Weird Science

The Brave New World of Genetic Engineering

Richard Caplan
U.S. Public Interest Research Group

Ellen Hickey
Pesticide Action Network North America

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PANNA and the State PIRGs are founding members of the **Genetically Engineered Food Alert Campaign**. Genetically Engineered Food Alert is a coalition of organizations concerned with the protection of consumers rights, public health and the environment. In an effort to better educate the public, Genetically Engineered Food Alert has launched a nationwide campaign about the risks associated with genetically engineered foods. For more information visit www.gefoodalert.org.

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The Brave New World of Genetic Engineering

by Richard Caplan and Ellen Hickey

Executive Summary

If you listen to Monsanto, Aventis and even the U.S. Food and Drug Administration (FDA), genetic engineering is merely an extension of traditional plant breeding. These companies and regulators say it is the same thing that farmers and plant breeders have been doing for generations, and that is why the FDA does not require any tests for these crops. But traditional plant breeders have never crossed apples with chickens or strawberries with fish.

Genetic engineering permits scientists to manipulate genetic materials in ways that were once inconceivable. But the technology relies on methods that result in haphazard insertion of genetic elements into a plant's genetic code. This in turn may lead to disruption of complex gene interactions and unintended, potentially catastrophic results. It is a technology that has the power to transform food and the food supply in ways not possible with traditional breeding. Genetic engineering is very different, very powerful and worth a great deal of caution.

Currently, the process of introducing genes is done through a limited number of relatively crude methods resulting in haphazard placement which in no way can be described as precise. The inability of developers of genetically engineered crops to fully understand what genes they are inserting into a plant cell was dramatically revealed in May 2000. Monsanto disclosed that its genetically engineered soybeans—their largest selling genetically engineered crop—contained gene fragments that scientists had not intentionally inserted. Neither Monsanto nor government regulators had any idea the supposedly inactive pieces of genetic material were inserted during the process of engineering the crop.

The science of genetic engineering as applied to agriculture has other fundamental differences with traditional plant breeding. One is that scientists insert marker genes, frequently one that codes for antibiotic resistance, in addition to the gene with the desired trait. This process raises serious questions since these genes may exacerbate the problem of antibiotic resistance in the general population. Another difference is the use of powerful "promoters," usually disabled plant viruses, to increase the expression of the gene in the new plant. These promoters may create problems of their own, such as turning on or off genes in the host plant, or they may become a major source of new viruses arising from recombination.

There have been unexpected results in the field of genetically engineered plants. A field test of genetically engineered petunias that were designed to produce one color wound up having wildly fluctuating results in the field. An experiment on a plant in the mustard family found that a species that was normally self-pollinating and had very low rates of cross-pollination changed dramatically when it was genetically engineered. And after being commercialized, both genetically engineered cotton and soybeans have had unexpected problems, including massive crop failures.

Using genetic engineering, scientists can, for the first time, insert genes from different species, families or even kingdoms, something inconceivable in traditional breeding. Despite all of the unknowns, proponents of genetic engineering continue to push forward with previously unheard of combinations. Some of these combinations that have been field tested in the U.S. include:

- Chicken genes in apples and corn
- Human genes in corn, potatoes and rice
- Mouse genes in potatoes
- Cow genes in soy and sugarcane
- Flounder genes in tomatoes

Genetic engineering is an imprecise and haphazard technology—something completely different from traditional plant breeding. Since its inception, biotechnology companies have clearly demonstrated that scientists cannot control where genes are inserted and cannot guarantee the resulting outcomes. Unexpected field results highlight the unpredictability of the science, yet combinations previously unimaginable are being field tested and used commercially.

To protect public health and the environment, **Genetically Engineered Food Alert** calls for the following:

Genetically engineered food ingredients or crops should not be allowed on the market unless:

1. Independent safety testing demonstrates they have no harmful effects on human health or the environment,
2. They are labeled to ensure the consumer's right-to-know, and
3. The biotechnology corporations that manufacture them are held responsible for any harm.

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The Brave New World of Genetic Engineering

If you listen to Monsanto, Aventis and even the U.S. Food and Drug Administration (FDA), genetic engineering is merely an extension of traditional plant breeding. These companies and regulators say that it is the same thing that farmers and plant breeders have been doing for generations, and that is why the FDA does not need to require any tests for these crops. But genetic engineering breaks down the barriers that exist in nature, and now it is possible for scientists to cross apples with chickens or strawberries with fish—things that are impossible to do using traditional plant breeding methods.

Genetic engineering permits scientists to manipulate genetic materials in ways that were once inconceivable. But the technology relies on methods that result in haphazard insertion of genetic elements into a plant's genetic code. This in turn may lead to disruption of complex gene interactions and unintended, potentially catastrophic results. It is a technology that has the power to transform food and the food supply in ways not possible with traditional breeding. Genetic engineering is very different, very powerful and worth a great deal of caution.

Substantial equivalence

The biotechnology industry and the FDA claim that genetically engineered crops and traditionally bred crops are "substantially equivalent."[1] Because some crops that are genetically engineered can be characterized as largely similar to 'natural' crops, the biotechnology industry and the FDA would like us to assume they pose no new health or environmental risks. This concept, aggressively advocated by manufacturers of genetically engineered foods and crops, has been endorsed by the UN Food and Agriculture Organization and World Health Organization and forms the basis of regulation of these products by the United States government.

Although the idea of "substantial equivalence" is simple and may even seem plausible to some, many scientists feel it is misguided. The agencies regulating genetically engineered food have never properly defined the term. As a result, there are no guidelines to test foods to see if this assumption holds true. At the same time, this vagueness makes the concept particularly useful to industry. Monsanto's Web site, for example, quotes Henry Miller of the Hoover Institution saying that, "genetic engineering [is] essentially a refinement of the kinds of genetic modification that have long been used," and the company itself calls the technology an "extension" of traditional plant breeding, only "more precise."[2]

However, a closer examination of the technology used to engineer plants and a look at some of the genes that scientists are inserting clearly demonstrates that traditional plant breeding and genetic engineering are radically different.[3]

The technology: Gene insertion

Proponents of genetic engineering maintain that scientists can locate genes and insert them into new plants with great precision. But currently, the process of introducing genes is done through a limited number of relatively crude methods resulting in haphazard placement which in no way can be described as "precise." One common method of insertion uses bacteria that attach themselves to a plant and then transfer DNA into the host plant's genetic code.[4] Genes can also be introduced directly into plant cells using a "gene gun" that shoots microscopic particles (such as gold) covered with DNA into the plant tissues themselves. These techniques and others provide little control over the precise location of the inserted genetic material.[5]

The inability of developers of genetically engineered crops to fully understand what genes they are inserting into a plant cell was dramatically revealed in May 2000. Monsanto disclosed that its genetically engineered soybeans—their largest selling genetically engineered crop—contained gene fragments that scientists had not intentionally inserted.[6] After four years of commercialization, researchers discovered the two extra gene fragments in the soybeans. Neither Monsanto nor government regulators had any idea the supposedly inactive pieces of genetic material were inserted during the process of engineering the crop.

In 1997, a lack of precision in the insertion process for genetically engineered canola also proved to be a costly mistake for Monsanto. Approximately 60,000 bags of canola—enough to seed between 600,000 to 750,000 acres of land—had to be recalled by Monsanto because the seed mistakenly contained an unapproved gene. According to some reports, quantities of seed had already been planted when Monsanto discovered the mistake.[7]

Marker genes

Scientists cannot always be sure if a plant has incorporated inserted genetic material into its own DNA. To help determine if the insertion was successful, scientists put a "marker gene" into the plant along with the gene for the desired trait. The marker gene most commonly used in genetically engineered crops is a bacterial gene for antibiotic resistance.

There is growing concern that over time widespread use of antibiotic resistance marker genes may contribute to the increasing problem of antibiotic resistance in humans and animals. The British Medical Association has gone so far as to call for a permanent end to all use of these marker genes.[8] Some scientists fear that resistance genes may move from a genetically engineered crop into bacteria in the environment. Since bacteria readily exchange antibiotic resistance genes, such genes might eventually find their way into disease-causing bacteria resulting in antibiotic resistance, and therefore making control more difficult.

It is known that DNA can be taken up by bacteria, so the possibility exists that antibiotic resistance genes could be transferred to bacteria present in the human digestive tract. Furthermore, a recent report found that the human mouth contains bacteria capable of taking up and expressing DNA containing antibiotic resistance marker genes.[9]

Gene promoters

Scientists may insert a gene for a desired trait into a plant's genome, but that doesn't necessarily guarantee that the trait will be expressed as the plant grows. As a result, in addition to the gene, powerful promoters or enhancers are inserted to maximize its expression. Promoters can respond to signals both from other genes and from the environment that tell it when and where to switch on, by how much and for how long. A promoter may produce different effects depending into which chromosome it has been inserted as well as its precise location on the chromosome. The uncertainty of where the promoter will be inserted means that there will be a fundamental unpredictability related to expression not only of the inserted gene(s), but also the expression of a large number of the host's genes, as well as the influence of chemicals, climate fluctuations, and geographical and ecological changes.

Most genetically engineered crops contain a promoter from the Cauliflower mosaic virus (called CaMV 35S), which in nature causes a disease in plants in the mustard family. The CaMV 35S promoter is used because it is so powerful that it leads to expression of the introduced gene at orders of magnitude two to three times that of the organism's own genes. Some scientists are concerned that use of this viral promoter may result in a major source of new viruses arising from recombination.[10]

Unusual and unexpected results

The unpredictability of genetic engineering was illustrated by an experiment performed on a plant in the mustard family frequently used for biological research.[11] Scientists compared three lines of the plant that all contained the same gene for herbicide tolerance—one developed by a modified form of conventional breeding and two by genetic engineering. Since the plant is normally a self-pollinating species with very low rates of cross-pollination, researchers thought that there would be virtually no gene flow to other individual plants and little risk of genes moving from engineered plants to non-engineered neighbors.

They designed an experiment to test these assumptions, planting engineered, semi-conventional and wild varieties in close proximity, and later collecting seeds from the wild variety to see how many carried genes for herbicide tolerance. The results, as the authors note elsewhere, have "great implications for biotechnology and the controversy surrounding the risk of releasing transgenic crops into the environment."[12] The two genetically engineered varieties were four and 36 times more likely to cross-pollinate than the semi-coventional variety. With such a high rate of cross-pollination, the act of genetic engineering functionally turned a species that does not usually cross-pollinate into one into one capable of relatively higher rates of cross-pollination. This experiment demonstrates that genetic engineering can change the basic character of a plant.

In another example, scientists attempted to suppress the color of petunia flowers by transferring a gene created to turn off a pigment gene in the host plants.[13] However, the inserted gene did not have the anticipated effect and the color varied from plant to plant in both shade and pattern. The weather also affected the expression of the genes—some of the flowers changed colors or color patterns as the weather changed.

These problems were totally unexpected and unanticipated. If such dramatic changes could occur in the way the plants developed, it is possible that there could be changes in the plant itself that could affect the nutrition or safety of genetically engineered crops.

New genes, new problems?

Conventional breeding allows only mixing and recombination of genetic material between species that share a recent evolutionary history, and in the vast majority of cases, employs processes that occur in nature, such as sexual and asexual reproduction. These methods result in plants that emphasize certain desirable characteristics—characteristics that are not new, but rather are already present in the species' genome. Genetic engineering, however, makes it possible to combine genes from very different sources, and as a result, effects on the organism as a whole and on the environment

Crop Failures: One More Problem

There have been a number of crop failures with genetically engineered cotton and genetically engineered soybeans. In the case of cotton, bolls were deformed and fell off the plant before harvest. Some attributed this problem to the companies hurrying Roundup Ready cotton to market without allowing state and federal cotton experts to test the seeds.[1, 2] As a result of the losses suffered, compensation was paid to farmers in a number of states including Mississippi, Arkansas, Tennessee, Missouri and Texas.[3] Farmers also discovered that Monsanto's genetically engineered soybeans grown in hot climates are more likely to grow shorter and have their stems split open. Genetically engineered soybeans grew an average of 15 centimeters in hot climates compared to a conventional height average of 20 centimeters, and 100% of the genetically engineered plants had split stems compared to 50-70% for conventional varieties.[4]

1 J.L. Fox. "Farmers say Monsanto's engineered cotton drops bolls." Nature Biotechnology *(15) 1997.*
2 Allen R. Myerson. "Breeding Seeds of Discontent: Cotton Growers Say Strain Cuts Yields." New York Times. *November 19, 1997.*
3 Bill Lambrecht. "Many farmers finding altered cotton lacking." St. Louis Post-Dispatch. *April 12, 1998.; see also Hansen 2000.*
4 Andy Coghlan. "Splitting headache: Monsanto's modified soya beans are cracking up in the heat." New Scientist. *November 20, 1999.*

become very hard to predict.

Using genetic engineering, scientists can, for the first time, insert genes from different species, families or even kingdoms, something inconceivable in traditional breeding. Under normal circumstances, for example, a strawberry can only acquire genetic material from other strawberries—that is, plants of the same or closely related species. However, using genetic engineering, scientists can develop strawberries containing genetic material from trees, bacteria, fish, pigs or even humans if they choose.

The following is a list of genetically engineered plants that have been cleared by the U.S. Department of Agriculture for field tests in the United States. Biotechnology corporations often refuse to list the type of gene inserted, calling such data "confidential business information." As a result, only those crops engineered by public institutions such as state universities regularly list the donor of the inserted gene and therefore it is not possible to determine how many other strange combinations might exist. It is also important to note that Environmental Assessments are not required for these releases (field tests).

- Apples and chickens

  To make apples resistant to fire blight, Cornell University has developed a type of genetically engineered apple that contains a gene from a chicken. They tested the crop in both 1994 and 1991 in the state of New York.[14]

- Corn and humans

  In 1998, Limagrain, a French multi-national corporation and one of the world's largest seed companies, conducted field tests in Iowa, Illinois and Indiana on genetically engineered corn that contained a human gene. The corn was engineered to produce a pharmaceutical protein.[15]

- Potatoes and mice and humans

  The University of Idaho has engineered two types of potatoes—one using a mouse gene and one a human gene. Both were developed to be resistant to a number of viral diseases that infect potatoes. Field tests were held in Idaho in 1998.[16]

- Rice and humans

  To produce pharmaceutical proteins, Applied Phytologics, a California-based firm, inserted a human gene into a rice plant. The field test took place in California in 1996-97.[17]

- Soybean and cows

  The University of Illinois has inserted a gene from a cow into soybeans in order to alter a protein in the soy plant. The field test was in 1998-1999 in Illinois.[18]

- Sugarcane and cows

  Both the United States Sugar Company and Texas A&M University have field tested sugarcane in Florida and Texas that contains a gene from a cow as part of an effort to develop a crop resistant to clavibacter, a disease-causing bacteria. The test periods extend from 1998 to 2001.[19]

- Tomato and flounder

  In perhaps one of the most famous cases of unusual genetic combinations, DNA Plant Technology field tested a tomato with a gene from the flounder in an attempt to develop a tomato that was tolerant to cold temperatures. The field test took place in California in 1991.[20]

Fifty acres of corn and chickens

None of the above crops has yet been commercialized; however, corn engineered to contain a chicken gene is being grown commercially in Texas. A Texas-based company, ProdiGene, has been working with the U.S. Department of Agriculture to engineer a gene from a chicken into corn in order to produce the protein avidin found in chicken egg whites. Avidin is toxic to many grain-feeding pests and may make the corn resistant to pests that can harm grain in storage. The research was conducted by the Grain Marketing and Production Research Center in Manhattan, Kansas and by scientists at ProdiGene in College Station, Texas.[21]

Currently, ProdiGene extracts avidin from the genetically engineered corn to be used in various medical diagnostic tests, contracting with farmers who are growing approximately 50 acres of the corn.[22]

Conclusion

Genetic engineering is an imprecise, haphazard technology—something completely different from traditional plant breeding. With alarming regularity, biotechnology companies have demonstrated that scientists cannot control where genes are inserted and cannot guarantee the resulting outcomes. Unexpected field results highlight the unpredictability of the science, yet combinations previously unimaginable are being field tested and used commercially.

To protect public health and the environment, **Genetically Engineered Food Alert** calls for the following:

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Richard Caplan is an Environmental Advocate at U.S. Public Interest Research Group. Ellen Hickey is Director of Research at Pesticide Action Network North America.

For a more in-depth discussion of many of the above issues, read "Genetic Engineering Is Not an Extension of Conventional Plant Breeding: How genetic engineering differs from conventional breeding, hybridization, wide crosses and horizontal gene transfer," by Michael Hansen, Research Associate at the Consumer Policy Institute. Available at http://www.consumersunion.org/food/food.htm.

Notes

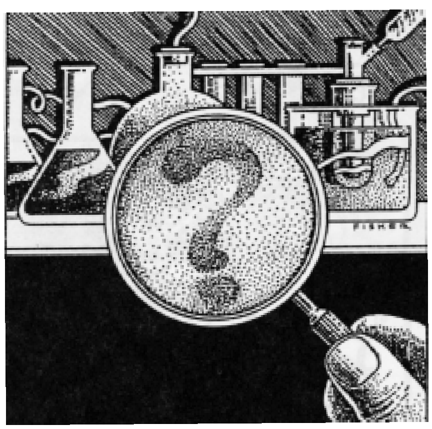
1 The term appears to have been coined by the Organization for Economic Cooperation and Development in their 1993 publication "Safety Evaluation of Foods Derived by Modern Biotechnology: Concepts and Principles."

2 From http://www.biotechbasics.com/basics.html. Accessed on October 10, 2000.

3 Michael Hansen. "Genetic Engineering Is Not an Extension of Conventional

Plant Breeding: How genetic engineering differs from conventional breeding, hybridization, wide crosses and horizontal gene transfer." Consumer Policy Institute/Consumer's Union. 2000. Available at http://www.consumersunion.org/food/food.htm.
4 These bacteria cause a disease in plants by attaching themselves to the plant and then transferring part of their DNA into the host plant's genome. To use this bacterium in genetic engineering, scientists must delete the disease-inducing genes and insert genes that produce the desired traits. This engineered bacterium, sometimes called a bacterial "truck," is then mixed with the plant cells and allowed to infect them.
5 Michael Hansen and Ellen Hickey. "Genetic Engineering: Imprecise and Unpredictable." Global Pesticide Campaigner. Volume 10, Number 1. April 2000.
6 James Meikle. "Soya gene find fuels doubts on GM crops." The Guardian (London). 31 May 2000.
7 Peter Montague. "Genetic Engineering Error." Rachel's Environment & Health Weekly. 5 June 1997.
8 British Medical Association press release. "BMA statement on genetically modified organisms." 18 May 1999.
9 Mercer, D.K., K.P. Scott, W.A. Bruce-Johnson, LA. Glover and H.J. Flint. 1999. "Fate of free DNA and transformation of the oral bacterium Streptococcus gordonii DL1 by plasmid DNA in human saliva." Applied and Environmental Microbiology. 65: 6-10.
10 Ho, Mae-Wan, Angela Ryan and Joe Cummins. Hazards of Transgenic Plants Containing the Cauliflower Mosaic Viral Promoter: Authors' reply to critiques of "The Cauliflower Mosaic Viral Promoter—a Recipe for Disaster?" Microbial Ecology in Health and Disease (in press).
11 Joy Bergelson, Colin B. Purrington and Gale Wichmann. 1998. "Promiscuity in transgenic plants." Nature. 3 September 1998.
12 Wichmann, Gale, Colin B. Purrington and Joy Bergelson. Abstract of "Male promiscuity is increased in transgenic Arabidopsis." Available at http://genome-www.stanford.edu/Arabidopsis/madison98/abshtml/321.html. Accessed 12 October 2000.
13 Peter Meyer, Linn Felicitas, Iris Heidmann, Heiner Meyer Z.A., Ingrid Niedenhof and Heinz Saedler. "Endogenous and environmental factors influence 35S promoter methylation of a maize A1 construct in transgenic petunia and its colour phenotype." Molecular Genes and Genetics (1992) 231: 345-352.
14 Permit #99-088-09N, Permit #94-039-03R. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
15 Permit #98-117-01R, Permit #98-117-02R, Permit #98-117-03R. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
16 Permit #98-100-15N. Permit #98-100-16N. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
17 Permit #96-355-01R. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
18 Permit #98-128-17N. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
19 Permit #98-071-74N, Permit #98-320-03N, and Permit #98-049-04N. http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm
20 Permit #91-079-01R, http://www.nbiap.vt.edu/cfdocs/fieldtests1.cfm.
21 ProdiGene press release, June 7, 2000, "New Biopesticide Developed from Egg White Featured in Nature Biotechnology Magazine."
22 "Protein from Egg Whites into Corn," Progressive Farmer, June 14, 2000, http://www.rooster.com/news.

An extension of basic chemistry?



There are some interesting similarities between genetic engineering and the creation of synthetic organic chemicals in the twentieth century. For example, just like the biotechnology industry argues that genetic engineering is an extension of traditional plant breeding, one could argue that synthetic chemicals are just an extension of basic chemistry. In certain ways, that's true. Yet when researchers began creating new chemicals, we discovered that many had unexpected, adverse impacts on the environment and human health—even though these new substances were made of the same elements as "natural" chemicals.

After several decades of use, the adverse impacts were causing such concern that the U.S. Congress passed the Toxic Substances Control Act requiring premarket screening of synthetic organic chemicals for such effects as carcinogenicity and mutagenicity. Lawmakers also changed pesticide regulations to reflect these concerns. Although different in many ways from genetic engineering, our experience with synthetic organic chemicals underlines the potential for unexpected results when new substances are introduced into our environment.

U.S. Public Interest Research Group
218 D Street, SE
Washington DC 20003
phone (202) 546-9707
fax (202) 546-2461
www.pirg.org

Pesticide Action Network North America
49 Powell Street, #500
San Francisco, CA 94102
phone (415) 981-1771
fax (415) 981-1991
www.panna.org