REGIONAL RESOURCE

The Council of State Governments ■ 3355 Lenox Road, N.E., Suite 1050 ■ Atlanta, Georgia 30326 ■ 404/266-1271

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Agriculture and Biotechnology

By Jonathan Watts Hull

Background

For centuries, farmers have improved the varieties of their crops by careful selection for desired traits, breeding out inferior strains and choosing plants for their hardiness, the quality of their seed or fruit, and their overall desirability. As our understanding of genetics has improved, so has our ability to manage crops and species in such a way as to produce positive strains. With marked advances in hybridization and the establishment of a seed industry in the latter part of the 19th century, plant genetics became a specialized and potentially profitable business.

The process of crossing strains in a species to produce an improved variety relies on techniques dating back centuries. Recent scientific breakthroughs have given modern seed companies, now more often called "life sciences" companies, the ability to move beyond varietal advancements to introduce genes from other unrelated species into a plant, generating new strains with previously impossible capabilities. Such transgenic, or genetically-modified organisms (GMOs), are the heart of what is now known as biotech and have recently become one of the greatest controversies in agriculture.

The first wave of biotech crops provide several advantages to farmers, most often through built-in protection from pests and disease or resistance to selected herbicides, but also through increased hardiness and improved shipping and handling characteristics. The first genetically-engineered whole food approved for human consumption in the United States was the Flavr-savr tomato, created by the Calgene Corporation (now a part of Monsanto). The Flavr-savr, introduced in 1994, was intended to give store-bought tomatoes homegrown flavor by making ripe tomatoes more transportable. Three genes were introduced into a tomato strain that would allow a market tomato to remain on the vine until ripe and then be shipped to its destination (most market tomatoes are picked when green and firm and then ripened with ethylene after shipment). Among the problems the Flavr-savr had was a limited resistance to disease and disappointing yields, as well as a number of complaints about the texture and flavor of the fruit and overall consumer resistance.

Currently, there are nearly 60 genetically-engineered crops approved for production in the United States. The two most heavily commercialized genetic innovations in agriculture are those that make a plant resistant to herbicides or that provide augmented pest protection. The most common example of the former is Monsanto's Roundup Ready technology, which has been applied to soybeans, cotton, and corn, among other crops. Using genes from a virus, a bacterium and a petunia, Roundup Ready varieties are engineered to withstand Monsanto's Roundup herbicide, the most popular such product in America. By using this technology, farmers can apply Roundup to a field post-emergence, after the crop and its competitor weed seeds have germinated, and eliminate only the weed species. This reduces both the amount of herbicide and the number of applications and gives the farmer a much greater window of opportunity for application. An example of crops with pest resistance are so-called “Bt” varieties, including Bt corn and cotton. Bt varieties include genetic information from *Bacillus thuringiensis,* a natural soil microorganism that produces a protein toxic to some insects, including the European corn borer, which is a major corn pest. Genetic engineering has been applied to numerous crops, including potatoes, squash and tobacco, to enhance resistance to disease.

Other important genetically-modified products include chymosin, a protein enzyme from calf stomachs used for cheese-making—which can now be made by bacteria into which the gene for producing the chromosome has been added—and human insulin—which is now produced in lab-grown bacteria at a fraction of the cost of harvesting it from sheep pancreases. Recombinant Bovine Growth Hormone (rBGH), manufactured by bacteria into which the bovine genes that trigger the production of a certain hormone have been spliced, was introduced in 1993 and now is injected into as much as 30 percent of all dairy cattle to increase milk production.

A second wave of genetic innovation promises added value for consumers through enhanced or targeted output characteristics, such as vitamin-rich or high oil-varieties. Among these are canola with enhanced beta carotene and rice that has iron or vitamin A, all of which are poised to be released for field trials either in the United States or abroad. There are a number of new crops in development that will offer increased oil, protein levels, or starch content or offer targeted amino acid content or fatty acid composition in the oil, important factors for both the human and animal feed markets. There also are plans to develop genetically-engineered cotton with polyester-type traits, including, some researchers hope, wrinkle-resistant and fire-retardant cotton. For supporters of GMOs, these second generation transgenic crops offer a growing world a chance to eliminate malnutrition and hunger within the constraints of limited agricultural land and without the use of massive amounts of chemical fertilizers, pesticides and herbicides. They will also, it is hoped, provide a substantial return to everyone who invests in them, from farmers and processors to corporations and stockholders.

A third wave of innovations consists of what are termed nutriceuticals—genetically-modified crops raised with valuable medical properties—turning the plant into a living pharmaceutical factory. While this advance is still decades away, the potential opportunities for profit and promise in this area are in many ways a motivator for advancing biotech crops through the development stages. One of the most touted advantages of this technology would be to introduce necessary vaccines into fruit crops which would combine an easy delivery mechanism and a more affordable vaccine for people everywhere, particularly in the developing world, where vaccines are costly and in limited supply.

Biotech and American Agriculture

American farmers adopted GMOs quickly. While only a few years have elapsed since the first commercial introductions, genetically-engineered crops cover nearly one-fourth of U.S. farmland and account for about 57 percent of the soybeans, 65 percent of the cotton and 38 percent of the corn grown in the United States in 1999.

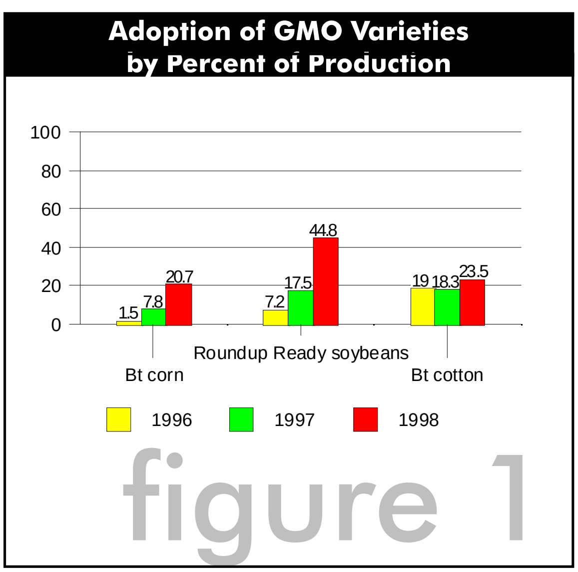
Roundup Ready soybeans, introduced in 1996, accounted for approximately one million acres planted in its first year. This figure has increased spectacularly since then, with about 35 million acres—nearly half—

of the U.S. soybean crop planted in Roundup Ready seed in 1999. Because soy products find their way into about 60 percent of all foods in the United States, it is very likely that most Americans have consumed some GMO soy product.

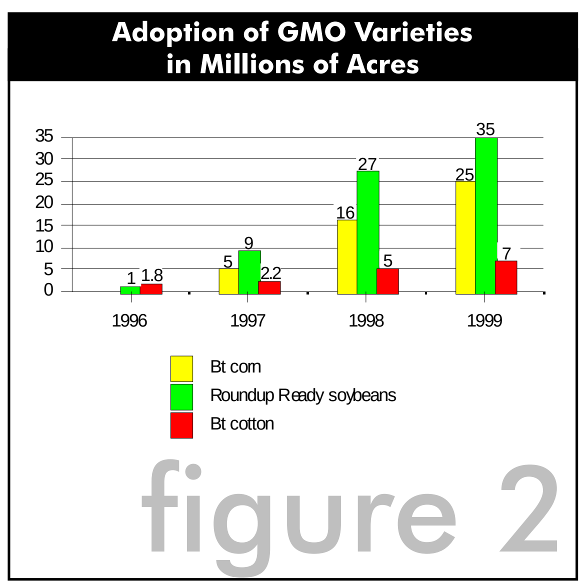
Roundup Ready cotton accounted for more than one-fourth of all cotton plantings in 1998. Bollgard cotton, which incorporates the Bt genetics, accounted for about slightly less, but amounted to nearly one-fourth of that year's cotton production. Also earning a niche in the market is cotton engineered to produce colored bolls that do not require additional dyes.

Bt corn was introduced in 1996 in limited quantities. In 1997, Bt corn accounted for five million acres, a figure which grew to more than 16 million acres in 1998 and reached an estimated 25 million acres in 1999. In 1997, a variety of corn with "stacked" herbicide tolerance and Bt protection was introduced and accounted for about five million acres in its first year, with more than 11 million acres of the stacked variety planted in 1998. In all, bioengineered corn account for slightly more than one-third of all corn planted in the United States. Figures 1 and 2 demonstrate the increasing importance of transgenic crops to American agriculture. In the coming years, biotech corn with value-enhanced output traits for special end-uses—including animal feed, starch content, and other qualities—is expected to reach the market, which should increase the presence of GMO corn. Given all of this, farmers and their communities have a great deal at stake in the debate over GMOs.

In addition to corn, cotton and soybeans, there are dozens of transgenic crops currently deregulated by the United States Department of Agriculture (USDA), meaning that they can be sold commercially. In addition to these, thousands of transgenic varieties are currently licensed for field trials, which allows for limited releases into the environment for research and testing. In the past few years, the number of field trials has grown considerably, as well, with little indication of slowing down. Table 1 provides the number of approved field trials in 1996 and 1999.



Source: Monsanto; USDA.



Source: Monsanto; USDA.

USDA Approved Field Trials for Selected Crops 1996 and 1999

Plant	1996	1999
Alfalfa	18	32
Beet	23	89
Corn	1019	2442
Cotton	191	350
Cucumber	12	22
Grape	<6	22
Lettuce	6	42
Peanut	<6	12
Pepper	<6	11
Potato	261	657
Rapeseed	57	158
Rice	13	93
Soybean	278	510
Squash/Melon	106	191
Sweet potato	<6	9
Tobacco	98	158
Wheat	14	95

table 1

Source: USDA, Animal Plant Health Inspection Service (APHIS), Field Test Permits as of January 25, 2000; APHIS quoted in Hemmer, 1997.

Why were GMOs so quickly adopted?

American farmers were very quick to adopt new genetic technologies for several reasons. Particularly with Roundup Ready soybeans, the new varieties offered an economic advantage in a very tight commodity market. First among them is the economic advantage they provide by reducing input costs. This is particularly true with crops engineered to be resistant to herbicides. Since herbicides can be a major cost component for several crops, the ability to reduce the number and volume of applications, along with a more flexible application window, saves farmers money and time. The new seed saves farmers time on pretreatment and cultivation, reduces the total load of herbicides required for raising soybeans, and reduces a farmer's total input costs, even with the higher cost of the seed. With crops engineered for pest resistance, a farmer's return may not be as direct because pesticide costs are often a factor of localized infestation rates, and individual farmer's pesticide costs may vary greatly season to season and area to area. Thus, Bt varieties may provide cost savings only when target pest loads are high, and are thus viewed by many farmers as more a form of insurance than an actual value-enhancing technology.

American farmers were offered this new technology at a critical juncture. With the passage of the 1996 Farm Bill, commodity payments to farmers were scheduled to end, and producers were eager for an opportunity to maximize their outputs and profits. Furthermore, pressure on farmers to reduce the total chemical load on their land was increasing, as were total farm costs. Once a few early innovators had success with the new crops, Monsanto and other life sciences companies found themselves with an unprecedented agricultural success story. Indeed, one of the most significant limiting factors in the adoption of these new technologies has been the availability of seed, with major producers selling all that they were able to produce most seasons.

Monsanto and other biotech companies also were aware of the lessons to be learned from Calgene's experience with the Flavr-savr tomato. While the tomato's genetics were successful, questions arose over the adaptability and hardiness of the variety of tomato that was used as the base. In developing all of their genetically-modified products, companies have been careful to select what were already premium varieties, bred for high yields, strong growth patterns, and resistance to a variety of diseases. In this way, yields of Roundup Ready soybeans, Bt corn and cotton all have been reported to be at or above yields experienced by farmers with conventional varieties. There have been some bumps along the road, however, including some problems with Bt and Roundup Ready cotton in a number of areas as well as some germination complaints with soybeans, and a recall of Roundup Ready canola seeds due to some problems with the genetics. Most problems were reported in the earliest issuances of the products and have become less frequent as the varieties have become more established.

A Storm Brewing

Transgenic crops are not without critics, however. Consumer groups, environmentalists, and advocates for the developing world all have concerns over the health and ecological implications of this technology and the ability of the companies controlling these genetic innovations to patent varieties and restrict the farmers from planting seed held back from a previous harvest. In response to consumer pressure, governments in the European Union, Australia, Japan, and elsewhere have moved to block or restrict access to their markets for GMOs and foods produced containing them. Some food companies—including Gerber and Heinz—also have begun to ask producers to certify that the soybeans or corn they are delivering are free from GMOs and Frito-Lay Inc. informed its suppliers in January 2000 not to use any genetically-modified corn varieties.

According to the Consultative Group on International Agricultural Research (CGIAR), a Washington-based association dedicated to food security and poverty eradication in developing countries, the risks associated with genetically-engineered foods are no different than those associated with classic Mendelian crossing and hybridizing. The group was at the center of the research for "golden" rice which contains beta-carotene and is hoped will help reduce the impacts of vitamin A deficiency in the developing world, a condition affecting nearly one-third of the world's population. The Consultative Group, an informal association of 58 public and private sector members that supports a network of 16 international agricultural research centers cosponsored by the World Bank and three agencies of the United Nations, is fighting for greater acceptance of transgenic crops and limited access restrictions to the technology.

Robert Shapiro, Monsanto's CEO and biotech's most determined promoter and defender, has argued forcefully that genetically-engineered foods aren't just valuable, they are necessary in order to feed a world of six billion people, a figure that is projected to climb to 10 billion before the next century. The world has not added significantly to its cultivated land in the past 30 years, Monsanto executives pointed out in an interview, although population has grown by nearly two-and-a half billion. Supporters maintain that biotech provides the best, and possibly only, means to feed the world without converting important natural areas, such as the vast Brazilian and Central African rainforests, into agricultural land. Critics counter, however, that hunger and food insecurity are more often economic, not production, concerns and that better, but more expensive technologies will only exacerbate the disparities between the world's developed and underdeveloped economies and further concentrate wealth and control over global food stocks in the hands of a few wealthy multinational corporations.

Initially, the controversy over transgenic foods seemed limited to Europe, where early resistance to the Flavr-savr tomato set the stage for even more vigorous efforts to keep other GMOs from the European market. Subsequent to the approval of GMO products by the European Union's own science board, many European governments responded to public pressure and instituted bans or restrictions on GMO products which essentially blocked access to this important market for many American products and commodities. Recently, many of the protests voiced in Europe over GMO foods have begun to be heard in the United States, perhaps most notably during the November 1999 World Trade Organization meeting in Seattle.

Among the principal concerns with the technology currently being discussed is the potential for "blow-over," a process in which pollen from a genetically-engineered plant fertilizes a closely related non-GMO variety. This can cause problems in two ways. If the conventional variety that is inadvertently pollinated is a food crop, the resulting fruit, vegetable, grain or seed will be a transgenic crop, which potentially restricts that crop from some markets without the farmer receiving any of the benefits of the genetic technology. Liability for this "genetic invasion" is an ambiguous area, since pollen blow-over between closely related, but non-GMO, crops—which does not essentially alter the marketability of the crop—has taken place without consequence since plants began to be differentiated by variety.

The second possibility is more troubling, and that is if the GMO pollen should fertilize a closely related weed species, transferring the genetically-enhanced pest control, herbicide resistance, or increased hardiness into a species farmers want to eliminate. In both cases, scientists from the agriculture industry respond that GMO products are extensively tested and that the potential for such an event happening are minimal. The three principal transgenic crops currently in commercial production—corn, cotton and soybeans—lack close wild relatives, so the potential for GMO varieties of these crops to create a "superweed" in the United States is almost nonexistent. Others, including canola, sunflowers, squash and millet, all have close "wild" relatives which could, some scientists contend, pick up the genetically-altered trait and become resistant to herbicides or pose greater threats because they have developed pesticide- or enhanced-hardiness qualities.

Another concern is that plants engineered with pest control quantities, particularly the Bt strains, will facilitate the development of Bt-resistant insects and reduce the effectiveness of these transgenic Bt strains as well as topical Bt treatments, a critical pest control strategy for organic and other commercial producers. The potential for pests, bacteria, and viruses to develop resistance to any genetic technology aimed at controlling them increases as the transgenic varieties become more widely adopted. Because this technology is so new, there is little available research on the practical threat this poses, although resistance to chemical treatments is well-documented.

Also, GMO critics contend that the introduction of pest control technology into a plant could have a deleterious effect on both beneficial predator insects and harmless, nontarget species. Probably the most publicized example of this concern is a recent research claim, still in dispute, over Bt corn pollen harming populations of caterpillars that become Monarch butterflies. Further concerns center on the potential for the loss of biodiversity as farmers switch to a relatively limited stock of transgenic plants. This is tied to a concern over the potential for a pest or disease either not targeted by or resistant to the genetically-altered crop decimating wide areas of the planted crop.

Consumer groups and environmentalists also frequently cite the danger of the unknown with GMO crops. Indeed, very little is known about the long-term effects of these crops, and their potential to play havoc with human or animal health remains largely uncharted. Chief among health concerns are the possibility for the introduction of unknown allergens into food through genetic modifications, the introduction of new toxins or increased levels of toxins, and the spread of antibiotic resistance. This final concern is raised because when scientists inject genetic material in a target variety they often link it to antibiotic-resistant "tracker" genes. In the absence of long-term tests to study the impacts transgenic foods may have on human and animal health, consumer advocates are calling for stricter controls on GMOs and labeling of any product that contains them, as well as increased independent research on the health impacts, if any, of these crops.

While many supporters of transgenic crops argue that the controversy is largely being stirred both at home and abroad by extremist groups, resistance to and concern about genetically-altered foods is growing in the mainstream. The Consumer's Union, a group most well known for its product quality ratings in *Consumer Reports*, recently made several recommendations regarding GMOs. Among them were: including safety reviews that include research on pest resistance, harm to beneficial insects and genetic "blow-over" to wild species; assuring for seed company liability for any economic or biological damage resulting from GMOs; and labeling for any food, either domestic or imported, containing GMOs.

While surveys conducted by the Gallup Company indicate that Americans are comfortable with GMOs, research conducted last year by the International Food Information Council indicates that consumers did not consider themselves well informed about the issue. In the months since that survey was conducted, the controversy surrounding transgenic crops has increasingly been in the headlines, and not always in a positive light. Nonetheless, American consumer acceptance of GMO products is predicted to grow by agriculture and food industry analysts as the full range of advantages to transgenic foods becomes known. Skeptics, however, counter that without labeling, the American consumer won't have the opportunity to "vote" on the technology, but either must accept it or suffer a price premium for organic products.

The food industry which strongly opposes labeling GMOs, fears that to do so would stigmatize and restrict the products. The Food and Drug Administration, while encouraging voluntary labeling, only requires labeling if the genetic innovation changes the nature of the food or introduces an allergen into the product.

Some states have considered legislation requiring the labeling of GMO foods, although no state has yet instituted such a requirement. The logistical challenges of labeling foods as either GMO-free or as containing GMOs can be mammoth, depending on the commodity. As discussed later, in order to provide guarantees to consumers over a food product's contents, complete traceability has to be assured. Traceability, which is currently being developed for food safety assurance, would require the establishment of product segregation and identification systems, essentially "de-commodifying" the major commodity groups.

Who owns the seed?

Because of the enormous investment required to develop new genetically-engineered strains, very few small companies are players in the seed genetics business. There are only five major players in the transgenic seed market: Monsanto, Dupont, Dow Chemical, Syngenta (formerly Novartis and AstraZeneca) and Aventis (formerly Hoechst and Rhone Poulenc). The market for genetically-engineered seed for some foods is, in a number of instances, controlled by one company. This trend has raised concern over the vertical integration of the food chain. Specialized GMO crops could require specialized, and proprietary, production methods and inputs, something that will only increase the concentration of control in the sector.

U.S. Secretary of Agriculture Dan Glickman noted this concern in a recent address to the National Press Club, commenting that "consolidation, industrialization and proprietary research...threathens to make [farmers] servants to bigger masters, rather than masters of their own domains."

Currently, Monsanto holds patents or licenses on about 90 percent of the genetically-modified crops now on the market and is the world's second largest seed company. Monsanto's preeminent position in the "new agriculture" is well established, and its exposure is tremendous. As more GMOs become deregulated in the United States, Monsanto's share of the transgenic seed market may decline somewhat, but most analysts predict that Monsanto's seed division is well positioned to remain dominant for years to come.

Because of the massive amount of capital investment in research and development, companies that develop new seed technologies want to protect their inventions through patents on the seed. In order to exercise this patent, it is seen as necessary by the seed company to restrict farmers' reuse of seed from the previous year's harvest. Such restrictions on so-called seed holdbacks often are outlined in seed contracts which bind farmers to using only company-licensed pesticide or herbicide inputs, or which stipulate particular cultivation practices. These demands are necessary, companies maintain, to guarantee that they will be able to benefit from their investment and to ensure high yields from a technologically advanced crop. Seed use agreements also include stiff penalties for violators, and companies have aggressively pursued farmers who have broken their agreements. Many farmers have bristled at the terms of these contracts and enforcement actions, calling them invasive and heavy-handed.

Impact

The controversy over GMOs, especially the essential exclusion of many American products from the European market, has had major implications for the future of bioengineered crops. Farmers who had grown genetically-engineered corn or soybeans in the past few seasons are reporting plans to pare back on their genetically-engineered plantings until the international commodity market for GMOs has stabilized. This was in part due to a number of grain and oilseed handlers and elevators refusing to take GMO varieties for fear of not being able to sell them to European or Asian customers.

In the United States, genetically-altered crops must be approved for experimental and commercial release by the USDA. Experimental releases of any GMO crop are reviewed by the USDA's Animal Plant Health Inspection Service (APHIS), which considers the genes involved, particularly if they are potential allergens, the conditions for conducting the field trials, possible environmental impacts, and the impact the new plant variety may have on other plants, including threatened and endangered as well as nontarget species. For a transgenic crop to be released commercially, developers must petition APHIS to have the plant deregulated. The U.S. Environmental Protection Agency also must review any new variety that has pesticidal or herbicidal qualities, and the Food and Drug Administration of the U.S. Department of Health is available for comment, although currently no special FDA review outside those required for other, conventional foods is required. The USDA, which plays the principal role in approving transgenic plants, has yet to reject any of the dozens of applications it has reviewed, although some applications have been withdrawn. Outside observers, including some in state departments of agriculture and colleges of agriculture, have noted that the USDA is heavily reliant on data from the applicants, with little outside review possible (often due to proprietary concerns) until after the plant has been deregulated. The USDA has acknowledged that the approval system is still inchoate but maintains that none of the deregulated crops have had negative environmental or health impacts.

Market response. In the 1990s major companies were as responsive to their stockholders as they were to their customers. Particularly in a capital-intensive industry such as biotechnology, investor support is important to ensure adequate funds for product research and development. When the agriculture industry rushed to embrace the new genetically-modified organisms, it was largely caught off guard by the visceral rejection of the products in the European Union. While Europe's response has been pinned on everything from a fear of bio-imperialism led by the United States to a backlash over the outbreak of "Mad Cow" disease in the United Kingdom, the simple fact remained that consumer resistance was sufficient in the EU to essentially shut down the approval process for new GMOs, even after the EU's own science commission reported them to be safe.

In the wake of Europe's rejection of GMOs, and the emergence of a U.S. movement to limit GMOs, the stock market has begun to look less favorably on GMO ventures. Monsanto has perhaps been the hardest hit from this, since it is the world's leader in the field. The company's agricultural unit has been characterized as a handicap on its stock performance due to the European backlash to its biotech products. When Monsanto announced a merger with pharmaceutical giant Pharmacia-Upjohn, both partners downplayed the role of Monsanto's agricultural unit and let it be known that an agricultural subsidiary will be created to provide a firewall between that currently troubled unit and the less controversial aspects of Monsanto's business. Nonetheless, industry analysts point to a long-term outlook which sees GMOs becoming more and more important—and unavoidable—in the food supply system and predict a rebound for Monsanto and the industry.

In January, representatives from 130 countries reached an agreement on trade in GMOs at global biosafety talks conducted under the auspices of the United Nations Convention on Biodiversity in Montreal. The agreement, the first international treaty on biotechnology, allows countries to refuse entry to GMO plants or animals for reasons based on sound science, but allows for countries to reject crops in the absence of scientific certainty. The agreement warded off the labeling of GMOs for at least two years—a major concession to the United States and other major food exporters—but it does require commodities handled in bulk to have documentation stating that the shipment may contain GMOs. One justification for the delay was the cost involved in establishing, essentially overnight, a system of segregated handling and verification for commodities. If, in two years, market forces have encouraged the development of such a system, the United States has indicated that it would not vigorously oppose some labeling requirements on exports.

A key element of the agreement is a requirement of prior approval for exporters shipping a transgenic "living organisms" meant for release into the wild, such as crops and microbes. Because the U.S. Senate has not ratified the U.N. Convention on Biodiversity, the United States had no official standing at the Montreal discussions and is not bound to honor the treaty. However, the Clinton administration has said that the United States would abide by the agreement.

These talks were long deadlocked over what is known as the "precautionary principle," an element central to many environmental treaties. The precautionary principle essentially allows countries to restrict or outright ban crops or animals as a precaution without scientific certainty that they pose a threat. Opponents of a vigorous precautionary principle argued that it allows a country to establish a non-tariff trade barrier based on unscientific presumptions about foods which most scientists maintain are safe. In the end, a coalition of major agricultural exporting nations, including the United States, Canada, Argentina, Australia, Chile and Uruguay, compromised on the inclusion of the principle in the final agreement, allowing countries to reject GMOs because of fears that they might be harmful to the environment or health. In exchange for their compromise on this issue, the major food exporting nations were able to include language that is intended to prevent countries using the precautionary principle to avoid opening markets as per World Trade Organization agreements. In the weeks following the Montreal Agreement, Germany banned the cultivation of, and thus the import of seed for, genetically-altered corn because of the potential affects GMO corn could have on the effectiveness of antibiotics in humans.

Another outcome of the talks was the establishment of a global clearinghouse for information on bioengineered crops. The database is intended to act as a single point for technical data regarding varieties of GMOs approved by various countries. As countries approve varieties, they would post this information to an Internet-based system that would allow a country to review a crop and make a decision based on regulatory information from approving countries. It is hoped that this will streamline the decision-making process and make it facilitate product approval for producers. This element and the agreement's stance opposing labeling on GMO products may slow the need for crop segregation, although this could be complicated if countries do decide to exercise their option to restrict GMO crops as a precautionary measure.

Implications for the future

As these new value-enhanced food products enter the market as a result of the biotechnology revolution, there almost certainly will be an increased need to modify the commodity marketing and handling system to preserve brand identity and to separate genetically-modified products from conventional ones. This already has become a critical issue for many American producers in the wake of the European Union's refusal to approve some GMO varieties as well as to reap the price premiums offered by many U.S. grain merchants for non-GMO products.

Interest in Europe and the United States in labeling foods with GMO content is increasing. For any labeling regime to have credibility, some system for handling and identifying GMOs will be necessary. Furthermore, as the next generation of biotech foods comes to the market offering a variety of value-added properties, the crop will need to be sufficiently isolated from field to harvest to on-farm storage to elevator and shipping through the final destination to ensure brand identity. For either contingency there can be only minimal, inadvertent intermingling of conventional and GMO crops, or even between GMO crops engineered to produce different results. For this to be possible, a system of separate storage facilities is necessary at every stage, which may have the effect of increasing costs for both the enhanced products and non-GMO crops. Many industry analysts point to a movement away from handling crops as bulk commodities which can be blended in an undifferentiated manner under broad grades and standards categories to a system where crops maintain their identity from farm to table.

Additionally, in order to guarantee that crops can be exported to countries with restrictions on some GMOs, a marketing and certification system will be necessary to ensure that shipments are within tolerances for GMOs. Furthermore, any labeling efforts domestically will be tied to the need to certify that the claims made by the marketer are accurate. Such traceability is already being developed for food safety purposes, and industry analysts have noted that a similar, integrated system could apply to genetically-altered foods. Organic foods are handled separately from farm to market and provide an example of the possibilities, and costs, of identity preservation. There undoubtably will be added costs for any system which requires crops to be handled in smaller, discrete units, costs which will almost definitely be passed on to consumers. These added costs will have to be justified by the value to consumers of the new crops or of avoiding them.

Labeling Hurdles

The labeling of GMO foods, or foods which do not contain GMOs, is a thorny issue. The U.S. Food and Drug Administration only requires labeling of a GMO product if it differs significantly from its conventional counterparts or if the genetic modification incorporates genes from a known allergen. An example of this is if the alteration is likely to cause an allergic reaction not common with the conventional variety. The USDA has encouraged the voluntary labeling of biotech products, but this approach has not received much support from either producer or consumer advocates. When rBGH was introduced, efforts to label milk produced with the hormone were struck down by a federal court on the grounds that labeling a product in response to consumer concern violated commercial free speech. Following that decision, dairies attempting to label their products rBGH-free met with lawsuits alleging that their assertion created unfounded—and unscientific—claims about the relative wholesomeness of milk produced with rBGH. In the European Union, labeling of products as GMO-free has had the predictable effect of limiting the market for GMO products. Because of this, most analysts foresee that further labeling efforts will be vigorously resisted by the food industry, particularly any effort to label GMOs in the United States.

All foods have set tolerances, levels of "contamination" set in accordance with allowable risks or market acceptance. With transgenic foods, this situation is complicated because much of the agriculture industry maintains that current GMOs are identical to non-GMO products as food, and thus any distinction between them is an unscientific barrier to trade. As second-generation transgenic foods with enhanced nutritive or other end-user benefits enter the marketplace, however, the need to establish "purity" tolerances will become a vital quality control question, since, in this case, any mixing of a non-GMO product with the engineered product would amount to a dilution of the (presumably value-enhanced) commodity. Furthermore, as handling facilities become more specialized in the kinds of products they accept, standardized tolerances will be necessary for the assurance that their products are able to find suitable markets.

Even those nations with restrictions on GMOs still are grappling with what tolerance levels to set. The European Union and Japan have yet to issue any direction on this, which makes trade more complicated. Tolerances of 5 percent (meaning that the product would have to be 95 percent free of genetically-modified content) are the most likely, according to trade analysts at the U.S. Department of Agriculture, but some countries have raised both zero-tolerance and a 1 percent threshold as possibilities. Should a country choose these more stringent standards, it would almost be impossible for U.S. producers of some crops to export there, creating a trade barrier. Such restrictions on trade will be challenged by the United States at the World Trade Organization as unallowable hindrances to free commerce.

For those markets which currently are restricting GMO products, one of the immediate challenges facing the agriculture industry is the question of tolerances. Most analysts agree it would be impractical and almost impossible to establish a zero-tolerance level for transgenic content in non-GMO certified foods (where no transgenic content would be permitted). Nonetheless, currently no standard exists for how much of a sample can be genetically-altered before it can be rejected as a restricted transgenic food, nor are there standard approved tests for determining genetic content, although several different testing protocols are under development. Because of the uncertainty over what constitutes allowable levels of genetically-engineered content, shipments have been halted for what amounts to residual modified content from inadvertent overlap at the handling or storage stage. In the absence of any clear standard, such rejections are easily perceived as arbitrary, and it is this very perilous situation that has made grain dealers so concerned about handling GMO products.

Changes in the Fields

Most agriculture analysts are predicting a slowdown in the market for GMOs in the next planting season, if not a decline in planted acreage. This concerns some in the financial world, and has been reflected in drops in the share price of major life sciences companies, but is of less concern for many in the field. Genetically-engineered crops were so swiftly adopted by so many producers that there was an inevitable point where some adopters would opt out, and new adopters would decrease, analysts say.

Given the uncertainty in marketing GMO crops, and future needs to ensure brand identity, the USDA's Economic Research Service predicts that more contracting for these products may result. By contracting, farmers isolate a number of risk factors, including market access, even though they may have to accept a lower price premium for their specialty crop. Furthermore, since success in growing a specialized crop depends on a coordinated system between seed technology companies, growers and end-users, more control and more rigid requirements are likely to result from the next generation of enhanced-value crops. This in turn could spur a more vertically-integrated system, in which one firm owns the seed technology, marketing system, and processing operations for a specialized crop. Farmers, in this system, would most frequently be contractors for the integrating company.

Farmers growing specialized crops also may opt to bypass local grain elevators and sell directly to a commodity buyer, a move that could spell trouble for smaller elevators and consolidators. A possible response to this pressure would be for marginal elevators to focus on special handling for select crops, moving out of the bulk handling business entirely and dedicating resources to price-premium crops.

As the commodity system evolves to handle new, engineered products, the likelihood is that a niche market for non-GMO products will develop. Dedicated facilities for handling GMO or non-GMO products and special handling procedures to guarantee a minimum of product mixing will need to be developed to provide adequate safeguards that farmers who invest in new technology are able to reap the financial benefits of their decisions. This is also necessary to allow those farmers who opt for traditional crops the opportunity to continue to sell their non-GMO products without fear of rejection by countries or companies where GMOs are restricted.

The Role of State Governments

State government officials may feel that they are on the sidelines of the GMO debate, though the future of GMOs may be central to the health of a major part of their state's economy. Many of the decisions regarding the new genetics are directed either by the federal government or by large multinational corporations. States have a limited role to play in the labeling of crops and many states do not restrict experimental licenses approved by the USDA, although a few have. Nonetheless, states do have an important role in developing and managing this emerging technology for the benefit of their citizens and the health of the agricultural economy.

Funding for research institutions: Much of the early development of transgenic foods was conducted by state land-grant universities, and these institutions continue to play a vital role in both the development and testing of genetically-engineered foods. The consolidation and concentration among life sciences companies, the high cost of conducting genetic research, and the continuing need for credible, disinterested evaluation of these innovations will make these state-supported research units even more important. Traditionally, seed companies have been important sources of funding for research at these institutions, although this close relationship has caused some concerns over the independence of evaluations conducted by such state-run research institutions. As more and more GMOs enter the market, the resources for reviewing and evaluating these foods could become strained. Additional funding to state research institutions could protect the independence and capacity of the state to conduct the necessary evaluations and development it needs to keep its agricultural economy and its citizenry healthy, safe and prosperous.

Support for testing and certification systems: There are numerous testing protocols in development to assess whether a crop has transgenic contents. These tests vary in their effectiveness, sensitivity and costs. It is likely that much of the burden for testing crops for GMOs will fall on the initial integrator who generally are small operators with little capital to invest in expensive testing equipment. State support for testing protocols and standardization of GMO certification would be of great assistance to this crucial link between farmers and markets. Providing information and technical support for farmers and elevator operators on the various tests available would require very few new resources, but would be tremendously helpful.

Information on where GMOs are being accepted: In response to the backlash against GMOs, some grain elevators and commodity handlers began to refuse accepting transgenic crops. Many of the major commodity growers' associations established a service for their members by providing information on the nearest elevators or handlers who were accepting their varieties. State departments of agriculture are well situated as central clearinghouses for such information on who will accept what GMO products and who is requiring product segregation.

Seed boards and the new genetics: State seed boards, which certify the lots and varieties of seeds sold in most states, remain little changed since the first hybrid seed entered the market. Recent disputes over GMO seed have focused mostly on germination and performance matters unrelated to the genetically-introduced characteristics. Some adjustments may be needed, however, in arbitration procedures in an environment where farmers are subject to contract requirements and technology fees. Strengthening the capacities of state research labs to conduct tests on product claims and to investigate complaints of poor performance would also better position state seed boards to respond appropriately to farmer complaints and inquiries.

State role in new marketing structure: If the structure of the commodity market shifts from bulk to segmented and segregated handling, there could be short-term, regionalized shortages in storage and handling facilities for all crops. This could be particularly true with new crop introductions requiring special handling or which, because of their special characteristics, must be highly segregated from other varieties. Unless local volume of a specialized crop is adequate to support a dedicated elevator, early adopters of what could be highly profitable new technologies could find that they have to incur tremendous storage and transport costs to market their crop. Consideration of state support in this transition period for local handling facilities and on-farm storage could assist in minimizing the risk farmers face in pursuing new technologies.

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