Have Transgenes

ISSUES RAISED BY GENE FLOW
FROM GENETICALLY ENGINEERED CROPS

Will Travel

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This paper, prepared by the Pew Initiative on Food and Biotechnology, is one in a series of background briefs intended to provide a non-technical introduction to various issues relating to genetically modified food and agricultural biotechnology.

Have Transgenes, Will Travel

Issues Raised by Gene Flow from Genetically Engineered Crops

Concerns surrounding the widespread commercial use of genetically modified (GM) plants generally have focused on two questions: are GM plants safe to eat and do they pose dangers if they spontaneously breed with wild relatives or conventional crops. While food safety issues have garnered much of the attention, there is also much discussion about what could happen if transgenic plants accidentally co-mingle with their wild and domesticated relatives. The issue revolves around the extent to which GM plants may spread their novel traits into surrounding crops and ecosystems via pollen or seed and just what sort of problems, if any, one might encounter from this “gene flow.”

Gene flow is not something peculiar to transgenic plants. In the world of living creatures, gene flow is as old as life itself. It happens any time one organism breeds with a related species, thus passing along their combined DNA to the offspring. That said, gene flow that involves genetically manipulated organisms raises a new set of issues for scientists and policymakers to consider.

ECOLOGICAL ISSUES. Investigators interested in fleshing out the particular risks posed by gene flow from GM plants generally are interested in the ramifications of several distinct scenarios. One widely discussed scenario among ecologists is whether a transgenic plant might breed with a wild relative, and perhaps forever alter the wild plants’ genetic identity. Another issue is whether the transgenic plant might endow a wild relative with a so-called “fitness” gene, making it hardier and giving it the potential to become a kudzu-like “superweed.” In addition, there is a separate environmental concern related to the conveyance of pest-killing properties. While such a trait might be desirable for a domesticated crop, could its presence in a wild plant alter the ecosystem by killing off beneficial insects and soil organisms?

ECONOMIC ISSUES. Somewhat separate from the analysis of these potential ecosystem effects are efforts to evaluate the economic implications of GM crops spreading their transgenes to other, conventional crops. The concern here is that if pollen or seed travels from a field of transgenic corn to a field of conventional corn, it could hinder efforts to maintain distinct varieties of crops for the marketplace. This may be of particular concern if farmers are trying to grow and market “GMO-free” commodities.

Meanwhile, applications on the horizon that would modify plants to make them produce pharmaceutical or industrial products appear destined to present a new set of concerns about gene flow between conventional and transgenic crops.

Gene Flow Hits the Headlines: The Mexican Corn Controversy

Scientific inquiry into the implications of gene flow from transgenics is a relatively new and still developing field of study. But it appears that the public is interested in getting some answers to the many questions about what happens when transgenes become mobile.

In late 2001 and early 2002, it became clear that gene flow from transgenics was no longer an esoteric debate of interest only to ecologists, plant geneticists, biotechnology companies and public interest groups. The watershed event was a report by David Quist and Ignacio Chapela, two scientists at the University of California, Berkeley, that transgenic corn had cross-pollinated with a native ancestor of corn growing in Mexico, despite the fact that Mexico had banned cultivation of transgenic varieties. Originally published in *Nature* magazine, the findings were challenged widely by scientists who felt the research was flawed. *Nature* editors agreed and took the rare step of essentially retracting the report, claiming that upon further review there was insufficient evidence to justify the original publication.

Charges flew between both sides that criticism and support of the paper was really motivated by pro or anti-GM food agendas. But what was most confusing to many observers is that, when the dust settled — if it has indeed settled — it appeared the debate over the incident was not over whether there was transgenic corn in Mexico. Rather, the argument focused on the methods used by the researchers to detect its presence and on their complex scientific analysis of how the transgenes were behaving in Mexican corn. As *Science* magazine noted in a March 2002 report on the incident, "Surprisingly, even Quist and Chapela's most strident critics agree with one of their central points: Illicit transgenic maize may well be growing in Mexico."

If, then, most parties generally agree that GM corn is growing in Mexico, the question really becomes, should we be concerned?

Those alarmed about the discovery argue it is a problem because Mexico, where corn first originated, is a global center of corn biodiversity. They claim that valuable strains of corn and corn's wild ancestor, teosinte, could be irrevocably altered should their genes co-mingle through crossbreeding with the DNA from the transgenic corn. At the height of the controversy, advocacy groups asked the United Nations to impose a moratorium on the cultivation of transgenics in areas deemed centers of genetic diversity. They referred to the presence of GM corn in Mexico as a "contamination" and said it would impose new burdens on internationally-supported seed banks maintained in Mexico. Among other things, they argued that at a minimum the ability to distribute a healthy diversity of corn seed to farmers globally would be constrained by the need to screen seed for the presence of GM traits.

Others, who believe the furor unjustified, have argued there is no more reason to be concerned about the presence of transgenic corn in Mexico than there is about the fact that non-native commercial strains of conventionally bred corn have been grown there for decades. Countless varieties of conventionally bred corn have been growing in Mexico with no apparent harm and little or no controversy. So why, they counter, are transgenic varieties being singled out for vilification?

For example, a February 2002 "Joint Statement" published by Agbioworld.org that was signed by more than 100 public and private sector scientists, states that "it is important to recognize that the kind of gene flow alleged in the *Nature* paper is both inevitable and welcome." The statement went on to argue that the spontaneous flow of DNA from GM corn to Mexican varieties is part of a process farmers have used for thousands of years to improve their seed stock by "planting seeds of new varieties adjacent to old ones and then (selecting) the desired offspring while discarding the rest."

These arguments have not satisfied some critics of GM crops who believe that gene flow from transgenics is qualitatively different than gene flow involving conventional crops. They claim transgenics are inherently more threatening because the technology itself so disturbs a plant's genome as to make its behavior unpredictable.

While the majority of scientists who have studied the issue do not support such claims, the polarizing debate over the significance of transgenic corn's incursion into native Mexican plants highlights the need to better understand the risks posed by gene flow from GM crops.

Do Transgenics Deserve Special Consideration? No and Yes

So far, most scientific inquiry into the subject has failed to support the notion that there is something about the genetic engineering **process** itself that intensifies any threats from gene flow. In the 2002 report, *"The Environmental Effects of Transgenic Plants,"* a panel of experts assembled by the National Academy of Sciences (NAS) concluded that "the genetic engineering process, *per se,* presents no new categories of risk" to the environment compared to conventional breeding.

In other words, scientists are quick to point out that gene flow did not begin with transgenic plants or even agriculture, and that the kinds of risks from transgenic crops are similar to those from conventionally bred crops. Naturally occurring instances of gene flow is the reason there is such an abundant variety of related plant species.

On the other hand, although the **process** of genetic engineering may not introduce new categories of risks, the **traits** introduced through biotechnology may pose different risks. As the NAS report pointed out, "this technology could introduce specific traits or combinations of traits that could pose

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unique risks." Biotechnology certainly broadens the horizon of potential risks posed by gene flow, since it greatly increases the number and type of traits that can be added to individual species. In fact, it is the revolutionary ability to improve plants by infusing them with genetic material borrowed from a wide variety of species that sets biotechnology apart from conventional breeding.

For example, through biotechnology, farmers now have access to corn and cotton that contains a gene obtained from a bacterium, *Bacillus thuringiensis* or Bt, that gives these crops the ability to produce an insect-killing toxin. One concern is that transgenic crops containing these genes could breed with a wild relative and in the process pass along this insect-fighting capability. If this new trait made the resulting hybrid more "fit," it could out-compete and eventually replace the unmodified wild relative.

So through the age-old process of gene flow and the modern industry of biotechnology, there is the opportunity for new traits to be integrated into species where they have never been seen before. Furthermore, the most widely used applications currently on the market—which convey such traits as Bt expression, herbicide resistance and protection from plant viruses—are just a hint at the technology's potential. Scientists currently are experimenting with a variety of transgenic traits, such as those that would give plants the ability to survive in salty soils or harsh conditions. In many cases, seed companies will want to "stack" multiple traits into a single plant, further complicating the assessment of environmental impacts.

Breeding With Immediate Family and Consorting With Wild Relatives

CROP-TO-CROP GENE FLOW. The first thing scientists must consider when studying the risks of gene flow from GM species is the likelihood that transgenic plants will move "off the farm," so to speak. Scientists generally expect that if a GM variety of a crop is grown near non-modified varieties, gene flow will be a fairly common occurrence. It is well known that pollen from, for example, one variety of corn (conventional or transgenic) can spread to an adjacent field containing another variety and create a hybrid. There are plenty of documented cases of this kind of spontaneous "crop-to-crop" gene flow occurring between transgenic and conventional varieties of corn and canola.

The likelihood of gene flow through pollen drift will depend on the specific crop. Crops that are fertilized through wind-blown "open" pollination, like corn, are more likely to hybridize. Other plants that self-pollinate, such as soybeans, will be less susceptible to gene flow problems.

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A widely discussed instance of crop-to-crop gene flow occurred in 2000 in Canada, where discovered growing on the roadside and as a weed or "volunteer" in a farmer's field, was a variety of canola that, due to gene flow between different fields of canola, had come to possess resistance to three herbicides. Two of the resistance traits were acquired from inadvertent cross breeding involving genetically engineered canola plants. One was acquired from a canola plant whose herbicide resistance was produced through conventional breeding techniques. Its relatively quick emergence—herbicide resistant canola has only been on the market for a few years—is viewed by scientists as a good example that gene flow happens and it can happen soon after a new variety is introduced.

Crop-to-crop gene flow creates two potential problems for farmers. The first concern is that the new hybrid could become a troublesome weed. For example, if a hybrid canola resistant to three herbicides begins growing as a "weed" in a farmer's cornfield, it may be difficult to control using herbicides and would have to be mechanically removed. Some believe that this outcome is unlikely because of the availability of other herbicides. In any event, the development of weed resistance to herbicides is certainly not a new phenomenon, and has been a management issue for farmers for decades.

A second concern is that gene flow from transgenic crops could pose an economic problem for growers seeking to avoid the use of genetically engineered crops for a variety of marketing reasons. Most notably, producers of organic food are particularly concerned about crop-to-crop gene flow involving transgenics, because in many countries, the United States and Canada among them, regulations regarding organic foods ban the use of biotechnology in their production or processing. (In the U.S., a food may still be labeled organic if it contains low levels of unintended GM ingredients caused by gene flow, as long as the farmer followed the requirements of organic production, but organic food manufacturers might still insist on no GM content.) In January of 2002, the Saskatchewan Organic Directorate in Canada filed suit against makers of transgenic canola for the loss of markets because of cross-pollination between organic and GM canola crops. GM canola represents between 50 and 60 percent of all canola planted in the province. According to the suit, the prevalence of GM canola makes it difficult or impossible for organic farmers to produce GM-free canola.

Even conventional farmers are concerned that GM crops may endanger some of their overseas markets. As they seek to meet market demands in countries that do not want or do not permit all GM crop varieties, some farmers are growing concerned that gene flow from GM crops in neighboring fields may render their crops unacceptable in those markets. For instance, the European Union adopted new policies in July 2003 that require food and animal feed containing more than 0.9 percent of GM content to be labeled as genetically modified. The possibility of gene flow makes such a threshold potentially difficult to reach in some cases.

CROP-TO-WILD RELATIVES GENE FLOW. Biologically speaking, gene flow of the crop-to-crop variety is relatively easy to understand, but what do we know about the potential of GM crops to spread their traits not just to nearby farms but into the world of wild plants.

The conditions must be right to result in successful cross-breeding between domesticated GM crops and wild relatives. There must be pollen drift from the GM crop, there must be wild relatives nearby to receive the pollen, and the wild relatives must be compatible enough to result in a fertile hybrid that contains the GM genes. Scientists are investigating these factors in determining the probability of gene flow from crops to wild relatives.

Norman Ellstrand, an expert on plant population genetics at the University of California-Riverside, has done extensive research on the capacity of cultivated crops to distribute their genetic material by breeding with wild relatives. He said that even as recently as the early 1990s, the general assumption was that gene flow from crops to wild species was a rare event. This was based on the belief, he said, that crops had been growing in isolation from their wild relatives for so long that they simply were no longer very compatible. This was supported by anecdotal reports from plant breeders that they routinely failed when trying to create hybrids by crossing a domesticated crop with a wild variety.

But Ellstrand has found spontaneous cross breeding, and hence gene flow, between crops and their wild relatives to be a fairly common occurrence. Overall, Ellstrand reports evidence that "at least 44 cultivated plants mate with one or more wild relatives somewhere in the world," including 12 of the world's 13 most cultivated food crops.

Other investigations support the notion that crop plants cross with wild relatives. Most recently, a study by the European Environment Agency examined crops widely grown on farms in the European Union to assess the potential of gene flow from transgenics into wild populations. Based on the ability of a crop's pollen to travel and its historical hybridizations, the agency concluded that the ability to breed with a wild relative was high for oilseed, medium to high for beets and many cultivated fruits, and low for potatoes, wheat and barley. It was nonexistent for corn for the simple reason that Europe harbors no wild relatives of corn.

It should be noted that Ellstrand's research also revealed that while many crops and their wild relatives do cross, not all the crosses result in fertile offspring. For example, crosses between either durum or bread wheat and a wild relative of wheat result in sterile hybrids. In other cases, such as with corn, only some of the wild relatives can cross with the crop.

Furthermore, to crossbreed at all, the wild relatives have to be present near domesticated crops. The two most widely grown crops in the United States, corn and soybean, both of which are commercially available in GM varieties, do not have wild relatives in close proximity in this country, so gene flow from these crops into natural settings via crop-to-wild hybrids is not an issue. This is not necessarily the case in other countries. As Ellstrand points out there are wild relatives of corn in Mexico and wild relatives of soybean in Korea and China. He said it is important to keep this in mind so crops found to pose no risk of crop-to-wild gene flow in the United States are not assumed to pose no risks in other nations.

Food crops in the United States with wild relatives include wheat, which can breed with a related weed called jointed goat grass. Ellstrand notes that crosses between domestic sorghum (a crop used in human and animal food products) and wild johnson grass provided genetic material that has contributed to the weedy qualities of johnson grass, one of the world's most troublesome weeds. In addition, for U.S. grown food crops like rice, sunflowers, alfalfa, radishes, and strawberries there are wild versions (i.e. wild strawberries, wild rice, some of which are intrusive weeds) that have been known to cross and produce viable hybrids with domesticated varieties.

Then there are the non-food crops that have the potential to breed with wild populations. For example, cultivated cotton has been known to breed with wild cotton. Also, for farmed turf and forage grasses and trees, there is almost no difference between cultivated and wild varieties, making cross breeding that much more likely.

The NAS report on transgenics and the environment notes that the research to date does not suggest that hybrids produced by crosses between conventional crops and wild varieties routinely cause problems. Negative consequences have been relatively uncommon, the report states, but there have been instances in which such gene flow has done damage. For example, breeding between wild and domesticated sugar beets has been economically devastating to European sugar producers because the unproductive hybrids can take over a crop and render it worthless. Hybrids created by spontaneous breeding between wild rice and domesticated rice are blamed for the extinction of Taiwanese wild rice.

"In summary, crop-to-wild gene flow is not uncommon, and on occasion, it has caused problems," Ellstrand said. "Would we expect transgenic plants to behave any differently? The answer is 'no' and that's not necessarily good news. It is clear that the probability of problems due to gene flow from any individual cultivar is extremely low, but when those problems are realized they can be doozies."

Gene Flow Happens, Now What

While scientists know that gene flow from crop-to-crop and from crop-to-wild relatives happens, and are working on better understanding the probabilities of such flow, the more difficult policy question is: so what? What is the harm of gene flow?

For farmers, the problem of crop-to-crop gene flow is primarily economic. Farmers may need to find ways to manage more difficult weeds, or find ways to limit or prevent gene flow from GM

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crops to crops intended for organic or non-GM markets. While these issues present new challenges, farmers may be able to respond to them by managing crops to minimize gene flow problems.

The ecological harm raised by crop-to-wild relative gene flow is more difficult to assess for a number of reasons. To survive and thrive in a natural environment, the genetic trait passed on to the new hybrid needs to give the plant a "fitness" advantage over the non-modified wild plant. A new "fitter" hybrid could become established or even replace non-modified plants, grow in new places, and change ecological balances. For example, a new hybrid that retains the ability to repel pests could change the abundance or distribution of insects or soil microbes. Whether such ecological changes are benign, beneficial, or adverse will depend on perspectives and case-by-case considerations. What do scientists know about such issues?

Alan McHughen, a plant geneticist at the University of Saskatchewan who explored popular perceptions of biotechnology in his book *"Pandora's Picnic Basket,"* said the knowledge that gene flow between domesticated crops and wild relatives has been relatively common in the history of agriculture should remove some of the anxiety surrounding gene flow from transgenic crops. He believes a misconception inflaming the controversy about the environmental impact of transgenics is the mistaken belief that gene flow from crops to wild plants began with biotechnology.

McHughen said there should be acknowledgement on all sides that gene flow happens with conventional crops, and that it is going to happen with transgenic crops. Therefore, he believes transgenic crops, and conventional crops, for that matter, should be dealt with on a case-by-case basis, with the focus primarily on whether there is the opportunity for the crop to mate with a wild hybrid and on the potential environmental impact of the trait in question.

For example, McHughen said that outside of creating problems for farmers, an herbicide resistant transgenic plant breeding with a wild relative to produce an herbicide resistant hybrid should not pose a direct threat to the environment. That's because in wild environments the hybrid is unlikely to encounter herbicides. In this case, McHughen points out, the transgene becomes irrelevant to the wild plant. It does not give the plant any competitive advantages and, as such, would likely disappear over time. Gene flow in this instance should be of little consequence to the natural ecosystem.

By the same token, transgenic varieties that carry genes that increase the fitness of the plant, providing it with pest or disease resistance, could be of concern since such traits could be advantageous to a wild species. For example, the Environmental Protection Agency (EPA) has prohibited plantings of transgenic Bt cotton in parts of Arizona, Southern Florida and Hawaii where condi-

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tions might be more favorable for cross-breeding between Bt cotton and wild cotton. The concern was that giving wild cotton a Bt producing gene would increase the chances of it becoming an invasive plant.

Gene flow is expected to be a major issue in the regulatory approval of transgenic crops now in the pipeline that have been engineered to endure harsh conditions, including drought and salty soil.

According to Allison Snow, a plant geneticist at Ohio State University, the key issue is this: “Whenever we have a transgene that is going to increase survivability or seed production or could allow a plant to extend its range to places where it has not occurred before, then we should raise a flag.”

Predicting Ecological Impacts of Gene Flow

New research performed by Snow and her colleagues shows how much progress scientists have made in illuminating the issues raised by gene flow from transgenics. But it has also put a spotlight on how difficult it is to predict the magnitude of the risks and on the many factors that can influence whether problems can be expected to occur.

As it now stands, scientists have good data allowing them to predict which crops are likely to breed with wild relatives, some of which has been gained via a sort of DNA finger printing for plants, new technology that gives scientists the ability to trace plant lineage with incredible precision. They also are defining the kinds of traits that may deserve the most attention. At the cutting edge have been experiments that examine what happens to a transgene when a crop is allowed to breed, in a test setting, with a wild relative.

For example, Snow and her colleagues at Ohio State recently conducted an experiment where they took sunflowers that have been genetically engineered to contain a Bt gene—the transgenic plants produce toxins lethal to insects that prey on sunflowers—and crossed them with a wild sunflower. They then took the offspring or hybrid from that mating and allowed it to breed, under laboratory conditions, with other wild sunflowers, the goal being to mimic what might happen to the transgene if the hybrid began breeding in natural settings.

In this experimental setting, the Bt gene survived in the hybrids and remained active as the hybrid crossed with other wild sunflowers.

“We got this new kind of protection that we had never seen before in wild sunflowers and the fitness advantage (from the Bt gene) turned out to be very high,” she said. As Snow explained, the Bt toxin reduced the amount of insects chewing on the sunflower and allowed the wild sunflower hybrid to make more flower heads and more seeds.

But how hazardous is a wild Bt expressing sunflower to the environment?

“If you start getting twice as many wild sunflowers as before, just how bad is that?” Snow asks. “That is the sort of big question no one knows the answer to. You could argue ‘lets just move forward because we can’t examine the effect until we do large-scale field trials.’ Others would say ‘why do this at all since you can’t recall the genes once they are out there?’ So it becomes a really sticky issue.”

Adding to the stickiness is the different outcomes that are emerging from experiments involving the mating of transgenic crops with wild relatives. For example, while Snow’s experiment with sunflowers shows that gene flow from a Bt-carrying transgenic can increase the fitness of a wild plant, an experiment by Neal Stewart, a plant geneticist at the University of Tennessee, Knoxville, shows that it can do the opposite as well.

Stewart published a report in early 2003 on a field trial he conducted, which involved breeding transgenic oilseed rape with a wild relative. The coupling produced a hybrid, which was then mated or “backcrossed” with a wild plant and released into a wheat field as a weed. Stewart was interested in observing how wheat production faired in a field containing the newly created transgenic weed versus a field in which the wheat competed with the regular, non-transgenic weed.

What he found was that the transgenic weed was much less effective at limiting crop production. Rather than making it stronger, the gene flow from the transgenic crop apparently made it weaker. One reason for this outcome, according to Stewart, is that when wild plants breed with crop plants they inherit a large load of crop genes that reduces their overall fitness. Thus, any fitness gained from the Bt gene is counteracted by the fitness lost to the other, essentially weaker crop genes.

Also in contrast to Snow’s work was a recent study involving the insertion of a different transgene into wild sunflowers—one that confers resistance to white mold—which found that the new trait did not result in increased seed production. The co-author of that study, Indiana University biologist Loren Rieseberg, did not portray it as contradicting Snow’s work. Rather she said it points to a “need to examine each transgene and crop on a case-by-case basis. Some transgenes will have major ecological impacts and others probably won’t.”

Carol Mallory-Smith, a plant geneticist whose research at Oregon State has focused on the potential of gene flow between wheat and a weed called jointed goat grass, believes that predicting long-term environmental effects of gene flow is nearly impossible without the data gained from long-term observation. For example, while transgenic wheat varieties, of which none are yet on the market, could potentially breed with jointed goat grass, there is so much difference between the species that it is not clear what sort of hybrid would result. The differences between the two species also suggests that there might be a way to create transgenic wheat so that it is less likely to pass on the novel trait to jointed goat grass.

“There are a whole bunch of us who are in the middle on this issue saying we just don’t have the data,” she said. “Yes, we know that outcropping with hybrids will occur where you have relative compatibility with a wild species. But what happens over several generations is where we are really lacking the knowledge. We know you can move a gene from a crop to a wild relative, but under continued growth in natural conditions in the field, we don’t know what will happen to that gene long-term. And even if it is retained, will it matter?”

One potential problem is that a new transgenic hybrid could become “invasive” – that is, compete with, take over and replace other established or native species, with sometimes serious ecological consequences. The nation has had experience with invasive plant species, like kudzu, that have been deliberately or accidentally introduced into the United States with disastrous results. On the other hand, thousands of beneficial non-native crops and plants have been brought to the U.S. which have become established but not invasive. Trying to predict in advance whether a new introduced plant will become invasive and problematic, benign, or beneficial remains a scientific challenge. The National Academy of Sciences report observes that past experience with the study of invasive species illustrates that “we have little power to predict which species will be a successful invader, which ecosystem may be particularly vulnerable to invasion or what the impact of invasions will be.”

A related concern is that a transgenic hybrid could outcompete and replace native varieties, leading to a loss in genetic or biological diversity. There is concern in Mexico, for example, that genes from GM varieties of corn could flow into native strains of maize, reducing the genetic diversity of various wild strains of maize. Others note that such native wild varieties constantly swap genes in their natural environments, and that the introduction of transgenic genes is unlikely to have an impact on overall genetic diversity.

One limiting factor to understanding the risks posed by gene flow from transgenics is the lack of good baseline data. Snow points out that while evidence to date suggests that conventional crops do not routinely cause problems by breeding with wild relatives, it could be that “we haven’t looked for them that much or maybe the effects are very subtle.”

Authors of the NAS report agree that limited scientific knowledge is hampering our ability to “judge whether extensive commercialization of transgenics and other crops bearing novel traits will significantly perturb agro ecosystems or neighboring ecosystems…”. The report further states that accurate assessments of environmental impacts resulting from transgenics require routine and comprehensive environmental monitoring of agricultural and natural ecosystems. And unless the U.S. begins collecting such systematic data, the NAS report states, “it will not be possible to separate coincidental anecdote from real ecological trends.”

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Technologies to Control GM Gene Flow

Snow and others believe some of the concern about gene flow could be reduced if technology and techniques are developed that limit the ability of transgenic crops to spread their pollen or seed. Indeed, there already is a considerable amount of work underway to identify the best methods of segregating transgenic crops, planting “buffer crops” to catch drifting pollen, and controlling the timing of flowering and seed production so that they are less likely to breed with either other crops or wild relatives.

Some researchers are working on creating transgenic plants incapable of outcrossing with other plants or plants that produce only sterile seeds. These technologies are known as “technology protection systems (TSPs)” or “genetic use restriction technologies (GURTs)”.

But when news that geneticists were developing such technology spread around the world, an international furor erupted. Critics dubbed it the “terminator” technology, and raised many fears about possible environmental impacts and impacts on small farmers who save seeds to plant year after year. Lost in the public uproar was a discussion of how gene use restriction technology could be used as a tool to mediate potential impacts of gene flow.

Nevertheless, developing an acceptable biological check on gene flow may become a necessity for industry if it wants to broadly commercialize the newest generation of transgenic plants, plants for which gene flow has become the dominant concern. Recent published research suggests that there may be other approaches to preventing unwanted gene flow without producing sterile seeds.

Many biotech scientists and companies are close to commercializing transgenic crops that have been modified to produce pharmaceutical proteins and industrial materials. Other researchers are creating plants that might be able to produce vaccines against such diseases as Hepatitis B, rabies, and possibly HIV. The plants with which they are working include corn, rice, potatoes, canola, wheat, barley, spinach, and alfalfa, all food and feed crop plants. Because these crops would not be intended to be used as food or feed, preventing unintentional commingling with food and feed crops becomes a paramount concern.

In fact, scientists like Norm Ellstrand believe that while scientific investigations of gene flow from transgenics have concentrated mainly on potential ecological problems, the advent of pharmaceutical and industrial crops—coupled with the growing controversy surrounding the co-mingling of transgenics with organic varieties--is shifting the focus from crop-to-wild gene flow to crop-to-crop gene flow.

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"While there is certainly no reason to abandon research on crop-to-wild gene flow, the data and skills accumulated in this endeavor may prove helpful in addressing the simpler, but perhaps more urgent, issues of transgene flow among crops," notes Ellstrand.

In the past year, concerns about gene flow from newly-developed pharmaceutical and chemical producing plants has prompted calls from opponents for a moratorium on cultivating these varieties outside of greenhouses. Even some in industry have considered voluntarily restricting production to areas far removed from agricultural areas, such as in the middle of the desert, actions that were never contemplated in response to the potential ecological impacts of gene flow.

Given the financial stakes—millions of dollars invested in pharmaceutical and industrial plants, farmers eager to find new forms of cash crops and organic growers fearing the loss of lucrative markets—the issue of gene flow from transgenics appears destined to generate more headlines, and possibly more laws and regulations, in the coming years.