in question prior to planting, a grower can plant and then paper-punch leaf tissue from each plant. These punches of material can be treated as one lot, or several, and can be ground into composites at



**Papaya Fruit and Seeds.** In creating a testing plan, it is important to consider that different crops require different approaches to sampling: a papaya tree is either GE or not, whereas the seeds of the papaya, similar to corn, represent individual pollination events and therefore can be comprised of a mix of GE and non-GE material. Photo by Lyn Howe, Beach Road Farm.

the lab. A test could then identify if the lot is hot or not [34].

Of course, this plant tissue testing plan does not account for the potential of cross-pollination and commingling that could lead to genetic contamination

during that growing season. A seed grower would then have to self-assess likelihood of such contamination in determining their own testing plan [34].

This is just one example to illustrate creativity and flexibility that small producers can take in addressing contamination. It is encouraged that they work with genetic testing experts in determining a workable plan [34].

OSGATA submitted recommendations for testing of organic seed based on scale to the National Organic Standards Board (NOSB)'s GMO Ad-hoc Subcommittee in June 2013. OSGATA identified three basic categories of organic seed producers along with (a) seed purity standards and (b) testing protocols to comply with their membership-approved standard that any identifiable GE content in organic seed is unacceptable.

The recommendations were made with the acknowledgement that the science of genetic testing is rapidly advancing and thereby subject to change. It was also the intent of the organization that the protocols would not be burdensome for the organic community. Individual organic seed farmers, and organic seed companies, should not be hampered by the cost of seed purity testing. Instead, according to the polluter principle, OSGATA made the following recommendations to the NOSB with the stipulation that *all* seed purity tests and costs of seed lost to testing should be paid by the biotechnology industry.

### Scale-Based Recommendations for Organic Seed Testing

1. *Small-scale organic farmers who primarily raise their own seed for own use.* There is further categorization within this group, based on whether growers are channeling some amount of seed into the organic seed market or not. The necessity for small farmers to test seed lots is predicated on their own assessment of perceived risk of contamination.

- If a small-scale grower is producing and saving organic seed exclusively for their own family's use, they should be exempt from testing requirements.
- If a small-scale grower is growing organic seed of an at-risk crop exclusively to then grow out and produce a marketable food crop sold as an organic food product, the seed should be held to a zero tolerance standard of contamination. Each at-risk seed lot, as determined by the farmer, should be tested a minimum of once every third crop year via a PCR test of a representative sample of a minimum of 3,000 seeds.
- If a small-scale grower is growing organic seed of an at-risk crop for both personal seed use as well for organic seed trade channels, they should also be held to a zero tolerance standard of contamination. Each at-risk lot, as determined by the farmer, should be tested annually via a PCR test of a representative sample of 10,000 seeds.

2. *Mid-scale organic farmers who raise seed for personal use, as well as or-*



*ganic seed trade channels.*

(a) 0.00% tolerance standard of contamination.

(b) Every at-risk seed lot should be tested annually via a PCR test done on a representative sample of 10,000 seeds.

*3. Large-scale organic farmers and seed businesses who primarily supply organic seed to the organic marketplace.*

(a) 0.00% tolerance standard of contamination.

(b) Every at-risk seed lot should be tested annually via a PCR test done on a representative sample of 10,000 seeds.

# PART TWO

## Avoidance and Testing for Threatened Varieties

### **Best Management for At-Risk Crops**

The risks of contamination differ amongst crops based on their biology, the region in which they are grown, and the relevant production practices. Particulars of planting, harvest, storage, and established trade channels all introduce potential points of genetic contamination [63]. It is critical to acknowledge that farmers are working within the context of a dynamic, unpredictable biological system and that each individual crop will behave differently in each individual landscape [72].

To reduce risk of GE contamination, one must know the specifics of any at-risk crop. This includes the crop's life cycle, whether the crop is self-pollinating or cross-pollinating, and if pollen is transported by wind or insects [72, 81]. Prospective gene flow comes down to the details [63].

Differences in wind-pollination versus insect-pollination in outcrossing crop species impact isolation distance. Windborne pollen can travel considerable distances and raises distinct considerations prior to planting. Are there prevalent wind patterns in the area? Is your crop downwind or upwind of potential contamination sources? [72]

Insect-pollinated crops have their own set of questions. What type of pollinators are present? What is their population density? A large population of pollinators could equate to further foraging distances, thereby increasing instances of crossing at otherwise safe isolation distances [72].

Also, bees for hire should be scrutinized. Will shared use of bees and beekeeping equipment lead to GE contamination? Research in this area is

pending, but evidence has shown that residual pollen in transported hives is sometimes viable. Pollen life varies between crops and should be addressed on a crop-by-crop basis [61].

Gene flow between crops is further dependent on individual varieties within a given crop type. Some varieties may produce more flowers per plant, experience extended bloom times, and yield higher volumes of pollen than other cultivars of that very same crop. Pollen viability and vigor can also differ on a varietal basis [72].

An awareness of individual field characteristics is also important. Distance to potential sources of contamination, the presence or absence of physical barriers (like windbreaks and hedgerows), and direction of prevailing wind should all be considered [81]. Physical barriers, such as woodlands or hills, can reduce the risks of cross-pollination by obstructing the movement of pollinators and/or wind-mediated pollen flow. Barriers sometimes make it possible to reduce the isolation distance needed by as much as half of what it might be in an open, unobstructed landscape. Less complete barriers, like a modest hedgerow or a building, may warrant a reduction in isolation distance to somewhere between the minimum standards for open environs and half that minimum distance [72].

There is some evidence that planting crops immediately behind a barrier is best: a single row of trees with undergrowth reduced outcrossing by 50% in a study conducted on corn [92].

Environmental factors also come into play. Temperature and relative humidity will influence pollen longevity. High temperatures and low humidity spell early death for pollen; cold weather can also diminish viability. Conversely, high humidity enhances the opportunity for pollen to reach a sexually compatible plant [72].

Additionally, risks associated with seed commingling need to be individually assessed. Shared-use equipment (whether rented, borrowed, or contracted) for planting, harvesting, and cleaning, and storage facilities and means of transport are all possible points for inadvertent seed mixing [81]. Owned, dedicated equipment lowers the risk.

Some farmers choose to follow the guidelines of identity preserved (IP) crops. Such contracts can be set up to ensure that a commodity having a special characteristic, like corn with a high oil content, meets the given standards from moisture and damage-quality specifications to levels of acceptance for GE content. To reduce post-harvest commingling, IP contracts stipulate best practices via an “Identity Preservation Checklist.” This checklist includes field management strategies like adhering to a field planting history for non-GE fields and establishing physical separation between GE and non-GE crops. Prior to planting and harvest, drill boxes and combines are to be blown or

***The risks of contamination differ amongst crops based on their biology, the region in which they are grown, and the relevant production practices.***

vacuumed clean and also visually inspected. Post-harvest, GE seeds are required to be stored in separate, labeled containers [70].

## 🌻 Wild Relatives and Their Impact

Wild relatives can factor into the likelihood of GE contamination by acting as future reserves, or genetic bridges, of contaminated germplasm. Though the extent of gene flow between cultivated crops and their wild relatives is limited by both geographic distribution and timing, it is not possible to fully prevent gene flow amongst compatible relatives occurring in the same place [30]. Where the domesticated crop and wild relatives grow in close proximity, their genes have been flowing back and forth between cultivated crops and weeds since the advent of agriculture [89].

Once a GE gene is transferred to a wild relative, it has the potential to persist among feral populations indefinitely if the gene confers a beneficial, or at least neutral, effect on the wild-GE hybrid [10]. For example wild squash in the Southeast could obtain a fitness advantage from a virus-resistant GE trait if such a virus infection posed threat to those particular free-living populations [77]. Scientific research shows these crosses can be partially to fully fertile [30].

Studies have also shown that in certain instances, like with sunflower, agronomic genes in wild relatives could even increase the hardiness of the relative [55]. This could, in turn, create a feral DNA bank of GE genes for continued contamination.

The likelihood of such a scenario depends on the presence of wild populations, as well as reproductive biology. Corn and soybean have no such presence in the U.S. Canola, on the other hand, has a high probability of gene transfer due to its outcrossing nature and the widespread presence of weedy forms [102].



**Organic Sunflowers.** Agronomic genes transferred to wild relatives may increase the hardiness of the relative (like with sunflower). Such a genetic transfer could lend to the creation of a feral DNA bank of GE genes for continued contamination. Photo by Holli Cederholm.

## **An Outline for GE Contamination Avoidance**

1. Identify at-risk crops and potential points of contamination. This may include talking with other growers in your area.
2. Test any at-risk seed prior to planting. Alternatively, receive verification from seed seller(s) that a specific seed lot has tested clean.
  - Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
  - Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
  - Work with a trusted lab to determine which PCR test is best for your situation.
3. Understand the potential for gene flow. Avoid renting pollinators that have been used in proximity to GE fields. Determine where neighboring or feral hives exist and advise neighbors of this risk.
4. As appropriate, implement isolation distances when planting. Plan isolations for time as well as space if possible.
5. Control any volunteers, feral populations, and/or wild relatives in proximity to fields.
6. Avoid mixing during harvest, cleaning, storage, transport, and sales. Clean all equipment and facilities prior to use [26, 76, 81].

## **Current At-Risk Crops: Crop-Specific Overview of Contamination**

### **Alfalfa (*Medicago sativa*)**

In 2005 alfalfa became the first perennial GE crop to attain approved status in the U.S. It also has the distinction of being the only GE crop thus far to be returned to a regulated status by USDA-APHIS in 2007 [63]. It was again deregulated in 2011 [29].

Like most of the crops undergoing genetic engineering, alfalfa is one of global agricultural and economic significance: it is the number one forage crop on the planet [63, 76].

Alfalfa's major domestic markets include the dairy industry, followed by feed for beef cattle and horses. Only a fraction of domestically grown alfalfa is exported, with Japan as the primary recipient. Crops destined for export are often consolidated into specific regions, like southern California and central Washington, and have more stringent growing requirements as seed and hay purity standards tend to be higher for these export markets [76].

*Genetic Traits Currently Approved:*  
Herbicide-resistance (glyphosate) [45].

*Biology:*

Alfalfa has a perennial life cycle: initial growth is from seed, but re-growth can occur from buds on stubble or crowns [99.] Alfalfa is largely outcrossing, and reliant on insects for pollination such as cultured honeybees (*Apis mellifera*) and leafcutter bees (*Megachile rotundata*) [63, 76, 99]. Alkali bees (*Nomia melanderi*) are sometimes introduced. Wild honeybees and native bees, like bumblebees (*Bombus terrestris*), can also contribute to alfalfa pollination [14].

*Regions Grown:*

Alfalfa hay is grown across the continental U.S. [99.] Alfalfa seed is primarily produced in the Western states including California, Oregon, Washington, and Idaho [63, 76, 99].

*GE Contamination:*

Estimating gene flow between GE alfalfa fields and organic fields is critical to maintaining seed purity. Alfalfa seed crops have fewer obstacles for gene flow than hay crops. Fields of alfalfa seed flower for extended periods of time, and are often host to rented pollinators to maximize seed production. Cross-pollination is therefore most likely to occur between two alfalfa seed fields [99].

The probabilities of gene transfer from a GE alfalfa hayfield is much lower than from a GE alfalfa seed field, but it is still entirely possible [76, 99].

Optimally, alfalfa hayfields are harvested with minor amounts of individual plant flowering (between 0 and 25%), as pre-bloom stage equates to a higher quality product [76].

However, unplanned pollination activity can occur due to weather, such as rain, resulting in delayed hay harvest [97]. High levels of pollinator activity and excess heat also raise the risk of contamination via cross-pollination [76].

Alfalfa contamination has already been documented. Within a year of GE alfalfa's initial commercial release in 2005, contamination had occurred in the commercial sector. The Roundup Ready™ trait was identified in conventional non-GE plantings of alfalfa in Montana, Wyoming, and Idaho, as well as in feral populations of alfalfa sampled by Colorado State University Extension [97]. In September 2013, GE contamination of conventional alfalfa hayfields in Washington state was also documented [41].

Perhaps this GE contamination is because current industry standards for alfalfa isolation are simply not large enough. For plantings under 5 acres, 900 ft. (272 m) is recommended for foundation seed and 165 ft. (50 m) is recommended for certified seed. For plantings over 5 acres, the recommended distances are 600 ft. (183 m) and 165 ft. (50 m), respectively [63, 99].

Note however, these standards were designed for varietal purity. Coexistence between GE and non-GE systems of agriculture would no doubt require some magnitude of increased isolation [63].

The National Alfalfa & Forage Alliance (NAFA) adopted a series of best



management practices for Roundup Ready™ alfalfa seed production in 2008. Their isolation stipulations are as follows: 900 ft. (272 m) in the presence of leafcutter bees, 1 mile (1.6 km) for alkali bees, and 3 miles (4.8 km) for honeybees [7].

Studies on different pollinators and glyphosate-resistant alfalfa gene flow in Idaho and California are consistent with possible transgene movement in line with these recommendations. The studies affirm NAFA's isolation distance for leafcutter bees, which transferred pollen upwards of 900 ft (272 m). Honeybees were responsible for sporadic gene flow up to 2.5 miles (4 km) away [76]. The Xerces Society for Invertebrate Conservation, however, recommends 5 miles (8 km) between GE and non-GE fields. They double this distance in the presence of honeybees [61].

Leafcutter bee cocoons and beekeeping equipment common to hired pollinator operations are another avenue for GE gene flow. The cocoons, which are kept under refrigeration, can be covered with large quantities of pollen. Alternatives to hired pollinators, e.g. encouraging native ones, are recommended to lessen chances of inadvertent contamination [61].

Planting seed fields that are 5 acres or larger may also help reduce instances of contamination. The seed field border has a higher probability of cross-pollination and could be harvested as a separate lot [99].

Alfalfa seeds are small, hard, and capable of remaining dormant for years, potentially leading to future generations of volunteers if left in the soil [63]. Alfalfa seed can also be spread by grazing animals. At least some mature alfalfa seed can pass through animals' digestive tracts intact, allowing for unintentional "planting" via their excrement. However, commingling of viable seed during harvest, processing, and planting is of higher concern [99].

Alfalfa plants themselves can act as a source of genetic material; stem cuttings or crowns are capable of regenerating new plants. Machinery can inadvertently move viable plant material between fields [63]. Alfalfa's perennial nature makes containing GE genes even more difficult [97].

#### *Wild Relatives:*

Alfalfa has no compatible relatives in the U.S. [63]. Feral populations of cultivated alfalfa are present in areas of cultivation and are more likely to act as genetic bridges than cultivated alfalfa stands [63, 76]. These populations are prone to establishing on roadsides or in ditches. Original seed sources include seed spilling during transport, seed from harvested hay, and seed moved via birds [76].

Scouting and removal of such feral populations is paramount for continued clean seed production.

#### *Best Management:*

- Identify potential points of contamination.
- Plant clean seed a minimum of 2.5 miles from GE sources. 5 miles is optimum. Increase isolation distance to 10 miles in presence of honeybees.

- If possible, plant larger fields (greater than 5 acres).
- Control feral alfalfa near hayfields and seed fields.
- Communicate with neighbors who are growing alfalfa hay to express how cutting their crops early would lesson potential cross-pollination with your seed crops.
- Avoid renting pollinators previously used near GE alfalfa fields.
- If renting pollinators, choose species that range shorter distances (i.e. leafcutter bees).
- Avoid seed mixing during harvest, cleaning, storage, transport, and sales. Use dedicated equipment and facilities if possible. Otherwise, clean thoroughly between use.

#### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### **Canola (*Brassica napus*; *B. rapa*)**

Glyphosate-resistant canola debuted in Canada in 1995, and was deregulated in the U.S. four years later. As in Canada, adoption by U.S. canola growers became widespread over a short period of time [63].

#### *Genetic Traits Currently Approved:*

Glyphosate Herbicide-resistance (glyphosate, glufosinate, oxynil); Antibiotic-resistance; Phytase production; Pollination control system (male sterility); Modified oil quality; Stacked traits [45, 83, 89].

#### *Biology:*

Canola is an annual that is self-fertile and outcrossing. It is pollinated by wind as well as insects [63]. Notably, the *Brassica* genus is unique in that several of the common crops were derived from the same species, resulting in a highly interfertile group of crops and weeds that have the capability to cross with one another [63].

#### *Regions Grown:*

Approximately 75% of all GE canola grown in the U.S. is in North [63]. Other

large canola-growing states include Minnesota, Oregon, and Montana [20].

#### *GE Contamination:*

Canola is a high-risk crop in terms of genetic contamination. Its basic biology along with its ability to persist outside of cultivation in disturbed habitats (like field edges and roadsides) presents multiple avenues of potential contamination [63]. Traditional varieties containing cytoplasmic male sterility are at an elevated risk: they will outcross with fully fertile GE canola at higher rates because they do not produce their own pollen to compete with the GE pollen [92].

There is potential for transgenes from *B. napa* canola to move to *B. napa* vegetables (rutabaga and Siberian kale) and to *B. rapa* vegetables—including turnip, broccoli rabe, Chinese cabbage, Chinese mustard, and other Asian *Brassica* vegetables—because they share a common set of chromosomes [3, 83, 89]. While crosses are possible between *B. napa* and *B. rapa*, resulting hybrids, if they do occur, tend to have lower fertility and subsequent seed set [63, 83].

Nonetheless international seed growing standards dictate a buffer of approximately 2 miles (3.2km) surrounding compatible *Brassica* vegetable seed fields [63].

Theoretically, crosses between *B. napa* and *B. oleracea* (cauliflower, cabbage, broccoli, Brussels sprouts) are also possible because they too share a common set of chromosomes. Research has shown that crossing occurs at low frequencies and is unlikely to occur under natural conditions [83].

Pollen dispersal is generally variable and dependent on prevalent conditions, like wind direction and speed, presence or absence of natural vegetative barriers, and topography. Reports have shown that pollen dispersal distances up to 1 mile (1.5 km) is common. Bees, known to pollinate canola, are likewise known to travel up to 2.5 miles (4 km) from their hives [63]. Additional studies of canola pollen movement confirm that gene travel as far as 2 miles (3 km) from the source is not unlikely, and pollen has been detected as far as 16 miles (26 km) from the source [65, 78]. Increased distance between fields correlates with lower instances of cross-pollination [78].

Canola's potential for wide pollen dispersal is aided by its long flowering window, up to 40 days, as well as the durability of the pollen itself. Canola



**Organic Lacinato Kale.** The Brassica family is highly interfertile. There is varying potential for transgenes from *B. napa* canola to move to *B. napa*, *B. rapa*, and *B. oleracea* vegetables. Photo by Holli Cederholm.

pollen can remain viable a full week in ideal conditions [63, 83]. All organic canola stands should be at least 5 miles (8 km) from potential contaminants; 10 miles (16 km) is better if GE canola and honeybees are present [61].

Introducing managed beehives into seed production fields should be treated as another potential source of cross-pollination. Knowing the recent history of these hired pollinators is critical to avoiding yet another avenue of GE gene flow [61].

Volunteer and feral populations of canola can act as additional pollen sources outside of cultivated crops. Canola volunteers emerge from seed banks over time as a result of seed shatter and residual viable seed left in the field [89].

Studies in Manitoba, Canada, determined that harvested canola seed is left in the field at rates of 3 to 10% [63]. However, up to 50% is not unheard of [31]. Canola seedbanks can persist for several generations, especially if the seed is buried [60, 63]. University of California Cooperative Extension found that shatter at harvest can produce up to 10 times the initial first-generation seeding rate over the course of subsequent years [20].

To manage the development of a persistent seed bank, a crop rotation plan should be implemented and plowing should be avoided to prevent prolonged dormancy [31, 60]. It is best to delay cultivation until moisture has caused some of the residual seed to germinate. Light tine cultivation and delayed deep cultivation is recommended [60].

Canola is also a candidate for contamination via inadvertent mixing. Small seed size makes it likely to remain in transportation or storage vessels, as well as harvesting and cultivating equipment. One University of California Cooperative Extension agent likens trying to encase canola seed for transport to containing water. Canola is so tiny that it flows through the cracks [20]. Roughly 4 lbs. of seed, 500,000 seeds, can easily be left inside a combine. Additionally, plows carrying residual soil may also transport residual seed [60].

Dedicated equipment and facilities are strongly advised. If not feasible, meticulous cleaning must occur between all seed lots.

#### *Wild Relatives:*

Many agricultural crops have sexually compatible wild relatives, often in regions of the world where they were first domesticated. In the U.S., canola falls into this category. With its outcrossing nature, a GE trait like herbicide-resistance can be transferred to a wild relative via cross-pollination. If the trait does not harm the relative or, if on the contrary, it presents a fitness advantage, then the trait could persist and even spread, resulting in a feral population with that GE trait [55].

This in fact did happen with canola in several countries around the world. Only a few seasons after its Canadian release, volunteer canola plants with GE traits were found in fields not under intentional cultivation. At the time two types of GE canola, each genetically engineered to withstand a different herbicide, were on the market. Individual volunteers were found possessing both GE traits, a cross that had happened under natural field conditions [65].

In the U.S., wild populations of canola were identified for the first time in

2010. Found in North Dakota, feral populations exhibited two different types of transgenes: one resistant to glyphosate, the other modified to resist glufosinate. The traits were present in the feral populations both singly and stacked [42].

Canola's compatible weedy relatives, including *B. rapa* and *R. raphanistrum* (wild radish), are considered "bridge species" as the resulting canola-weed hybrids may be sexually compatible with yet another species of *Brassica* [63].

#### *Best Management:*

- Identify potential points of contamination.
- Plant clean seed in fields a minimum of 1 mile from GE canola stands. 5 miles is better if possible. 10 miles is encouraged in the presence of honeybees.
- Avoid renting pollinators previously used in/near GE canola.
- Control volunteer/feral populations of canola near seed fields.
- Manage volunteer seed bank by minimizing seed shatter in the field. This can be done by harvesting at the right time with properly calibrated equipment.
- Plan cultivation practices to deplete a potential seed reservoir; this includes stale seed bed techniques and avoiding deep cultivation. Also use crop rotation.
- Avoid mixing seed during harvest, cleaning, storage, transport, sales. Use dedicated equipment and facilities if possible. Otherwise, clean thoroughly between use.

#### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### **Corn (*Zea mays*)**

Of the GE crops in production in the U.S., corn is grown in the greatest quantities. The first GE trait for corn was approved in 1997 and rapid adoption of glyphosate-resistant varieties swept the nation [63]. Since then, several other traits have been trialed, approved, and released.



### *Genetic Traits Currently Approved:*

Herbicide-resistance (glyphosate, glufosinate, sulfonylurea, 2,4-D); Insect-resistance (coleopteran, lepidopteran); Drought stress-tolerance; Modified alpha amylase; Modified amino acid; Pollination control system (male sterility); Antibiotic resistance; Stacked traits [45].

### *Biology:*

Corn has an annual life cycle and produces monoecious, or individual female and male, flowers on each plant. It is primarily outcrossing, and its pollen is reliant on wind for movement [3,63]. Corn is broken into five classes based on the endosperm of the kernel: flour, flint, dent, sweet, and popcorn. Though all five are sexually compatible, popcorn has a strong genetic preference for self-compatibility, thereby preventing most crosses from the other types [72].

### *Regions Grown:*

Nearly all commercial-scale plantings of sweet corn seed in the U.S. are grown in southwestern Idaho. Parts of Colorado and Washington are also host to corn seed production areas [72]. Corn seed is produced alongside corn field crops in Illinois and Iowa as well [66]. Several seed companies use Hawaii and Puerto Rico for breeding, as well as seed production.

Commodity-scale plantings of GE feed corn are grown largely in the mid-west. The following states account for principal production: South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, and Ohio [33].

### *GE Contamination:*

Organic corn seed faces high risk of GE contamination from pollen flow. Seed commingling is also an issue [63].

Corn has large pollen, among the heaviest of all the grasses, but still light enough for windborne travel. These characteristics shape the common route of corn pollen dispersal: downward from the tassels to adjacent rows. Most pollen is received within 20-50 ft. (6-15 m) of the donor plant, but much larger distances are possible and even probable [13, 63].

Conventional seed industry wisdom has maintained that 660 ft. (212 m) is sufficient for isolation [72]. An international survey of literature pertaining to isolation found recommendations ranging from 82 ft. (25 m) to 6 miles (10 km) [8].



**Anasazi Sweet Corn.** Corn is especially at risk of GE contamination by cross-pollination as its pollen moves long distances. Photo by Jonathan Spero, Lupine Knoll Farm.

The organic seed industry in the U.S. has yet to establish its own universal standard. Suzanne Ashworth, author of the seed saving classic *Seed to Seed*, recommends 2 miles (3.2km) [3]. The Xerces Society for Invertebrate Conservation advises a several mile isolation between GE and non-GE plantings when honeybees are present, as these foragers can spread pollen along with the wind [61].

Dr. John Navazio, Organic Seed Alliance's resident scientist, suggests doubling the conventional minimum, equating the distance to 1,320 ft (424 m) for maintaining varietal purity; he further recommends tripling the distance as a minimum standard as a general rule when GE crops are a concern. For evading GE contamination in corn specifically, Navazio suggests foregoing organic corn seed production all together in regions of GE corn production [72].

Mike Gumina, of Pioneer Hi-Bred International, also stated that traditional isolation standards are too low. In a presentation on coexistence in 2006, he announced that Pioneer had started to work with 2 miles (3.2km) as their isolation distance due to tightening market demands [74]. Similarly, High Mowing Seeds, a company dealing in 100% certified organic seed, stipulates in their grower contracts that producers must be a minimum of 2 miles from all corn fields, whether known as GE or unidentified [58].

If foregoing planting corn all together is not an option, all possible parameters of isolation should be considered. Studies show that rates of outcrossing decline in proportion to distance between donor and receptor plants. This makes isolation a common practice used in purity maintenance in corn seed lines. Unfortunately, while distance isolation can reduce potential contamination between cultivars it is unlikely to completely prevent it [63].

This is of special significance in hybrid corn seed production. Corn hybrids have a lower pollen grain-to-silk ratio than open-pollinated lines and are therefore more susceptible to contamination [63].

Isolating by both time *and* space tends to be the most effective. Corn pollen has a short viability window: 2 to 24 hours on average. For precise temporal isolation, the maturity of the corn must be considered in heat units rather than days to maturity. Therefore, variable weather poses challenges [3, 63]. Still a time difference of at least eight days has been shown to reduce cross-pollination [26]. Pioneer Hi-Bred uses a temporal isolation of 3 to 4 weeks [74]. This differential may not be achievable in regions with shorter growing seasons.



**Organic Corn Field.** To reduce risk of GE contamination in corn, isolation by time *and* space is recommended. Photo by Restoration Seeds.

Buffer zones are often recommended, and have been successful to some degree in mitigating contamination in corn. A border of non-GE corn around the source field has been determined to be more effective at reducing outcrossing than an equal isolation distance. The same is true of a buffer surrounding the potential receptor field (i.e. the organic or non-GE corn planting). If the latter practice were to be undertaken, those border rows should be harvested separately from the interior rows, and treated as a different seed lot entirely. It is important to note that a buffer alone is not adequate in preventing outcrossing [63].

In Spain, the European Union's largest producer of GE corn, the Ministry of Agriculture guidelines recommend a minimum of 4 rows of non-GE corn as a buffer for holdings under 2.5 acres; they suggest a 4-row buffer plus an isolation distance of 164 ft. (50 m) for larger farms trying to maintain purity standards below the 0.9% EU tolerance [96]. For a higher purity standard, the buffer and isolation distance combination would need to be increased.

Residual sources of corn contamination in the field are improbable. Corn's relatively low rate of seed shatter, due to its protective husks, contributes to its decreased potential for developing a seed bank of volunteers in the field. Whole leftover cobs, however, are much more likely to contribute to a volunteer population the following year. Dormancy in corn seed is basically non-existent, negating the existence of long-term seed banks within the soil [63].

Though the popular commodity-scale crop rotation of following glyphosate-resistant corn with glyphosate-resistant soybean could lend to unchecked corn volunteers in off-planting years. Farmers have to apply an additional herbicide to remove GE corn volunteers [63].

#### *Wild Relatives:*

While corn does have compatible wild relatives (teosintes), their distribution is limited to Mexico and Latin America [63].

#### *Best Management:*

- Identify potential points of contamination.
- Plant clean seed a minimum of 2 miles from GE corn plantings. Greater isolation distance is recommended.
- If possible, plan isolations for time to create dissimilar pollination windows from area GE corn. Stagger plantings by 1 week minimum; 3-4 weeks is recommended.
- Treat rows on the field perimeter as a different seed lot and harvest them separately.
- Clean up residual whole cobs to avoid volunteer plants next season.
- Avoid mixing during harvest, cleaning, storage, transport, and sales. Use dedicated equipment and facilities if possible. Otherwise, clean between use.

#### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### **Cotton (*Gossypium* spp: *Gossypium hirsutum*, *Gossypium barbadense*)**

#### *Genetic Traits Currently Approved:*

Herbicide-resistance (glyphosate, glufosinate, sulfonylurea, oxynil, dicamba); Insect-resistance (lepidopteran); Antibiotic-resistance; Stacked traits [45].

#### *Biology:*

U.S.-grown Upland and Pima cotton are both managed as annuals. They are self-pollinating, and are also pollinated by insects. Bumblebees (*Bombus spp.*), and other bees, are common pollinators and can affect rates of outcrossing. Wind is an unlikely vector for gene flow due to the sticky constitution of cotton pollen [63, 98].

#### *Regions Grown:*

Cotton is grown coast-to-coast across the 17 southern states in the U.S. [62]. Texas is a heavy producer, and the largest contiguous cotton-growing region in the world [49]. States with the highest percentages of GE cotton adoption include Texas, California, Arkansas, Louisiana, Mississippi, Georgia, and North Carolina [33].

#### *GE Contamination:*

Cotton has a relatively low risk of gene flow via pollen in comparison to other GE crops on the market [63]. However low the perceived risk, cotton contamination is still real. One U.S. government documented incident occurred in 2008 when Monsanto harvested an unauthorized strain of GE cotton alongside commercially approved GE cotton. The unapproved seed accounted for some 0.05% of the overall harvest [35].

In Texas, where over 90% of cotton grown is genetically engineered, most organic cotton farmers acknowledge the likelihood of contamination in their crops. Farmer members of the Texas Organic Cotton Marketing Cooperative (TOCMC) assume rates of GE contamination around 1-3% [49].

Gene flow can occur via pollen transfer in the field or via inadvertent mixing [98]. Potential for commingling is highest during the ginning process [63].

Cotton is considered self-pollinating. The presence of bees has been



determined to improve pollination thereby increasing seed and lint yields, but also opening up avenues for GE contamination [63, 98]. Many factors affect cotton's rate of outcrossing including location and pesticide use, which reduces



the presence of pollinators [98]. It is plausible that an organic cotton operation could harbor a higher population of pollinators [63].

Without heavy pollinator presence, California-based research shows that cotton pollen is unlikely to travel beyond 32 ft. (10 m) [98].

**Organic Cotton Bolls in Transport.** Cotton has a relatively low risk of gene flow via pollen in comparison to other GE crops on the market. GE contamination as a result of commingling is a concern. Photo by Sally Fox, Vreseis Limited.

Guidelines for production of cotton foundation seed dictates isolation for seed purity; it can be in the form of a crop boundary or a physical barrier. If there

is potential for transfer of a distinct and undesirable morphological trait, the isolation increases to 98 ft. (30 m) [63]. Distances are again increased between Pima and Upland cottons, from 656 ft. to 2,625 ft. (200 m to 800 m), depending on the designation of the seed as foundation stock or as certified seed, as well as proximity to dissimilar types [63, 98].

The states of Arizona and California passed legislation requiring a much larger isolation distance, 3 miles (4.8 km), in order to segregate naturally bred colored cottons from white cotton strains [75].

GE contamination due to subsequent volunteers is negligible. Cotton seeds have a short life span and no dormancy; accordingly, persistence in seed banks is low [63].

#### *Wild Relatives:*

Cotton can be grown in all states except Hawai'i and Florida where it is prohibited due to concerns about hybridization with weedy relatives [65]. Crossing with wild relatives is a threat in southern Florida, where wild populations of *Gossypium hirsutum* are present. However, it is not considered a source of contamination [63]. In Hawaii, the threat is horizontal gene transfer with *Gossypium tomentosum*, commonly known as Hawaiian cotton [52].



#### *Best Management:*

- Identify potential points of contamination.
- Plant clean seed a minimum of ¼ mile from all GE cotton. 3 miles is preferred.
- Avoid mixing during harvest, ginning, storage, transport, sales. Use dedicated equipment and facilities if possible. Otherwise, clean between use.

#### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### **Papaya (*Carica papaya*)**

At present papaya is the only GE fruit on the U.S. market and production occurs largely in Hawai'i. Between the 1940s and the 1960s the Hawaiian papaya industry was devastated by papaya ringspot virus (PRSV), with particular hardship in the 1990s. Research led to the development of GE PRSV-resistant cultivars in the 1990s. First grown in 1998, GE papaya had comprised half of the state's total production by 2006 [11, 16, 51]. There are now 3 GE varieties in cultivation [101].

#### *Genetic Traits Currently Approved:*

Disease-resistance (PRSV); Antibiotic-resistance; Visual marker (GUS) [45].

#### *Biology:*

Papaya is a soft-wooded perennial plant, normally cultivated as a single-stem tree and propagated from seed. Its life-span is 5 to 10 years [93].

Papaya plants are either dioecious or gynodioecious. Dioecious plants have male and female flowers on separate trees while gynodioecious plants have female flowers on some trees and hermaphroditic flowers on other trees [93].

Fruit production further depends on cultivar. They can be either cross-pollinating, self-pollinating, or parthenocarpic (producing fruit asexually without any fertilization) [93]. Male trees do not fruit and are usually cut down. Female trees can accept pollen from up to 500 different pollination sources and seeds in the fruits of female trees are therefore easily contaminated with airborne pollen. Hermaphrodite trees can self-pollinate and accept only minute amounts of outside pollen. Commercial farmers often select for hermaphrodite trees [52].

Flower morphology suggests insect-pollination, but some research points to wind-mediated pollen flow [93].

*Regions Grown:*

Most papaya production in the U.S. is confined to Hawai'i.

*GE Contamination:*

GE contamination of papaya is classified as either air contamination or seed contamination [11].

Papaya flesh always has the same genetic make-up as the seed of the tree that it came from [64]. Trees grown from GE seeds will have GE leaves and fruit flesh [47]. Planting a GE seed unwittingly in a non-GE operation is an example of seed contamination [11].

Air contamination refers to GE contamination of developing seeds as a result of inadvertent cross-pollination of a non-GE fruit by transgenic pollen [11]. A papaya tree planted from an organic, or non-GE, papaya seed will always bare GE-free flesh but can still yield contaminated seed. The potential for cross-pollination exists each growing season [16, 47].

Organic papaya contamination has been documented. In 2004, GMO Free Hawai'i (now known as Hawai'i Seed), collected 10,000 composite samples of seeds and leaves from organic and conventional farms, backyard gardens, and free-living roadside populations across the islands of Hawai'i, O'ahu, and Kaua'i. Independent PCR testing, performed by Genetic ID in Iowa, identified widespread contamination. The results were staggering; Hawai'i island showed seed contamination near 50%. Of all the organic farms sampled, none of the trees were GE, but seeds collected at one farm were contaminated [11].

Seed contamination avoidance can be mitigated from sourcing clean seed. Planting of GE papayas legally requires signing a technology agreement. However, GE papaya seed has been sold and traded without these legal parameters. The initial contamination is complicated in that most producers seed-save for future generations from what may be an already contaminated gene pool [11].

Air contamination avoidance is dependent on papaya biology. Depending on whether the plant is dioecious or gynodioecious, they have different modes of pollination and therefore have specific risks. Cultivars have variances in



**Papaya Tree.** GE-free papaya seed is best ensured by saving seed from a known non-GE tree. Photo by Lyn Howe, Beach Road Farm.

pollen viability as well [93].

Outcrossing is likely if female plants are present in fields adjacent to other papaya fields. Studies have shown that hermaphroditic plants, if separated by a distance of ¼ mile (0.4 km) or more, have less potential for outcrossing [64].

Alternatively, with gynodioecious (hermaphroditic) plants, seed purity can be maintained by bagging unopened hermaphrodite flowers that typically self-pollinate prior to opening. Bags can be left on the blossoms until the petals fall off. This practice prevents receptivity to foreign pollen, GE or otherwise [64].

Hawai'i Seed's protocol suggests that growers first test their tree to ensure it is not GE. To do so, growers should collect the newest leaves of the papaya plant and subject them to GUS testing. Then they should bag the flower, and mark the developing fruit so it is clear later on for seed collection [101].

Female plants in general are much more susceptible to cross-pollination, as they produce no pollen of their own [64]. A study of GE papaya contamination in Hawai'i concluded that 70% of traditional papaya plants within 85 ft. (26 m) of a GE crop were contaminated by GE pollen. Some experts suggest therefore removing female plants from organic production [94].

#### *Wild Relatives:*

Papaya is extremely weedy and apt to exist outside of cultivation. A wayward toss of the seeds of a single papaya fruit constitutes planting some 500 seeds [52].

#### *Best Management:*

- Trees planted prior to 1997 will be GE-free. Otherwise GUS test papaya trees and rogue out any that test positive as GE [101].
- Remove male trees and consider removing female papaya trees, which are much more susceptible to contamination. Instead grow hermaphroditic cultivars [101].
- Do not trust any seed sources in Hawaii as GE-free. Instead save your own clean seed [101].
- Save clean seed to plant by bagging a hermaphrodite flower on a known non-GE tree just prior to opening. Following pollination, remove the bag and flag the developing fruit for later identification. Harvest when the fruit is ripe; either plant seeds or dry and store them [101].

### *Testing:*

- When considering testing options for papaya, it is important to remember that each seed is an individual pollination event, and that papaya fruit can contain up to 500 seeds. A fruit grown from an organic, or non-GE, papaya plant that was cross-pollinated by a GE plant could then have GE and non-GE seeds [11].
- Test young papaya leaf samples with GUS analysis to see whether or not a papaya plant is GE [11]. To do so, harvest a young, quarter-sized leaf from each tree in question. A plastic bag can be used as a glove to harvest, as well as the container in which to submit a sample; harvest one leaf per tree per bag. Label the specimen trees and the bags, recording this information to later identify any necessary rouging [101].
- Seed embryos, extracted from their black outer coats, from an individual fruit of a given papaya tree can also be tested using a GUS assay to determine if the tree is GE or not. If several embryos test negative, the tree is not GE—as at least half the embryos would inherit GE genes. If all of the embryos turn blue, then the fruit itself and, most likely, the tree is GE. If a fraction of the seed embryos turn blue, the tree is either GE or the fruit has been cross-pollinated by a GE tree. A leaf test is recommended for clarification. [22].
- PCR is recommended for quantitative analysis, as GUS is not accurate in terms of low-level GE contamination [22].

### **Soybean (*Glycine max*)**

Soybeans have the distinction of being the first GE crop deregulated in the US in 1994. Just twelve years later, in 2006, 95% of the U.S. soybean acreage had been converted to GE [63]. In terms of worldwide product, soybean accounted for 60% of all GE plants in 2010 [18].

#### *Genetic Traits Currently Approved:*

Herbicide-resistance (dicamba, glyphosate, glufosinate, isoxaflutole, sulfonylurea, 2,4-D); Insect-resistance (lepidopteran), Modified oil/fatty acid; Antibiotic resistance; Stacked traits [45].

#### *Biology:*

Soybean has an annual life cycle, is self-pollinating and highly self-fertile [63].

#### *Regions Grown:*

Commercial soybean production spans the mid-west. The following states are among the largest soybean producers: South Dakota, Nebraska, Kansas,

Minnesota, Iowa, Missouri, Wisconsin, Illinois, Michigan, Indiana, Ohio, Arkansas, and Mississippi [33].

*GE Contamination:*

Soybean is considered a low-risk candidate for GE contamination due to its nature as a self-pollinating crop, coupled with the fact that its pollen is too heavy for wind transport. However, gene flow via insect pollination is still possible. Studies have shown rates of cross-pollination up to 44% in adjacent soybean rows; lower levels of cross-pollination have been tracked up to 46 ft. (14 m) [63].

In the U.S., soybean seed is often grown with little isolation distance between varieties—those isolation distances in place have been designed to prevent mechanical mixing during harvest [63].

The regulatory framework of Brazil, the world's second largest soybean producer, recommends a minimum separation of 10 ft. (3 m); research in the region dictates 33 ft. (10m) as a more effective mandate [1].

GE soybean stands can result in another generation of GE plants as volunteers. Short seed longevity and dormancy mean less of a likelihood of a persistent seed bank than other crops, such as canola or alfalfa [63]. Crop rotation is advised to reduce recurrent volunteers [17].

All things considered, commingling remains the largest source of soybean contamination [63]. Growers should be vigilant in cleaning all equipment and facilities.

*Wild Relatives:*

Soybean has no compatible wild relatives in the U.S. [63].

*Best Management:*

- Identify potential points of contamination.
- Plant clean seed at least 33 ft. from potential contamination sources.
- Rotate crops to avoid volunteer populations.
- Avoid mixing during harvest, cleaning, storage, transport, sales. Use dedicated equipment and facilities if possible. Otherwise, clean between use.



**Organic Soybean Seed.** Commingling presents the largest risk for GE contamination of soybean. Photo by Restoration Seeds.



### Testing:

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### Squash (*Curcubita pepo*)

GE squash is limited to the most widely grown species, *Cucurbita pepo* [72]. Several cultivars of summer squash (yellow crookneck, straightneck, zucchini) have been engineered to resist susceptibility to common viruses: watermelon mosaic virus 2 (WMV2), zucchini yellow mosaic virus (ZYMV), and cucumber mosaic virus (CMV). Though not often thought of as a prominent GE crop in the U.S., the first variety of GE summer squash, Freedom II, was the second GE crop to be approved by U.S. regulators and arrived on the market shelf in 1995 [51].

### Genetic Traits Currently Approved:

Viral disease-resistance (CMV, ZYMV, WMV2); Antibiotic-resistance; Stacked traits [45].

### Biology:

Squash is an annual which is largely cross-pollinated by insects. Flowers are monoecious but they have some tendency to self-pollinate, as they are not self-sterile. Their sticky, large pollen grains and their monoecious condition results in their status as a highly outcrossing vegetable. The common honeybee and native bees are active pollinators [72].

*Cucurbita pepo* includes all zucchini and summer squash, as well as several winter squashes (acorns, delicata, and jack-o'-lantern pumpkins) and some ornamental gourds [72].



**Organic Squash Blossom.** Squash is largely cross-pollinated by insects and is highly outcrossing. The recommended isolation distance between crops is a minimum of 1 mile. Photo by Holli Cederholm.

### *Regions Grown:*

Florida, New York, California, and North Carolina are the largest squash-producing states in the U.S. [39].

However, GE squash and zucchini have not been widely adopted in the U.S. because other viruses, such as cucumber mosaic virus, are not protected against by the current GE cultivars [23].

### *GE Contamination:*

As an insect-pollinated crop, *Cucurbita pepo* is at risk of cross-pollination by GE cultivars. *Cucurbita pepo*, like the rest of its taxonomic family, requires a minimum 1 mile (1.6 km) isolation distance between varieties. In following Dr. John Navazio's rule of thumb to triple the industry standard for maintaining genetic purity, the distance becomes 3 miles (4.8 km) [72]. On a smaller scale, specimens can also be physically isolated, by taping or bagging flowers, and hand-pollinated. Isolation cages can also be utilized [3].

Rented pollinators, common to commercial squash production, should be considered as a potential source of contamination. Oftentimes there are enough bees present to pollinate a crop without the addition of hives for hire [61].

Of course, care should also be taken to reduce commingling of seed.

### *Wild Relatives:*

Hybridization between GE squash and wild relatives is of concern as squash is a native North American species [88]. Free-living *Cucurbita pepo* populations exist in parts of Missouri, Illinois, Kentucky, Arkansas, Mississippi, Louisiana, and Texas [77]. In particular, the common Texas gourd (*Cucurbita pepo* var. *texana*) grows as an annual in cultivated and non-cultivated habitats, giving rise to both wild and weedy populations [88].

A study of wild-crop hybrids in Arkansas and Ohio found that such hybrids produce a fraction of the seed, only 28%, that is produced by wild cultivars. Still the crosses were deemed vigorous enough to contribute to the gene pool for successive generations. The study also concluded that flowering times of wild and hybrid plants were generally overlapping [88]. These spontaneous hybrids could then act as a reservoir for potential contamination.

### *Best Management:*

- Identify potential points of contamination.
- Plant clean seed in fields at least 1 mile from GE squash. An isolation distance of 3 miles is recommended. Alternatively, physically isolate plants and hand-pollinate.
- Avoid renting pollinators that have been used in proximity to GE fields.
- Be vigilant for wild relatives, which can act as genetic bridges; remove any that occur in proximity to plantings.
- Avoid mixing during harvest, cleaning, storage, transport, sales. Use dedicated equipment and facilities if possible. Otherwise, clean between use.

### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable to your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.

### **Sugarbeet (*Beta vulgaris*)**

Sugarbeets engineered to resist glyphosate were first deregulated in the U.S. in 1998. Market hesitancy, however, stalled the adoption by commercial producers until nearly a decade later [63].

### *Genetic Traits Currently Approved:*

Herbicide-resistance (glyphosate, glufosinate); Antibiotic-resistance [45].

### *Biology:*

Cultivated *Beta vulgaris* includes table beets (aka garden beets or beetroot), sugarbeets, fodder beets (or mangels) and Swiss chard; all of which have biennial life cycles [72]. It is an outcrossing, wind-pollinated species; all crops will readily cross with one another [3, 63]. Insects, including sweat bees and leafcutter bees, can also be responsible for pollination [61].

### *Regions Grown:*

In the U.S., most of the sugarbeet seed production is controlled by a handful of agribusiness corporations and is focused in and around Oregon's Willamette Valley [63, 72]. Independent seed growers in this region face significant challenges in maintaining the purity of organic seed as they are likely to be in close proximity to by GE producers [72].

About 50% of the world's chard and table beet seed is grown in Oregon and Washington state— putting the global seed supply at risk [36].

The top five sugarbeet production states are: Minnesota, Idaho, North Dakota,



**Organic Red Beets.** Members of the *Beta* family, including table beets, fodder beets, and Swiss chard, are all at risk of GE contamination by GE sugarbeets. Photo by Restoration Seeds.

Michigan, and California. Other big production areas are found in: Colorado, Montana, Nebraska, Ohio, Oregon, Texas, Washington, and Wyoming [37].

#### *GE Contamination:*

As with all wind-pollinated crops, contamination potential via pollen transfer is high. Beet pollen is light and can travel up to 5 miles (8 km) or more in ideal conditions [3, 5, 36]. Crop isolation or seed stalk bagging is recommended for maintaining seed purity on a smaller scale [3].

There are standard isolation distances for the sugarbeet industry, but they are voluntary in practice. Sugarbeet stock seed isolation is set just under 1 mile (1.6 km); certified seed isolations are set at 0.62 miles (1 km). Between plantings of sugarbeet and table beets, there is an isolation recommendation of 1.86 miles (3 km); roughly 1.5 miles (2.4 km) is recommended for Swiss chard. Major GE sugarbeet seed producers raised these standards to 3 miles (4.8 km) and 5 miles (8 km), respectively [63].

These isolation distances are conservative compared to recommendations by organic seed experts familiar with purity concerns. Beets produce copious amounts of pollen, which can traverse several miles in the wind. A 1930s study by a USDA researcher concluded that the pollen could actually travel between 12 and 20 miles (19 and 32 km) under optimum conditions. The Xerces Society for Invertebrate Conservation advises for a 6 mile (9.7 km) isolation between GE and non-GE plantings [61]. Organic Seed Alliance's resident scientist, Dr. John Navazio, recommends 10 miles (16 km) for maintaining the integrity of organic *B. vulgaris* seed [72].

As a biennial, sugarbeets need to undergo vernalization, either by surviving the winter in the field or a in storage facility, in order to produce offspring [6]. Often sugarbeet seed production forces this vernalization via a late summer planting, with anticipated seed set the following summer [63].

In commercial sugarbeet root production, plants are harvested prior to flower for processing but can still act as a potential source of genetic drift [63]. This is because early bolting and seed production can occur if plants are stressed during this first year of production [6, 36].

Seed bolters, less common in sugarbeets than other members of *B. vulgaris*, can act as an immediate source of genetic drift through viable GE pollen, or as a later source of genetic material in the form of seed [6, 72]. Scouting and rouging for GE bolters should be standard



**Organic Lutz Beet Seed Crop.** As with all wind-pollinated crops, GE contamination potential via pollen transfer for beets is high. Photo by Seven Tree Farm.



practice by GE sugarbeet seed growers. If these transgenic bolters are not destroyed, pollen flow and gene transfer is imminent [25].

Seed shattering can also occur during harvest [63]. Residual seed is more likely to overwinter in colder climates, where beet seed is traditionally produced, than volunteer beets [6].

Inadvertent mixing of seed is another issue. While seed producers should not grow both GE and non-GE sugarbeet crops on their farms within the same year, there are other possible avenues for commingling [63]. All seed drills, combines, and other equipment should be thoroughly cleaned between use. Seed transport containers likewise need to be cleaned [85].

#### *Wild Relatives:*

Gene flow to wild beets is a possibility in the U.S., especially in southern California. Here wild beets belong to two different taxa: *B. macrocarpa* from a European introduction and *B. vulgaris* from escaped garden cultivars. Both of these grow as weeds within sugarbeet cultivation areas. An examination of sugarbeet fields in California's Imperial Valley in 1998 confirmed that sugarbeet bolting, due to moderately cold winter temperatures, was a common phenomenon [6].

#### *Best Management:*

- Identify potential points of contamination.
- For beet family (*B. vulgaris*) seed production, plant clean seed in fields at least 6 miles from GE sugarbeets. 10 miles is recommended if possible.
- Control volunteers/bolters in and around seed fields.
- Avoid mixing during harvest, cleaning, storage, transport, sales. Use dedicated equipment and facilities if possible. Otherwise, clean between use.

#### *Testing:*

- Implement an individualized testing plan based on scale and pre-determined contamination thresholds.
- Use scale-appropriate sampling methods to collect a representative sample of the largest number of seeds acceptable by your operation.
- Work with a trusted lab to determine which PCR test is best for your situation.





**Organic Wheat Harvest.** The costs of GE contamination for organic farmers are high. If their crops become contaminated, organic farmers face diminished prices, market rejections, loss of consumer confidence, loss of genetic integrity of seed stocks, and liability concerns. Photo by Bryce Stephens, Stephens Land and Cattle.



**U.S. Court of Appeals for the Federal Circuit.** Under current law, organic farmers are liable for patent infringement if inadvertently contaminated by GE crops. The June 2013 ruling in *OSGATA et al. v. Monsanto* exempted farmers with inadvertent trace contamination (under 1%) from legal jeopardy for patent infringement.

# PART THREE

## Supplemental Sections

### The Costs of Contamination

When GE contamination does occur, organic farmers do not have access to an established system to recoup financial losses. Issues surrounding who is liable for contamination and the subsequent economic losses cloud the potential for recourse. In the meantime, organic farmers unfairly bear the burden of seed and crop contamination by GE sources [36].

Avoidance measures and testing costs are part of the organic farmer's damages. Frequent testing to ensure seed integrity, as well as the loss of seed to testing, and any discarding of contaminated seed lots is an unfair cost for organic farmers to shoulder. Additional costs have been borne and will continue to apply to preemptive confinement measures to avoid GE contamination within organic seed production systems. Measures such as geographic isolation for seed crops, vigilance in removing at-risk volunteers, and using dedicated equipment contribute to additional time and labor [26, 65].

Organic farmers also face diminished prices and marketing turmoil if they are forced to reroute contaminated crops from their intended organic markets. Furthermore they run the risk of straight-out blanket market rejections, especially on an international scale in dealing with more sensitive markets [8]. This could mean loss of income, and even loss of their entire livelihood [26].

Recent events also demonstrate the potential for widespread market disruption. The 2013 incident of GE contamination in an Oregon wheat field did indeed result in the loss of international markets as both Japan and South Korea halted all U.S. wheat exports temporarily.

Another example of market disruption pertains to GE papaya. This product

led to the constriction of international markets once open to Hawaiian papaya growers. Prior to the development of the GE strains, 40% of U.S. papaya production was exported to Japan [11]. That trade relationship had ceased until 2011 when Japan accepted the import of a single Hawaiian papaya shipment. However, GE papaya sales continue to fall [52].

Loss of consumer confidence, either on an individual basis or industry-wide, is another possible repercussion in light of GE contamination of organic crops. A Whole Foods Market survey from 2003 indicated that 76% of consumers believed that organic certification equates to GE-free [53].

Another difficult-to-calculate cost accrued is the potential loss of the genetic integrity of seed stocks upon which farmers are dependent [8, 36]. The permanent loss of choice in growing, as well as eating, organic and non-GE foods is virtually impossible to quantify in terms of economics [8].

Additionally, potential insurance and liability costs are also present [67].

## **Farmer Liability Concerns**

### **Regulation**

Regulatory decisions concerning GE crops date back to 1986. The Federal government determined that the U.S. Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and the Food and Drug Administration (FDA) would regulate GE crops using existing statutes regarding food safety, as well agricultural and environmental safety [55]. The USDA's Animal and Plant Health Inspection Service (APHIS) oversees the importation, state-to-state transport, and field testing of GE organisms [102].

Once approved by the federal government for commercial sale and planting, a process known as deregulation, a GE crop need not be segregated from non-GE crops. This approval designates the crop as equivalent to the traditional crop, thereby not requiring any further scrutiny [27].

The EPA has, however, imposed refuge requirements for farmers planting crops genetically engineered with pesticides, like Bt corn. Farmers planting those crops have been charged with the responsibility of helping to limit the development of pesticide-tolerances in insects. In this example, the buffer zone of non-GE corn acts as a refuge for pests that are not resistant to the Bt pesticide [55]. The EPA is not responsible for enforcing such requirements. This oversight instead falls to the GE technology holder, as stipulated in their technology use agreements [70].

As a result of unauthorized releases of GE crops into human food, animal feed, and the greater environment, the U.S. Government Accountability Office (GAO) has made recommendations regarding the oversight of commercial GE crops. In their 2008 report on GE crops, GAO proposed a risk-based strategy for monitoring the use of commercialized GE crops [40]. To date, no action has been taken on this recommendation.

## Patent Law Affects All Growers

Farmers have been saving their own seed since the advent of agriculture. Through the natural process of saving and re-planting seed, farmers have not only sustained their own planting stock for generations, they have also aided in the development and selection of resilient crop cultivars suited to their specific agronomic conditions and needs [4, 31].

This system has since grown more complicated. The system of patenting seed changed the playbook of our agricultural heritage. It was first initiated when Congress passed the Plant Variety Protection Act of 1970 (PVPA) which granted PVPA certificates that gave legal protection to developers of novel varieties. Just a decade later in 1980, the Supreme Court ruled that companies could obtain general utility patents on GE bacterium, a living organism. In 1985, U.S. Patent

and Trademark Office granted its first ever GE plant utility patent on a corn variety. The Supreme Court's 2001 ruling in favor of Pioneer, in *J.E.M. Ag Supply v. Pioneer Hybrid*, determined that plant utility patents do apply to seed. This ruling, in turn, allows the prohibition of farmers from saving patented seed [70].

Farmers adopting GE seed technology are in effect signing away their right to produce their own seed. However, the 2001 *J.E.M.* ruling has implications beyond GE farmers that reach

**Organic and conventional non-GE farmers choosing not to grow GE crops continue to face inadvertent GE contamination. If they were to save this inadvertently contaminated seed, under current law, they are liable for patent infringement litigation...**

into all agricultural sectors. Organic and conventional non-GE farmers choosing not to grow GE crops continue to face inadvertent GE contamination. If they were to save this inadvertently contaminated seed, under current law, they are liable for patent infringement litigation for possessing patented seed technology without authority [4, 70].

## Liability in the Face of Contamination

In the now infamous *Monsanto Canada Inc. v. Schmeiser* case in Canada, a traditional farmer and seed breeder, Percy Schmeiser, faced patent infringement accusations over inadvertent contamination. Schmeiser's 1997 canola crop, including his seed supply, had been inadvertently contaminated by Monsanto's Roundup Ready canola. Monsanto sued Schmeiser for patent infringement after he re-planted the seed, harvested his crop, and sold it in 1998—even though he did not spray the crop with Round Up™ [70]. The case was eventually settled in the Supreme Court of Canada in May 2004. The Court determined that while Monsanto's patent was valid, Schmeiser did not profit from the company's technology and was therefore not responsible for



damages [79].

Patent law dictates that damage awards can be up to three times the actual loss. Infringers may also be responsible for attorney fees [4].

The June 2013 ruling in *Organic Seed Growers and Trade Association et al. v. Monsanto* exempted farmers with inadvertent trace contamination (under 1%) from legal jeopardy for patent infringement. In the June 10, 2013, ruling in the Appeal of Dismissal the U.S. Court of Appeals judges affirmed an earlier District Court decision that the plaintiffs lacked standing to warrant adjudication by the courts. However, this decision hung on Monsanto's repeated statements during the lawsuit to not sue farmers with "trace amounts" of contamination of their patented technology. The Appeals Court issued estoppel ordering Monsanto to make good on its assurances [2].

Some states have passed limited laws to protect farmers facing instances of patent infringement. North Dakota, South Dakota, Indiana, Maine, California, and Montana are examples [4, 68]. Otherwise, litigation, though costly in terms of both time and resources, offers the only recourse for at-risk non-GE and organic farmers in protecting themselves from contamination [27].

Biotech seed companies and GE farmers responsible as the source of GE contamination might be liable for damages based on tort claims when genetic drift or outcrossing occurs concerning trespass of land, nuisance, or strict liability [69, 90]. Trespass of land, private and public nuisance, and strict liability claims could apply in different scenarios. Damages would be based on level of injury to crops, as well as potential loss of organic certification and organic markets [90].

"Trespass of land" tort claims arise on grounds of intentional property damage. In order to proceed with a tort claim, a farmer must demonstrate physical harm, such as GE contamination of their crops. "Nuisance" torts can arise when someone's use and enjoyment of their private property has been compromised by another. It can be argued that GE crops can affect what crops a non-GE or organic farmer would like to plant on their private farmland, thereby interfering with their ability to use private property. "Strict Liability" is a third type of claim in which a person harmed by abnormally dangerous activity can recover damages from the individual engaging in the activity. Again, spraying pesticides has been grounds for strict liability torts [70].

Tort law could shift legal liability to where it belongs: the companies responsible for the potentially polluting technology. In this sense pollen drift is viewed correctly as a case of contamination rather than patent infringement [90].

### Shared Responsibility

Ultimately, who is responsible when GE crops contaminate organic and non-GE crops? OSGATA and its membership believe that protecting organic seed integrity is a shared responsibility. Farmers should possess their practical right to choose the agricultural system that they wish to employ [31].

In 2011, USDA's Advisory Committee on Biotechnology and 21st Century Agriculture (AC21) was revived by Agriculture Secretary Thomas Vilsack with



this specific charge: “to develop practical recommendations for strengthening coexistence among different agricultural production methods.” AC21 also looked at what type of compensation mechanism, if any, would be appropriate in addressing economic losses incurred by farmers in the event their crop value is reduced by GE contamination.

OSGATA board member Isaura Andaluz, of Cuatro Puertas in New Mexico, serves on AC21 and was the only participant in the diverse group who refused to accept the consensus report and instead filed a dissent. Andaluz’s dissent offers valuable insight to this subcommittee’s discussion. The organic sector is important for rural economic development and consumer choice. It is as important to the conversation on coexistence as any other agricultural sector. AC21’s final report fails to recognize ongoing economic losses non-GE farmers are incurring as a result of maintaining seed purity and also unjustifiably faults seed producers who become contaminated. Maintaining organic seed purity is not exclusively the responsibility of non-GE farmers [73].

USDA shares the responsibility in protecting the interests of organic farmers, including non-commodity and smaller farmers, in light of threats of GE contamination. Organic farmers have a right to farm in the way they choose on their farm without threat of intimidation and transgenic trespass. It is also important that recommended and/or required measures are not unnecessarily burdensome to farmers and other members of the organic community.

## Glossary

**Adventitious presence-** Low levels of unintended material (ie. GE content) in seed, grain, or feed and food products.

**Clean Seed-** Physically and genetically pure seed.

**Coexistence-** For crop agriculture, can be defined as the sustainable production of seed, food and fiber from diverse plant varieties, crop types and production practices.

**Commingling-** Mixing of GE and non-GE seed.

**Contamination-** Refers to seeds or genetic sequences that are unwanted in a particular place.

**ELISA-** Enzyme-linked immunosorbent assays (ELISA) are the most accurate type of immunosorbent assay. ELISA are test kits, manufactured by various companies, and performed in a laboratory setting; they offer a higher degree of sensitivity in testing seed, grains, and leaves in comparison to strip tests

**Foundation Seed Stock-** Seed stock resulting from a small amount of breeder seed planted and grown out to produce either a larger amount of foundation seed or other classes of seed: registered, certified, or commercial.

**Gene Flow-** The dispersal, whether active or passive, of genes via seed, pollen, or clonal propagation within an environment.

**Genetically Engineered (GE)-** The human manipulation of an organism's genetic material involving recombinant DNA techniques; it does not occur under conditions found in nature.

**Germ Line-** The cellular lineage of a sexually reproducing organism.

**Glyphosate Resistance-** A GE trait which allows glyphosate, a broad-spectrum or non-selective herbicide, to be used on crops that would otherwise be killed by the herbicide.

**GMO-** Shorthand for "genetically modified organism." Refers to organisms created through the gene-splicing techniques of biotechnology (also called genetic engineering or transgenic).

**Identity Preserved (IP)-** Refers to the maintenance of a product's specific traits or characteristics through growing, production and marketing channels.

**Limit of Detection (LOD)-** The lowest presence of genetic material that can be detected when testing for GE content within a representative sample of seed.

**Limit of Quantification (LOQ)-** The lowest amount of genetic material that can be quantified when testing for GE content within a representative sample of seed.

**PCR-** A method of GE testing which targets particular sequences of DNA within a defined sample and, using a special DNA-copying enzyme (known as DNA polymerase), selectively multiply copies of the target sequence allowing for identification and measurement.

**Resistance-** Crop symptoms resulting from a biotic or abiotic stress are attenuated or absent.

**Rogue Seeds-** Seeds showing variation from the standard.

**Seed Lot-** A relatively homogenous representation consisting of seeds of a pre-determined set of characteristics.

**Stacked-** Refers to a combination of different GE traits expressed by a single plant.

**Tolerance-** A crop's ability to remain productive despite exhibiting symptoms to a biotic or abiotic stress.

**Transgenic-** Another term for GMO or GE technology.

**Transgenic Events-** GE DNA sequences.

**Variety-** A subgroup of plants within a crop whose genetic makeup and agricultural characteristics distinguish it from other varieties of that crop.

**Vernalization-** A particular length of time at, or below, a certain temperature necessary for a biennial crop to undergo flowering and seed production in a second season.

## Resources

*The publications cited in this text in [brackets] are listed here by reference number.*

1. Abud, S., P.I.M. de Souza, G.R. Vianna, E. Leonardecz, C.T. Moreira, F.G. Faleiro, et al. 2007. "Gene Flow from Transgenic to Nontransgenic Soybean Plants in the Cerrado Region of Brazil." *Genetics and Molecular Research*. 6(2):445-452.
2. "Appeals Court Binds Monsanto To Promise Not To Sue Organic Farmers." 2013. Public Patent Foundation. Online at <http://www.pubpat.org/osgatavmonsantocafcdecision.htm>.
3. Ashworth, Suzanne. 1995. *Seed to Seed: Seed Saving Techniques for the Vegetable Gardener*. Decorah: Seed Savers Exchange, Inc.
4. Barker, Debbie, Bill Freese, and George Kimbrell, et al. 2013. "Seed Giants vs. US Farmers." Center for Food Safety and Save Our Seeds. Online at [http://www.centerforfoodsafety.org/files/seed-giants\\_final\\_04424.pdf](http://www.centerforfoodsafety.org/files/seed-giants_final_04424.pdf).
5. Bartsch, D., U. Wehres, U. Goddecke, and A. Gathmann. 2003. "Introduction to Field Trial Data of Crop to Weed Beet Gene Flow." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.

6. Bartsch, D., S. Driessen, A. Gathmann, A. Hoffmann, M. Lehnen, T. Muecher, C. Saeglitz, U. Wehres, and I. Schuphan. 2002. "Monitoring the Environmental Consequences of Gene Flow from Transgenic Sugar Beet." *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
7. "Best Management Practices for Roundup Ready Alfalfa Seed Production." 2008. National Alfalfa and Forage Alliance. Online at <http://www.alfalfa.org/pdf/CSBMPPForRRA.pdf>.
8. Binimelis, Rosa. 2008. "Coexistence of Plants and Coexistence of Farmers: Is an Individual Choice Possible?" *Journal of Agriculture and Environmental Ethics*. 21:437-457.
9. "Biotech Test Methods and Protocols for Use in Organic Compliance." 2013. The National Organic Program. Online at <http://www.ams.usda.gov/AMSV1.0/getfile?dDocName=STELPRDC5103060>.
10. Blancas, L., D.M. Arias, and N.C. Ellstrand. 2002. "Patterns of Genetic Diversity in Sympatric and Allopatric Populations of Maize and its Wild Relative Teosinte in Mexico: Evidence of Hybridization." *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
11. Bondera, Melanie and Mark Query. 2006. "Hawaiian Papaya: GMO Contaminated." Hawai'i Seed. Online at <http://gmofreehawaiiisland.org/>.
12. Brookes, Graham. 2004. "Coexistence of GM and Non GM Crops: Current Experience and Key Principles." PG Economics Ltd.
13. Brunet, Y., X. Foueillassar, A. Audran, D. Garrigou, S. Dayau, and L. Tardieu. 2003. "Evidence for Long-Range Transport of Viable Maize Pollen." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
14. Cecen, Semiha, Fehmi Gurel, and Ayse Karaca. 2008. "Impact of honeybee and bumblebee pollination on alfalfa seed yield." *Soil and Plant Science*. 58:77-81.
15. "Certified organic and total U.S. acreage, selected crops and livestock, 1995-2011." 2013. USDA Economic Research Service. Online at <http://www.ers.usda.gov/data-products/organic-production.aspx>.
16. Chan, Kahon. 2011. "War of the papayas." *China Daily*, September 8. Online at [http://www.chinadaily.com.cn/hkedition/2011-09/08/content\\_13645581.htm](http://www.chinadaily.com.cn/hkedition/2011-09/08/content_13645581.htm).

17. Chen, Xin, Heping Gu, Jinxin Yi, Hongmei Zhang, Big Gao, and Peerasak Srinives. "Gene Flow from Transgenic Roundup-Ready Soybean to Wild Soybean." Online at <http://www.intlcass.org/files/congress-proceedings/2008-papers/cs3-s7/cs3-s7-o5-xin-chen.pdf>.
18. Chiari, Cesar Wainer, Maria Claudia Colla Ruvolo-Takasusuki, Emerson Dechechi Chambo, Carlos Arrabel Arias, et al. 2011. "Gene Flow Between Conventional and Transgenic Soybean Pollinated by Honeybees." In *Herbicides- Mechanisms and Mode of Action*, edited by Dr. Mohammed Nagib Hasaneen. InTech. Online at <http://www.intechopen.com/download/get/type/pdfs/id/25157>.
19. Christey, M. and D. Woodfield. 2001. "Coexistence of Genetically Modified and Non-Genetically Modified Crops." AgResearch Ltd. Online at <http://www.mfe.govt.nz/publications/organisms/coexistence-feb01.pdf>.
20. Cline, Harry. "RR canola evolves into vexing weed." 2010. *Western Farm Press*, August 20. Online at <http://westernfarmpress.com/management/rr-canola-evolves-vexing-weed>.
21. Cotter, Janet and Arnaud Apoteker. "Contamination of Conventional Rice with Genetically Engineered Rice?" Green Peace International. Online at <http://greenpeace.to/publications/rice-contamination-poster-final.pdf>.
22. Crouch, Martha. "How to Interpret the Test for the Presence of Genetically Engineered Traits in Papaya Seeds." GMO Free Hawai'i Island. Online at <http://gmofreehawaiiisland.org/>.
23. Cummins, Joe. 2005. "Escape of the Transgenic Zucchini." Organic Consumers Association. Online at <http://www.organicconsumers.org/monsanto/zucchini092205.cfm>.
24. Daniells, Stephen. 2014. "U.S. organic food market to grow 14% from 2013-18." *Food Navigator USA*, January 3. Online at <http://www.foodnavigator-usa.com/Markets/US-organic-food-market-to-grow-14-from-2013-18>.
25. Darmency, Henri and Marc Richard-Molard. 2008. "Gene Flow in Sugar Beet Production Fields." ISB news Report. Online at <http://www.isb.vt.edu/news/2008/artspdf/apr0804.pdf>.
26. Devos, Yann, Matty Demont, Koen Dillen, Dirk Reheul, Matthias Kaiser, and Olivier Sanvido. 2008. "Coexistence of Genetically Modified (GM) and Non-GM Crops in the European Union." *Agronomy for Sustainable Development*. Online at <https://biblio.ugent.be/input/download?func=downloadFile&recordId=512574&fileId=512579>.
27. Dillon, Matthew and Kristina Hubbard. 2011. *State of Organic Seed*. Organic Seed Alliance.
28. Dyer, George A., J. Antonio Serratos-Hernandez, Hugo R. Perales, Paul Gepts, Alma Pineyro-Nelson, et al. 2009. "Dispersal of Transgenes through



- Maize Seed Systems in Mexico.” *PLoS ONE*. 4(5). Online at <http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0005734>.
29. Egelko, Bob. 2012. “U.S. Judge OKs Alfalfa Strain Made by Monsanto Co.” *San Francisco Chronicle*, January 7. Online at <http://www.sfgate.com/business/article/U-S-judge-OKs-alfalfa-strain-made-by-Monsanto-Co-2447198.php>.
  30. Ellstrand, N.C. 2002. “Gene Flow from Transgenic Crops to Wild Relatives: What Have We Learned, What Do We Know, What Do We Need to Know?” *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
  31. “Enabling the Coexistence of Genetically Modified Crops and Conventional and Organic Farming in Finland.” 2005. Finland Ministry of Agriculture and Forestry Expert Work Group on Coexistence. Online at <http://www.biotechnologie.de/BIO/Redaktion/PDF/en/laenderfokus/gruene-gentechnik-finnland-2005,property=pdf,bereich=bio,sprache=en,rwb=true.pdf>.
  32. Fabi, Randy. 2001. “USDA to buy seed tainted with Starlink bio-corn.” *Reuters*, March 7. Online at <http://www.connectotel.com/gmfood/re070301.txt>.
  33. “Factsheet: Genetically Modified Crops in the United States.” 2004. Pew Initiative on Food and Biotechnology. Online at [http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Fact\\_Sheets/Food\\_and\\_Biotechnology/PIFB\\_Genetically\\_Modified\\_Crops\\_Factsheet0804.pdf](http://www.pewtrusts.org/uploadedFiles/wwwpewtrustsorg/Fact_Sheets/Food_and_Biotechnology/PIFB_Genetically_Modified_Crops_Factsheet0804.pdf).
  34. Fagan, John Dr. 2013. Personal communication with author, September 12.
  35. “FDA, EPA and USDA conclude that accidental release of genetically engineered cotton poses no safety risk to humans or animals.” 2008. USDA Newsroom, December 3. Online at [http://www.aphis.usda.gov/newsroom/content/2008/12/ge\\_cotton.shtml](http://www.aphis.usda.gov/newsroom/content/2008/12/ge_cotton.shtml).
  36. “Five Reasons Why GE Sugar Beets Threaten Organic.” Organic Seed Alliance. Online at <http://www.seedalliance.org/uploads/Why%20GE%20Sugar%20Beets%20Threaten%20Organic.pdf>.
  37. “Food Safety Fact Sheet: Tainted Sugar.” 2008. Center for Food Safety. Online at [http://www.centerforfoodsafety.org/files/final\\_sugar\\_beet\\_fact\\_sheet-color.pdf](http://www.centerforfoodsafety.org/files/final_sugar_beet_fact_sheet-color.pdf).
  38. “GE Contamination Avoidance and Testing: Surveying Organic Seed Growers and Organic Seed Companies.” 2014. Organic Seed Growers and Trade Association. Online at <http://www.osgata.org>.
  39. Geisler, Malinda. 2012. “Squash.” Iowa State University Ag Marketing

- Resource Center, May. Online at [http://www.agmrc.org/commodities\\_products/vegetables/squash/](http://www.agmrc.org/commodities_products/vegetables/squash/).
40. "Genetically Engineered Crops: Agencies Are Proposing Changes to Improve Oversight, but Could Take Additional Steps to Enhance Coordination and Monitoring." 2008. United States Government Accountability Office. Online at <http://www.gao.gov/highlights/d0960high.pdf>.
  41. Gillam, Carey. 2013. "Exclusive: Washington state testing alfalfa for GMO contamination." *Rueters*, September 11. Online at <http://www.reuters.com/article/2013/09/11/us-usa-alfalfa-gmo-idUSBRE98A16H20130911>.
  42. Gillbert, Natasha. 2010. "GM crop escapes into the American wild." *Nature News*, August 6. Online at <http://www.nature.com/news/2010/100806/full/news.2010.393.html>.
  43. Giovannini, Tiziana and Luigi Concilio. 2002. "PCR Detection of Genetically Modified Organisms: A Review." *Starch/Starke*. 54:321-327.
  44. "GM Contamination Report 2005: A Review of Cases of Contamination, Illegal Planting, and Negative Side Effects of Genetically Modified Organisms." 2005. Gene Watch UK and Greenpeace International. Online at <http://www.greenpeace.org/international/Global/international/planet-2/report/2006/3/gm-contamination-report.pdf>.
  45. "GM Crop Events approved in the United States of America." 2013. International Service for the Acquisition of Agri-Biotech Applications. Online at <https://www.isaaa.org/gmapprovaldatabase/approvedeventsin/default.asp>.
  46. "GMO Contamination Prevention and Market Fairness: What Will it Take?" 2010. National Organic Coalition.
  47. "GMO Papaya Contamination." Hawai'i Seed. Online at <http://hawaiiseed.org/local-issues/papaya/>.
  48. "GMO Testing Guidelines for the 2013 Harvest." 2013. Genetic ID.
  49. Hershaw, Eva. 2013. "Seeds of Discontent: A Texas Organic Cotton Farmer Takes on Monsanto." *Texas Observer*, February 7. Online at <http://www.texasobserver.org/seeds-of-discontent/>.
  50. Holst-Jensen, Arne, Sissel B. Ronning, Astrid Lovseth, and Knut G. Berdal. 2003. "PCR Technology for Screening and Quantification of Genetically Modified Organisms (GMOs)." *Anal Bioanal Chem*. 375:985-993.
  51. "How Many Foods Are Genetically Engineered?" 2012. UCBiotech. Online at <http://ucbiotech.org/answer.php?question=15>.
  52. Howe, Lyn. 2013. Personal communication with author, August 10.
  53. Hubbard, Kristina. 2010. "The Problem of Contamination: Sugar Beet

Update.” Organic Seed Alliance. *Seed Broadcast Blog*, December 21. Online at <http://blog.seedalliance.org/2010/12/21/the-problem-of-contamination-sugar-beet-update/>.

54. Hubbard, Kristina and Neva Hassanein. 2013. “Confronting Coexistence in the United States: Organic Agriculture, Genetic Engineering, and the Case of Roundup Ready Alfalfa.” *Agriculture and Human Values*. 30:325-335.
55. Jaffe, Gregory. 2012. *Straight Talk on Genetically Engineered Foods: Answers to Frequently Asked Questions*. Center for Science in the Public Interest. 2012. Online at <http://cspinet.org/new/pdf/biotech-faq.pdf>.
56. Jefferson, R.A., T.A. Kavanagh, and M.W. Bevan. 1987. “GUS Fusions: beta-glucuronidase as a sensitive and versatile gene fusion marker in higher plants.” *The Embryo Journal*. 6(13): 3901–3907.
57. Kahler, Dr. Alex. 2013. Personal communication with author, March 7.
58. Lew-Smith, Jodi. 2012. “Seed Companies Strive to Prevent GMO Contamination.” *Organic Seed Growers Conference Proceedings*. Organic Seed Alliance. Port Townsend, WA, January 19-21.
59. Lies, Mitch. 2010. “Feds Mum on GMO Spread.” *Capitol Press*, November 19. Online at [http://www.orenews.com/Contests/2011/bnc/webhtml/img/amc2011\\_103-a-3b.pdf](http://www.orenews.com/Contests/2011/bnc/webhtml/img/amc2011_103-a-3b.pdf).
60. Lutman, P.J.W. 2003. “Co-existence of conventional, organic, and GM crops– role of temporal and spatial behavior of seeds.” *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
61. Mador, Eric and Jennifer Hopwood. 2013. *Pollinator Management for Organic Seed Producers*. The Xerces Society for Invertebrate Conservation. Online at <http://www.xerces.org/wp-content/uploads/2013/06/PollinatorManagementForOrganicSeedProducers.pdf>.
62. “Major Crops Grown in the United States.” 2009. U.S. EPA. Online at <http://www.epa.gov/agriculture/ag101/cropmajor.htm>.
63. Mallory-Smith, Carol and Maria Zapiola. 2008. “Gene flow from glyphosate-resistant crops.” *Pest Management Science*. 64:428–440.
64. Manshardt, Richard. 2002. “Is Organic Papaya Production in Hawaii Threatened by Cross-Pollination with Genetically Engineered Varieties?” University of Hawaii at Manoa Cooperative Extension Service. Online at <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-1.pdf>.
65. Marvier, Michelle and Rene C. Van Acker. 2005. “Can Crop Transgenes Be Kept on a Leash?” *Front Ecol Environ* 3(2): 99-106.

66. Mellon, Margaret and Jane Rissler. 2004. *Gone to Seed: Transgenic Contaminants in the Traditional Seed Supply*. Union of Concerned Scientists. Online at [http://www.ucsusa.org/assets/documents/food\\_and\\_agriculture/seedreport\\_fullreport.pdf](http://www.ucsusa.org/assets/documents/food_and_agriculture/seedreport_fullreport.pdf).
67. Menrad, K. 2003. "Introduction to strategies and economic assessments." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
68. Mills, Allison. 2013. "A question of coexistence: Lewiston neighbors lay bare national GMO debate." *Science Source*, March 9. Online at <http://umsciencesource.com/2013/03/09/a-question-of-coexistence-lewistown-neighbors-lay-bare-national-gmo-debate/>.
69. Moeller, David R. 2001. "GMO Liability Threats for Farmers: Legal Issues Surrounding the Planting of Genetically Modified Crops." Farmers' Legal Action Group, Inc. Online at [http://www.gepolicyalliance.org/pdf/gmo\\_liability\\_threats.pdf](http://www.gepolicyalliance.org/pdf/gmo_liability_threats.pdf).
70. Moeller, David R. and Michael Sligh. 2004. *Farmers' Guide to GMOs*. Farmers' Legal Action Group and Rural Advancement Foundation International-USA. Online at [http://issuu.com/rafi-usa/docs/farmers\\_guide\\_to\\_gmos](http://issuu.com/rafi-usa/docs/farmers_guide_to_gmos).
71. Morisset, Dany. 2013. "How it Works: Digital PCR for GMO Quantification." *Lab Manager*, December 6. Online at <http://www.labmanager.com/how-it-works/2013/12/digital-pcr-for-gmo-quantification#.UsibdoeBuM8>.
72. Navazio, John. 2012. *The Organic Seed Grower: The Farmer's Guide to Vegetable Production*. White River Junction: Chelsea Green Publishing.
73. "OSGATA Board Member Dissents from USDA's Biotechnology Report and Recommendations." 2012. Organic Seed Growers and Trade Association. *Seed News Blog*, November 21. Online at <http://www.osgata.org/2012/osgata-dissents/>.
74. "Peaceful Coexistence Among Growers of: Genetically Engineered, Conventional, and Organic Crops. Summary of a Multi-Stakeholder Workshop." 2006. Pew Initiative on Food and Biotechnology. Boulder, CO: March 1-2. Online at [http://sbc.ucdavis.edu/old\\_files/29322.pdf](http://sbc.ucdavis.edu/old_files/29322.pdf).
75. "PSD Rules and Regulations: R3-4-501. Colored Cotton Production and Processing." 2013. Arizona Department of Agriculture. Online at <http://www.azda.gov/PSD/ColoredCottonProductionProcessing.aspx>.
76. Putnam, Daniel H. "Methods to Enable Coexistence of Diverse Production Systems Involving Genetically Engineered Alfalfa." *Agricultural Biotechnology in California Series*. University of California. Online at <http://anrcatalog.ucdavis.edu/pdf/8193.pdf>.

77. Quemada, Hector and Laura Strehlow. 2002. "Case Study: Gene Flow from Commercial Transgenic *Cucurbita pepo* to "Free-Living" *C. pepo* Populations." *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
78. Ramsay, G., G.R. Squire, C.E. Thompson, D. Cullen, J.N. Anderson, and S.C. Gordon. 2003. "Understanding and Predicting Landscape-Scale Gene Flow in Oilseed Rape." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
79. Ray, Dr. Daryll E. 2004. "Monsanto vs. Percy Schmeiser: The Canadian Supreme Court Rules." University of Tennessee Agricultural Policy Analysis Center. Online at <http://agpolicy.org/weekpdf/202.pdf>.
80. Remund, Kirk M., Doris A. Dixon, Deanne L. Wright, and Larry R. Holden. 2001. "Perspectives in Seed Technology: Statistical Considerations in Seed Purity Testing for Transgenic Traits." *Seed Science Research*. 11:101-119.
81. Riddle, Jim. 2012. "GMO Contamination Prevention: What Does it Take?" University of Minnesota Southwest Research and Outreach Center.
82. Robinson, Raoul A. 1996. *Return to Resistance: Breeding Crops to Reduce Pesticide Development*. Davis: agAccess.
83. Salisbury, Phil. "Gene Flow Between *Brassica Napus* and Other *Brassicaceae* Species." 2002. Institute of Land and Food Resources, University of Melbourne. Online at <http://abe.dynamicweb.dk/images/files/Gene%20flow%20to%20other%20Brassicaceae%20species%20report%20-%20April%202002.pdf>.
84. "Sampling for the Detection of Biotech Grains." 2000. USDA GIPSA. Online at <http://www.gipsa.usda.gov/fgis/biotech/sample2.htm>.
85. Sicard, G. and L. Nardi. 2003. "Definition of specific rules for GM sugar beet seed growing." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
86. Sinemus, K. 2003. "Communication measures for establishing co-existence: technical, economic, and social components." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
87. Spears, Tom. 2013. "Pooping Canada geese may have spread GM wheat seeds." *Ottawa Citizen*, July 23. Online at <http://www.ottawacitizen.com/technology/Pooping+Canada+geese+have+spread+genetically+modified+>



wheat+documents+show/8701092/story.html.

88. Spencer, Lawrence J. and Allison A. Snow. 2001. "Fecundity of Transgenic Wild-Crop Hybrids of *Cucurbita pepo* (Cucurbitaceae): Implications for Crop-to-Wild Gene Flow." *Heredity*. 86:694-702.
89. Stewart, C. Neil Jr., Matthew D. Halfhill, and Suzanne Warwick. 2002. "Gene Flow and its Consequences: *Brassica napus* (Canola, Oilseed Rape) to Wild Relatives." *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
90. Strauss, Debra M. 2012. "Liability for Genetically Modified Food: Are GMOs a Tort Waiting to Happen?" *SciTech Lawyer*. 9(2).
91. Swanson, Emily. 2013. "GMO Poll Finds Huge Majority Say Food Should Be Labeled." *HuffPost*. Online at [http://www.huffingtonpost.com/2013/03/04/gmo-poll\\_n\\_2807595.html](http://www.huffingtonpost.com/2013/03/04/gmo-poll_n_2807595.html).
92. Sweet, J. 2003. "Pollen Dispersal and cross-pollination." *Proceedings: The 1st European Conference on Co-existence of Genetically Modified Crops with Organic and Conventional Crops*. Slagelse, Denmark: Danish Institute of Agricultural Sciences.
93. "The Biology and Ecology of Papaya (paw paw), *Carica papaya* L., in Australia." 2008. Australian Government Department of Health and Aging. Online at [http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/papaya-3/\\$FILE/biologypapaya08.pdf](http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/papaya-3/$FILE/biologypapaya08.pdf).
94. "The Failure of GE Papaya in Hawaii." 2006. Green Peace International. Online at <http://www.greenpeace.org/international/Global/international/planet-2/report/2006/5/FailureGEPapayainHawaii.pdf>.
95. Thomison, P.R. and M.M. Loux. 2001. "Commonly Used Methods for Detecting GMOs in Grain Crops." Ohio State University Extension Fact Sheet. Online at <http://ohioline.osu.edu/agf-fact/0149.html>.
96. Tusumiime, Emmanuel, Hugo De Groote, Jeffrey Vitale, and Brian Adam. 2010. "The Cost of Coexistence Between Bt Maize and Open-Pollinated Maize Varieties in Lowland Coastal Kenya." *AgBioForum*. 13(3):208-221.
97. "Twelve Reasons Why Genetically Engineered Alfalfa Threatens Organic Farming." Organic Seed Alliance. Online at <http://www.seedalliance.org/uploads/Twelve%20Reasons%20GE%20Alfalfa%20Threatens%20Organic.pdf>.
98. Van Deynze, Allen E., Frederick J. Sundstrom, and Kent J. Bradford. 2005. "Pollen-Mediated Gene Flow in California Cotton Depends on Pollinator Activity." *Crop Science*. 45:1565-1570.

99. Van Deynze, Allen E., Sharie Fitzpatrick, Bob Hammon, Mark H. McCaslin, Daniel H. Putnam, Larry R. Teuber, and Daniel J. Undersander. 2008. "Gene Flow in Alfalfa: Biology, Mitigation, and Potential Impact on Production." The Council for Agricultural Science and Technology. Online at <http://sbc.ucdavis.edu/files/CAST%20Alfalfa%20Gene%20Flow157.pdf>.
100. Vidhya, S. Shree, P.H. Ramanjini Gowda, K.N. Yogendra, T.M. Ningaraju, and T. Salome. 2012. "Detection of genetically modified cotton seeds using PCR and real-time PCR." *Indian Journal of Biotechnology*. 11:176-181.
101. "Which Papayas are Genetically Modified?" 2013. GMO Free Hawai'i Island. Online at <http://gmofreehawaiiisland.org/>.
102. White, James L. 2002. "U.S. Regulatory Oversight for the Safe Development and Commercialization of Plant Biotechnology." *Scientific Methods Workshop: Ecological and Agronomic Consequences of Gene Flow from Transgenic Crops to Wild Relatives Meeting Proceedings*. Columbus, OH, March 5-6.
103. Zapiola, M.L., C. K. Campbell, M. D. Butler and C. A. Mallory-Smith. 2008. "Escape and Establishment of Transgenic Glyphosate Resistant Creeping Bentgrass *Agrostis stolonifera* in Oregon." *Journal of Applied Ecology*. 45:486-494.
- 104.





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