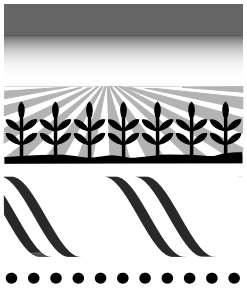
1 Products of Plant Biotechnology



Biotechnology is alive and well in the field of plant science. According to the US Department of Agriculture, field testing of new agricultural products continues its rapid pace of expansion, approximately doubling each year. With the capabilities of genetic engineering, **transgenic plants**, produced by inserting one or more genes from another source, are being developed for a wide variety of uses. Other products of biotechnology, including diagnostic products and pest management products, also play a part in the world of plant science.

The following list summarizes today's major applications for plant biotechnology.

Applications for transgenic plants

Crop plants developed for insect resistance. One of the leading groups of products today are crops with built-in resistance to insects.

Crops developed for herbicide tolerance. Another popular group of products are crops that grow in the presence of specific herbicides.

Crops developed for virus resistance. The third major new group of products has built in resistance to plant viruses.

Crops with other growing qualities. Other crop improvements being developed include the ability to withstand heat, cold, drought, and other adverse growing conditions; nitrogen-fixing capabilities in crops other than legumes; or male-sterile plants to aid in breeding of hybrid plants.

Food products with improved properties. Plants are also being modified to improve nutrition, flavor, texture and handling properties.

Plants for pharmaceutical purposes. Most pharmaceuticals produced through agriculture today use animals as their vehicle, but plants are now being developed to produce medicines too.

Plants for industrial purposes. Plants are being modified to increase their oil content for industrial lubricants, fuel, detergents, shampoos, and other cosmetic products; plants are being engineered to produce plastics.

Plants for environmental cleanup. Plants and bacteria are being engineered to clean up oils and other contaminants in soil and water.

Ornamental horticultural products with improved properties. Horticulturists are modifying plants to improve color, texture, and handling.

Fiber plants. Cotton is being developed to produce plants with grown-in pigment and modified strand structure to reduce wrinkling in finished cloth.

Applications for other plant biotechnology products (non-transgenic)

Biopesticides. Biopesticides are commercial products made from microorganisms found to be naturally harmful to specific plant pests such as viruses, fungi, insects, and weeds.

Plant diagnostics. Plant diagnostic products are used to detect specific plant pathogens on growing plants; to detect food-borne pathogens on fresh produce; and for testing seeds and plants for the presence of a desired transgenic trait.

A Closer Look at Today's Transgenic Plants

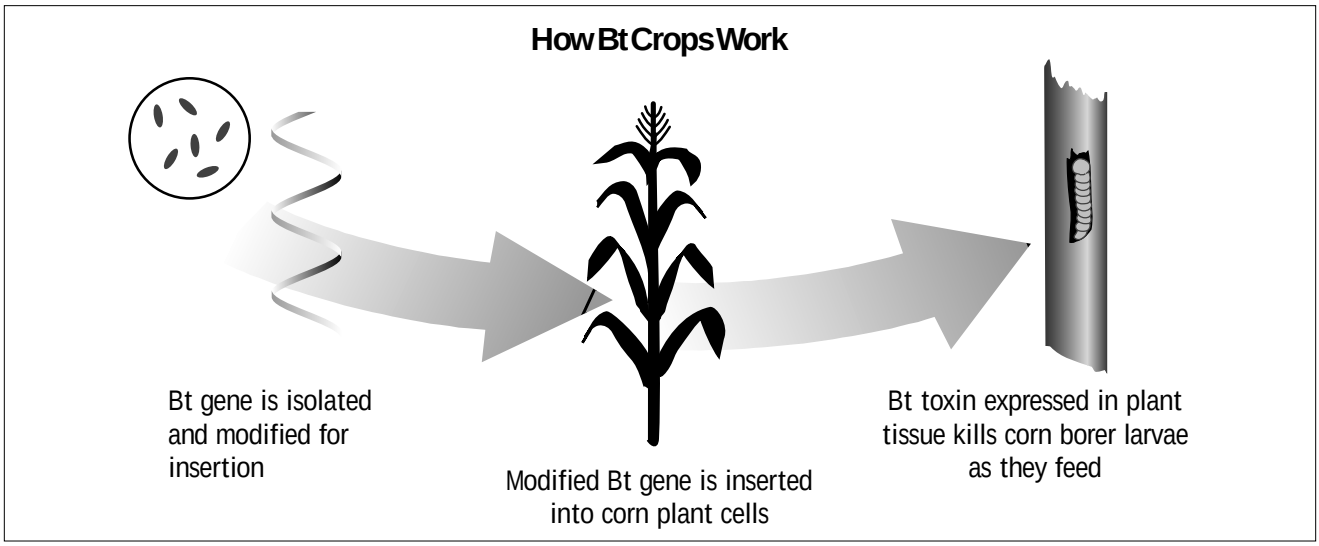
Insect-resistant transgenic crops—Bt Crops

Today's crops developed for built-in resistance to insects have been genetically engineered with a modified gene from a bacterium, ***Bacillus thuringiensis* (Bt).** Bt is a bacterium occurring naturally in the soil identified in 1911 as an insect pathogen. Bt produces toxins that kill the larvae of certain insects by disrupting their digestive systems.

Bt was registered as a **biopesticide,** a pesticide made from natural ingredients, in 1961. Bt is nontoxic to mammals, birds, and most other nontarget organisms. Today, Bt sprays are sold widely to home gardeners, organic farmers, and others worldwide to control insects. By contrast, only one percent of insecticide sprays used by US farmers contain Bt. The reason for the low use by farmers is that Bt toxins are quickly broken down by sunlight and degraded in the environment.

Bt crops are more attractive than sprays to farmers because they produce Bt toxin in many parts of the plant during all or part of the growing season. They also contain higher levels of toxin than the commercial sprays. When an insect eats the plant, it dies. Typically, somewhat different versions of a crop such as Bt corn are produced by different companies. These may differ from each other in the amount of toxin in the plant, where the toxin occurs in the plant, and when the toxin occurs in the plant's life cycle.

Bt crops were first approved by regulators in 1995. The first commercial Bt crop was NewLeaf® Potato, produced by Monsanto. Plants currently in production include potato plants that resist the Colorado potato beetle, corn plants that resist the



European corn borer, and cotton plants that resist the cotton bollworm. In 1997, 9 million acres of Bt crops were planted (7 million corn, 2 million cotton, 25,000 potato). Bt crops being developed in 1998 include tomatoes, apples, rice, and eggplant. The main producers of Bt crops are large seed companies including Monsanto, Novartis, Pioneer Hi-Bred, Mycogen, and DeKalb.

Herbicide-tolerant transgenic crops

Farmers have always had to control weeds in the field, whether by mechanical or chemical means. Many kinds of **herbicides**, chemicals that farmers use to kill weeds, are "non-selective," meaning that they don't distinguish between weeds and crop plants. This makes it impossible for farmers to use these herbicides once their crop plants have started growing. The most popular group of new plant products on the market today are **herbicide tolerant crops**, which allow farmers to spray their fields for weeds without killing the main crop.

Developing plants for herbicide tolerance is not new. Using traditional breeding techniques, breeders have built herbicide tolerance into some crops including canola. Now, however, genetic engineering technology makes the job easier and faster and can be applied to more crops.

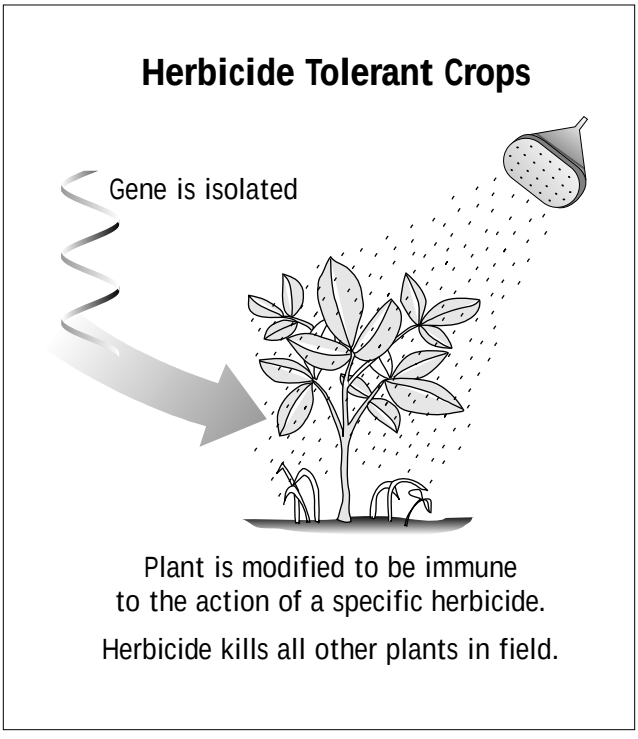
Genetically engineered herbicide tolerant plants are modified to counteract the action of a specific herbicide, or in some cases to degrade the herbicide. All herbicides are designed to disrupt a plant's functions, but different kinds of herbicides work in different ways. Thus, specific plants are designed to resist specific herbicides. Most engineering to date has incorporated resistance to either **glyphosate** or **glufosinate** herbicides. The first engineered herbicide tolerant crop seeds on the market were Monsanto's Roundup Ready® Soybeans, released in 1994. These soybeans are developed to grow in the presence of the Monsanto **glyphosate** herbicide, Roundup®.

Research and development of these transgenic plants is often conducted collaboratively by seed companies and producers of chemical herbicides. Some companies, such as Monsanto, produce both the seeds and the chemicals. Seeds are sold to be used with a particular tradename herbicide. DeKalb's GR corn® is tailored to Agrevo's Liberty® glufosinate herbicides, Monsanto's Roundup Ready® line of crops work with their own Roundup® herbicide.

The herbicide tolerant products on the market in 1998 are corn, soybeans, cotton, and canola. Future products include sugar beets, wheat, and rice.

Virus-resistant transgenic crops

Since the 1920's, growers have used a method called "**cross-protection**," intentionally infecting crops (citrus trees in orchards, tomatoes grown in greenhouses) with mild viruses to protect the plants from more severe strains. In 1980's re-



searchers showed that the virus's protein coat was involved in cross-protection. Scientists are now transferring the gene for **virus coat protein** to crop plants, providing natural protection or immunity against specific plant viruses. This immunity is passed on to future generations of plants.

The first genetically engineered virus-resistant crop developed was Asgrow's crookneck squash, released in 1995. Current research is being conducted on virus-resistant cantaloupes, cucumbers, potatoes, tomatoes, lettuce and alfalfa.

Transgenic crops with other growing qualities

Researchers are developing transgenic plants with other traits besides pest/disease resistance and herbicide tolerance. These traits include the ability to withstand drought, frost, or soil salinity, the capability to fix nitrogen, and plants with improved pH tolerance. These traits, however, are more difficult to achieve because they involve the manipulation of a larger number of genes.

Male sterile crops. Plants are currently being engineered for male sterility, which turns off the plant's ability to produce pollen to prevent plants from inbreeding. This technique is useful for hybrid plant producers. It may also be a way to prevent transgenic traits from moving through pollen to weedy relatives nearby.

Food products

Plant breeders and food scientists are applying biotechnology to the production of food crops to improve quality and nutrition; to enhance growing and ripening; to facilitate processing and handling; and to make food safer.

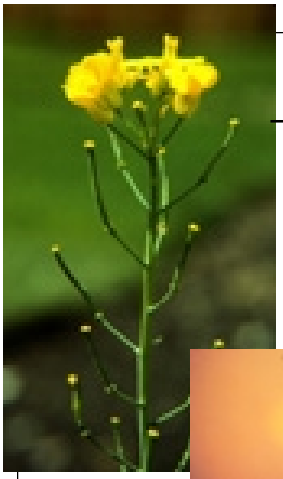
Changes for enhanced quality and nutrition.

The following are some of the foods being made more nutritious or better tasting through biotechnology:

- corn, soybeans, and canola engineered to produce cooking oils with less saturated fat
- potatoes modified to contain more starch, causing them to absorb less oil when fried. Traditional breeding techniques have been used for decades to produce high-starch potatoes.
- strawberries and other fruits modified to be sweeter
- popping corn modified for better taste, reducing the need for butter and salt
- tomatoes, squash, potatoes with contain higher levels of nutrients such as vitamin C, vitamin E, and beta carotene
- strawberries with increased levels of ellagic acid, a cancer-fighting agent
- garlic cloves that produce more allicin, an active ingredient thought to lower cholesterol
- grain products with increased levels and types of protein.

Fruit and vegetables modified for delayed ripening. Breeders are working to develop fruit, including tomatoes, melons, peaches, bananas, and papayas, that can be ripened on the vine without softening. This allows the fruit to develop its natural flavors and still be transported to market before softening. Fruit is normally picked while still green, then ripened with ethylene gas.

Researchers at Calgene were the first to develop a technique for changing the action of the gene in tomatoes that controls fruit ripening. The technique involves slowing the plant's production of



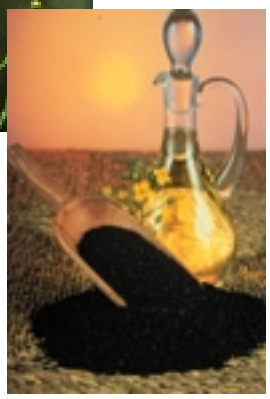
Canola Council of Canada

Plant Spotlight

CANOLA

What is canola?

Canola is an improved version of the rapeseed plant, developed by conventional plant breeding. It is grown primarily for its seeds that are crushed to produce oils for cooking and industrial uses.



Where does canola grow?

It is grown in western Canada and in the northwestern and central United States.

Why is canola important for biotechnology?

Canola is an important plant for biotechnology because

- it accepts transfer of genes more readily than many other crops
- it propagates especially well from tissue culture
- it can be developed for a large variety of uses.

What products are made from transgenic canola?

There are more transgenic varieties of canola than of any other crop. Research is being done with canola for potential uses in animal and human nutrition, industry, and medicine. More than 1000 patents have been taken out for new industrial uses. Some canola varieties that have been/are being developed:

- Several herbicide-tolerant varieties are on the market.
- DuPont and U. of Delaware have produced a canola plant with nearly double the lysine content, improving the value of the plant's protein.
- Plant Genetic System's (PGS) new canola variety offers a higher yield.
- Zeneca Seeds (Canada) is introducing anti-fungal genes into canola to control the fungal diseases black leg and white mold.
- Zeneca Seeds is inserting a plastic-producing gene for PHB into canola.
- Calgene inserted a gene from the California Bay tree into canola to produce varieties with nearly 40% laurate content. Laurate is commonly used to make detergents such as shampoos.
- Researchers have created a biodiesel fuel from canola called supercetane.
- SemBioSys Genetics is conducting research on producing interleukin, an immune-system booster and cancer fighter, from canola. Other pharmaceuticals are being developed from canola, including anti-coagulants.
- The Veterinary Infectious Diseases Organization is trying to make a vaccine using transgenic canola to prevent respiratory disease in livestock.

Adapted from
The Agbiotech Infosource,
"Canola—Biotechnology's
Powerhouse Crop, 21:5/96
Ag-West Biotech Inc.
www.agwest.sk.ca

polygalacturonase (PG), a naturally-occurring enzyme that degrades pectin and makes fruit soften. In 1994, their delayed-ripening tomato, called the Flavr Savr™, was the first genetically engineered food to get marketing approval from the Food and Drug Administration. Because of unexpected problems, however, the Flavr Savr™ did not remain on the market. In 1999, several companies, including Calgene, Monsanto, and Zeneca are working to perfect this and other delayed ripening techniques in tomatoes and other fruit. Zeneca has developed a reduced-PG tomato that is made into tomato puree, now on the market in the UK, and labeled as a product of genetic engineering.

Improvements for processing and handling. Modifications that will improve processing and handling include potatoes and fruit with a reduced tendency to turn brown when cut or bruised; products with reduced oil levels that result in a longer shelf life; fruits and vegetables that can be shipped more easily without bruising.

Pharmaceuticals from transgenic plants

Genetic engineering is now making it possible to modify plants to produce vaccines and other medicines. Current research includes work on forage plants like hay and alfalfa to produce animal vaccines; plants to produce proteins to prevent autoimmune diseases, such as juvenile onset diabetes, rheumatoid arthritis, and lupus.

Several researchers are working on modified food and feed plants containing edible vaccines, including a potato plant containing a vaccine to fight against several different diarrhea-causing diseases.

Genetically-engineered plant viruses. Researchers have found that they can take advantage of naturally occurring plant viruses as a vehicle to make new products from crop plants. A foreign gene for producing a specific drug is inserted into the virus. A plant is then infected with the virus, which spreads throughout the plant. The infected plant can then produce the desired drug in only a few days or weeks.

Using viruses to produce proteins through plants avoids many of the problems of creating a transgenic plant. The viruses are easily contained because they are not transmitted by the plant's pollen, but rather only by mechanical means. In the wild, the virus eventually loses its foreign gene.Tobacco mosaic virus (TMV), used with tobacco, has successfully produced several drugs, including one that shows promise in the treatment of non-Hodgkin's lymphoma.

Other uses for transgenic plants

Industrial products. Plants are being developed to produce industrial products such as oils, fuel, and biodegradable plastics.

Transgenic insects and nematodes. Another current area of research is modifying insects and nematodes that are useful for plant protection from other insect pests. One organism being developed is a transgenic predatory mite which may be useful for the control of spider mite in strawberries and other crops.

Transgenic plants producing reagents. One biotechnology company is developing a protein product from transgenic corn normallyproduced from chicken eggs. The protein is used as a reagent in numerous diagnostic kits and medicines. It has been found that to produce twenty grams of the reagent would normally take a ton of eggs, valued at $1000, but can be produced from four bushels of corn, valued at $20.

Preventing replanting of unauthorized seed. In April 1998 USDA and cotton seed producers Delta & Pine Land Co. received a patent on a technique that genetically alters seed so that it will not germinate if replanted a second time. Due to controversy, commercialization of this technology was halted or at least put on hold in 1999. For now, Monsanto requires growers to sign a licensing agreement stipulating that they will not replant their transgenic seeds.

A Closer Look at Non-transgenic Plant Biotechnology Products

Plant diagnostic products

Detecting plant disease. Identifying and combating plant disease is a regular part of agriculture. To manage plant disease, growers must first diagnose the disease. Some diseases can be diagnosed by eye, while others require time-consuming laboratory testing that may take days or weeks to complete. New **immunoassay** test kits let growers check for disease on suspected plants in a matter of minutes, often on site where a disease is suspected. Plant diseases already detectable by these kits include bacterial canker of tomato, soybean root rot, rice leaf fungus and botrytis fungus that grows on grapes. Immunoassay kits are also being developed to detect nematodes.

Detecting traits in transgenic crops. Producers of immunoassay technology have found a new niche in the agricultural marketplace—the need to test plants and seeds for the presence of the desired transgenic trait. Strategic Diagnostics produces a one-step test that gives a simple yes/no result. The test can be used at any point in the seed production cycle, including plant propagation, seed collection and processing, packaging operations, and in the development of new crop varieties. Tests can be administered by non-technical personnel in field or laboratory. Seed producers use the tests to ensure that 98% or more of their seeds contain the transgenic trait. Plant breeders can test plant tissue to eliminate plants that do not carry the desired traits. Growers and sprayers can use the tests before spraying to identify fields containing herbicide-tolerant plants.

Detecting food-borne bacteria. New tests are being used to detect food-borne bacteria and toxins. One example uses lightning bug chemistry to check for bacteria by measuring the amount of light the food emits under test conditions. Monoclonal antibody tests are being used to detect very low levels of microrganisms, chemical residues, and the carcinogenic fungal toxin, aflatoxin.

Biopesticides

Biopesticides, including **bioherbicides**, **bioinsectides**, and **biofungicides** are products of biotechnology based on natural agents such as microorganisms and fatty acid compounds. Some biopesticides are sprayed on crops and others are used as post-harvest fungus control agents. Biopesticides are generally toxic only to targeted pests, without hurting humans, birds, fish, and beneficial insects. Bt, *Bacillus thuringiensis*, the best-known bioinsecticide, has been used for decades by organic growers and home gardeners, and is now engineered into Bt crops.

Biopesticides have traditionally been used in their natural state, unmodified by genetic engineering. Now, however, scientists sometimes use genetic engineering to increase their persistence, their toxicity, and their range of targets. Companies producing biopesticides today include Ecogen, Mycogen, and Crop Genetics International.

Developing a biopesticide includes 1) studying thousands of microorganisms for a potential agent; 2) evaluating the candidate organisms to

see if one or more work best in combination and testing them for side effects; 3) producing large amounts of these organisms through bio-fermentation; 4) developing cost effective delivery methods; and 5) getting approval from government agencies.

Among the biopesticides on the market today is a biofungicide used to protect fresh produce from post-harvest rot. The active ingred ient is a naturally occurring yeast that is harmless to all other untargeted organisms.

The Future of Plant Biotechnology Products

Most seed producers and plant researchers are moving quickly to develop new products to compete in this fast-moving marketplace. One large company has ten full-time patent attorneys on staff to handle new company patents.

New crops on the way include ones that express multiple traits produced by more than one gene, for example, plants that are both insect resistant and herbicide tolerant. Companies are also planning to extend their current technologies to a wider range of plants, including Bt sunflowers and virus-resistant tomatoes. While Bt is alone in its place in insect resistant crops today, other proteins are being developed as insect control agents in plants. Pharmaceuticals and industrial products are getting more and more attention. See Activity 1-1 in this lesson for a closer look at current and future products.

Terms

***Bacillus thuringiensis* (Bt)** – a naturally-occurring soil bacterium containing Bt toxin that is lethal to certain insect larvae.

biopesticides, bioherbicides, bioinsecticide – natural pest control products made from naturally occurring microorganisms.

Bt crop – transgenic plant modified with a gene from the soil bacterium *Bacillus thurin-giensis* to kill certain insect larvae that eat the plant.

glyphosate – a non-selective herbicide that affects almost all vegetation it contacts.

herbicide tolerant crop – crop plant modified to grow in the presence of a specific herbicide.

immunoassay – a technique for identifying substances based on the use of antibodies.

polygalacturonase (PG)– naturally-occurring enzyme in fruit that causes ripening fruit to become soft by digesting part of the pectin that forms the cell walls.

transgenic plant – a plant modified to contain a gene from an organism in a different species.

Sources & Resources

Industry sites on the Internet

AgrEvo – www.us.agrevo.com. Global producers of insecticides, herbicides, and Liberty Link engineered plants linked to their own Liberty herbicide.

Archer Daniels Midland– www.admworld.com. Grain processors, producers of oils and feeds, other food and feed products.

DeKalb Genetics – www.dekalb.com. Large US producer of corn, soybean and other seeds, in-

cluding herbicide resistant corn and soybeans, resistant to imidazolinone, glufosinate, sulfonurea, and glyphosate herbicides.

DowAgroSciences – www.dowelanco.com. US agricultural chemical company with majority interest in Mycogen Inc., a global producer of biopesticides and one of the top marketers of corn, including Bt corn. Ongoing research on Bt crops (with Pioneer Hi-Bred) and on edible vaccines. (www.mycogen.com).

Monsanto – www.monsanto.com. Global company producing agricultural products and pharmaceuticals, including Roundup® herbicide. One of the largest producers of herbicide- and insect-resistant crops. Owns Calgene Inc. (www.calgene.com).

Novartis Seed Company – www.nk.com. Large US producer of corn, and soybeans, including Roundup resistant and Bt crops.

Pioneer Hi-Bred – www.pioneer.com. US-based global company producing seeds such as corn, rice and soybeans.

Strategic Diagnostics – www.sdix.com. Plant diagnostic immunoassay kits; transgenic quality control assay tests.

Zeneca Ag Products, a division of Zeneca Inc. – www.zenecaagproducts.com. Producers of chemicals for a wide variety of crops; genetically engineered tomato, potato, and banana.

News and information on the Internet or by subscription

Access Excellence – www.accessexcellence.org. Biotechnology information, news, careers, activities for teachers and students.

@g online – www.agriculture.com. Online news service with links to industries.

Agbiotech Infosource – www.agwest.sk.ca. AgWest Biotech Inc., Saskatchewan, Canada. Monthly agricultural biotech newsletter for schools, available on line or by subscription.

Biotechnology Industry Organization – www.bio.org. Links to current biotechnology news.

Biotechnology Information Series – www.biotech.iastate.edu/biotech_info_series/BIS.html. Developed by Iowa State University, 1994-1995. Easy to read information sheets about biotechnology products and issues.

Information Center at **USDA's National Agricultural Library** – www.nal.usda.gov/bic. Links to other sites, articles, journals. Links to other educational resources at www.nal.usda. gov/bic/Education_res.

ISB News Report – www.nbiap.vt.edu. Information Systems for Biotechnology at Virginia Tech. Monthly newsletter covers new products, issues and research findings.

International Food Information Council – http://ificinfo.health.org. News and information about nutrition and food safety. Special section on biotechnology.

USDA's **Agricultural Research Service** press releases – www.ars.usda.gov. USDA press releases – www.usda.gov/news.

Your World/Our World. User friendly magazine with teachers' guide, published 10x/year for 7th and 8th graders by Pennsylvania Biotechnology Association. Available from PBA, 1524 West College Avenue, Suite 206, State College, PA 16801, 814-238-4080.

Activity 1-1

Looking at Products of Plant Biotechnology

Teacher Worksheet

About this Activity

This activity is designed to familiarize students with 1) current products of plant biotechnology and their major uses and 2) future products of plant biotechnology. Two lists from the Biotechnology Industry Organization's survey of its members are reprinted in this activity: *Agricultural Products on the Market* 1998 and *Agricultural Biotechnology Products Expected on the Market Within Six Years.*

These lists can be used in a variety of ways to generate class discussion and for individual student assignments. A few questions and activities are suggested below.

Objectives

- discuss current applications of biotechnology in plant science
- discuss and compare future applications of biotechnology in plant science to current applications
- create appropriate displays for a given set of data (e.g. graph, table, chart).

Related Skill Standards

- organize and present oral summaries
- read and comprehend written documentation
- be open and adaptable to new technology and applications
- demonstrate various ways to display the same data

Time Required

This activity should take one or two classes.

Background Reading

Teachers and students should read and discuss Lesson 1, *Products of Plant Biotechnology*.

Materials

Students need copies of the Activity 1-1 Student Worksheet.

Teacher Preparation

Teachers need to photocopy lists for each student or group of students working together.

Answer Key for Student Questions

Students should be asked to summarize information from the lists in different ways, to compare information between the lists, and to depict the information using graphs and/or charts. These are a few suggestions.

1. As you look at the list of current products of biotechnology, you'll notice that most of the current crops created by biotechnology are designed for insect resistance or herbicide tolerance. How many of the products in the list are dedicated for insect resistance? How many for herbicide tolerance? Make a pie chart to show the percentage **by use**: 1) herbicide tolerance; 2) pest resistance; and 3) other.

   ANSWER: The total number of new products is 37; the total number of herbicide tolerant

products is 13; the total number of pest resistant products is 11; other uses is 13 .

2. Many of the new products are improved corn varieties. This time, make a chart (bar or pie) to show the relative amounts of these new products **by crop**, including corn, soybeans, potatoes, cotton, canola, and other.

   ANSWER: The total number of products on the list is 37; the number of products for each crop: corn–16; canola–3; potato-1; soybean–4; tomato–4; cotton–3; sunflower–2 ; other–5.

3. Look at the list of products expected to be on the market within six years. What are some of the major changes between those products and the products on the market today?

   ANSWER: herbicide tolerance in new crops, including sugar beet, rice, wheat; pest resistance in new crops, including sunflower, tomatoes, bananas, and wheat; multiple traits in one plant such as insect and virus resistance for potatoes; more foods for nutrition, flavor, and longer shelf life.

4. The information in these lists was created from a survey of the Biotechnology Industry Organization's members. Do you think that the product descriptions were written by the companies producing the product? Why or why not?

   ANSWER: Students may answer yes, they can tell by the way some companies' products are described in terms of benefits; others are described more neutrally. They may find other comparisons among the descriptions.

5. Imagine a list of products that will be on the market 10 years from now. Try to stay within the realm of possibility, addressing needs for which there are likely markets.

Related Activities

1. Ask the class to imagine their job is to develop a new plant product using genetic engineering. Knowing that they could modify a crop by inserting a gene from any source, what crop would they like to modify? What trait or traits would they like to bring to their new crop? Let them use their imaginations. Ask students to develop a sales pitch or advertisement for their new product.

2. Have students write to one of the major seed companies to get information about their products and report to the class.

3. Have students go to a local farm supply store to find out what biotechnology products are available and what information is available on these products.

Internet Activities

1. Have students access a major seed company Internet site to: see what products are being offered; research a report to the class on its biotechnology products; research information about the effectiveness of a product; determine new products the company is developing (in its "product pipeline").

2. Have students compare information on one crop, for example Bt corn, from several vendors' Internet sites. Some vendors have special web pages for an individual crop, for example Monsanto's Bt corn home page.

3. Have students periodically access the daily agricultural news journal **@g online** (www.agriculture.com) to look for the latest news about changes in the plant biotech industry. Have them keep a journal of the changes that occur during that time.

Activity 1-1

Looking at Products of Plant Biotechnology

Student Worksheet

About this Activity

This activity is designed to let you browse through information about current and future products of plant biotechnology, reprinted from the Biotechnology Industry Organization's Internet site. The first list describes products on the market in 1998, and the second one describes products currently in the "product pipeline."

You will be asked to summarize the information in different ways and to create visual displays of the data.

Student Questions and Activities

1. As you look at the list of current products of biotechnology, you'll notice that most of the current crops created by biotechnology are designed for insect resistance or herbicide tolerance. How many of the products in the list are dedicated for insect resistance? How many for herbicide tolerance? Make a pie chart to show the percentage **by use**: 1) herbicide tolerance; 2) pest resistance; and 3) other.

2. You probably noticed that many of the new products are improved corn varieties. This time, make a chart (bar or pie) to show the relative amounts of these new products **by crop**, including corn, soybeans, potatoes, cotton, canola, and other.

3. Look at the list of products expected to be on the market within six years. What are some of the major changes between those products and the products on the market today?

4. The information in these lists was created from a survey of BIO's members. Do you think that the product descriptions were written by the companies producing the product? Why or why not?

5. Imagine a list of products that will be on the market 10 years from now. Try to stay within the realm of possibility, addressing needs for which there are likely markets.

Agricultural Biotech Products on the Market 1998 –1–

From the Biotechnology Industry Organization web site (www.bio.org/whatis/guide2.dgw#market) from a survey of BIO members

- **LibertyLink® Corn** (AgrEvo) – Introduced in 1997 in the U.S. and 1998 in Canada, LibertyLink® Corn allows growers to apply Liberty® herbicide over the top during the growing season. Liberty herbicide kills over 100 grass and broadleaf weeds fast, with no crop injury. LibertyLink® Corn hybrids are offered by Pioneer, Novartis, Cargill, Garst and over 100 other seed company partners. Liberty® herbicide is offered by AgrEvo.

- **LibertyLink® Canola** (AgrEvo) – Introduced in 1995, LibertyLink® Canola allows growers to apply Liberty® herbicide over-the-top during the growing season. This results in weed control with no effect on crop performance or yield.

- **StarLink Corn** (AgrEvo) – Expected to be introduced in 1998, these plants express a protein toxic to various lepidopteran pests, which allow less insecticide usage.

- **IMI-CORN®** (American Cyanamid) – Introduced in 1992, imidazolinone-tolerant and -resistant corn allows growers to apply the flexible and environmentally friendly imidazolinone herbicides to corn. Registration of LIGHTNING™ herbicide, a new imidazolinone specifically for use on IMI-CORN®, was approved by the EPA on March 31, 1997. One postemergence application of LIGHTNING™ herbicide provides both contact and residual control of broadleaf and grassy weeds resulting in maximum yield potential.

- **SMART™ Canola Seed** (American Cyanamid) – Introduced in 1995, imidazolinone-tolerant canola allows growers to apply environmentally-friendly imidazolinone herbicides to canola. In Canada, registration of ODYSSEY™ herbicide, a new imidazolinone for use on imidazolinone-tolerant canola, was approved on April 4, 1997. One postemergence application of ODYSSEY™ herbicide provides both contact and residual control of hard-to-control broadleaf and grassy weeds resulting in maximum yield potential.

- **Bollgard with BXN Cotton** (Calgene, LLC, unit of Monsanto) – These cotton plants require less chemical herbicide and insecticide to lower grower input costs and achieve greater yield.

- **Laurical®** (Calgene, LLC) – A less-expensive source of high-quality raw materials for soaps, detergents and cocoa butter replacement fats. Canola (rapeseed) plants with more than 35 percent laurate in oil have been produced.

- **DeKalBt™ Insect-Protected Hybrid Corn** (DeKalb Genetics Corporation) – Approved in 1997, select DeKalb leader hybrids have built-in protection against the European corn borer.

- **DeKalb Brand Roundup Ready® Corn** (DeKalb Genetics Corporation) – Approved in 1998, DeKalb offers several elite hybrids with resistance to Roundup Ultra™ herbicide.

- **DeKalb GR Hybrid Corn** (DeKalb Genetics Corporation) – Approved in 1996, DeKalb GR hybrids provide growers the added weed control benefits of over-the-top glufosinate herbicide application.

Agricultural Biotech Products on the Market 1998 –2–

- **FreshWorld Farms® Tomato** (DNAP Holding Corporation) – The FreshWorld Farms® tomato is a premium, fresh market tomato developed through somaclonal variation3 to have superior color, taste and texture and a 10- to 14-day shelf life.

- **FreshWorld Farms Endless Summer® Tomato** (DNAP Holding Corporation) – The Endless Summer® tomato is a genetically engineered version of the FreshWorld Farms® tomato on the market since April 1993, and shares its superior color, taste and texture. What's new is its greatly extended shelf life of more than 30 to 40 days after harvest. Company scientists used Transwitch® technology to suppress production of ethylene, the hormone that causes tomatoes and other fruits to ripen. It is the company's first whole-food product developed through recombinant DNA technology.

- **FreshWorld Farms® Sweet Mini-Peppers** (DNAP Holding Corporation) – The FreshWorld Farms® sweet mini-pepper has a novel sweet taste, deep red color and is nearly seedless. It was developed through anther culture, an advanced breeding technique that captures and stabilizes preferred characteristics such as taste, texture and low seed count.

- **FreshWorld Farms® Cherry Tomatoes** (DNAP Holding Corporation) – The FreshWorld Farms® cherry tomato is specially bred for superior taste, color and texture. It is sold through distributors and supermarket chains in the Mid-Atlantic, Northwest and Midwest regions.

- **High pH Tolerant Corn Hybrids** (Garst Seed Company) – These corn hybrids are capable of growing successfully on the severely alkaline soils of the western U.S. corn belt.

- **Gray Leaf Spot Resistant Corn Hybrids** (Garst Seed Company) – Corn hybrids tolerant to the disease Cercospora spp., which attacks corn hybrids in the Central and Southeast corn belts.

- **G-Stac™ Corn Hybrids** (Garst Seed Company) – Corn hybrids featuring "stacked" genes providing multitask capability. For example, hybrids that contain genes for the control of European corn borer (B.t.), genes for resistance to Liberty® herbicide and genes for resistance to imidazolinone herbicide all in the same corn hybrid.

- **Bollgard® Insect-Protected Cotton** (Monsanto) – Introduced in 1996, cotton with Monsanto's Bollgard gene is protected against cotton bollworms, pink bollworms and tobacco budworms.

- **NewLeaf® Insect-Protected Potato** (Monsanto) – Introduced in 1995, the NewLeaf® Potato is the first commercial crop to be protected against insect pest through biotechnology. Thanks to a gene from a Bt bacteria, the NewLeaf® Potato is resistant to the Colorado potato beetle.

- **Roundup® Ready Cotton** (Monsanto) – Approved in 1996, Roundup Ready® cotton tolerates both topical and post-directed applications of Roundup® herbicide.

- **Roundup Ready® Soybeans** (Monsanto) – Introduced in 1996, Roundup Ready® Soybeans allow growers to apply Roundup® herbicide over-the-top during growing season. The result is dependable, superior weed control with no effect on crop performance or yield.

Agricultural Biotech Products on the Market 1998 –3–

- **Roundup Ready® Corn** (Monsanto) – Approved in 1997 Roundup® Ready Corn allows over-the-top applications of Roundup® herbicide for superior weed control.
- **YieldGard™ Insect-Protected Corn** (Monsanto) – The YieldGard gene provides control of the European corn borer throughout the corn plant during the season.
- **NatureGard® Hybrid Seed Corn** (Mycogen) – These corn plants express a protein toxic to the European corn borer that reduces or eliminates the need for insecticides.
- **IMI-Corn** (Mycogen) – Corn hybrid that can tolerate the application of imidazolinone herbicides.
- **High Oleic Sunflower** (Mycogen) – Sunflower plants modified by mutagenesis to produce sunflower oil that is low in trans- fatty acids, does not require hydrogenation and has improved temperature stability.
- **High Oleic Peanut** (Mycogen) – Peanut plants modified by mutagenesis to produce nuts high in oleic acid that result in longer life for nuts, candy and peanut butter.
- **NK Knockout™ Corn, NK YieldGard™ Hybrid Corn, Attribute™ B.t. Sweetcorn** (Novartis Seeds) – Novartis seeds has produced several corn varieties that have been modified to provide natural protection against certain pests.
- **Novartis Seeds Roundup Ready® Soybeans** (Novartis Seeds)
- **High Oleic Acid Soybeans** (Optimum Quality Grains, L.L.C.) – These soybeans produce an oil that contains a higher level of oleic acid than that found in currently available soybean oil and also contains lower levels of saturated fat. The oil will fit applications that require enhanced stability without the need for chemical hydrogenation, which generates trans-fatty acids.
- **Low Linolenic Soybean Oil** (Optimum Quality Grains, L.L.C.) – With less than 3.5 percent, linoleic is an enhanced stability oil that will reduce the need for chemical hydrogenation, therefore reducing trans-fatty acids.
- **Low Saturate Soybean Oils** (Optimum Quality Grains, L.L.C.) – This oil is 50 percent less saturated fat than commodity soybean oil (vegetable oil), or approximately 8 percent total saturated fat. A 14-gram serving has just one gram of saturated fat—the same as canola oil. Zero saturated fat can be reached in many formulations when a low saturated soy is used in place of commodity soy.
- **High Oleic Sunflower Oil** (Optimum Quality Grains, L.L.C.) – As an enhanced-stability oil, high oleic sunflower oil (less than 80 percent oleic) is excellent for use as an ingredient, in cooking or as spray oil, without the need for chemical hydrogenation. New hybrids currently in production are expected to increase oleic acid content to around 85 percent.
- **Increased Pectin Tomatoes** (Zeneca Plant Sciences) – Tomatoes that have been genetically modified to remain firm longer and retain pectin during processing into tomato paste.

Agricultural Biotechnology Products Expected on the Market Within Six Years

reprinted from the Biotechnology Industry Organization web site (www.bio.org/whatis/guide2.dgw#market) from a survey of BIO members

- **Genetically Engineered Cotton Fiber** (Agracetus, unit of Monsanto Company) – This biotechnology product will enhance fiber performance, reduce dye-shop pollution and improve textile manufacturing efficiency.
- **LibertyLink® Soybean, Cotton, Sugar Beet and Rice** (AgrEvo) – These LibertyLink® crops will be available in Canada and / or the United States. Like LibertyLink® Corn, when used together with Liberty® herbicide, they will allow farmers greater flexibility and environmental soundness in weed control.
- **SeedLink Corn** (AgrEvo) – These plants provide a more reliable pollination control system for corn seed production. The use of the SeedLink System eliminates the need for hand or mechanical detasseling.
- **IMI™Wheat Seed** (American Cyanamid) – American Cyanamid is cooperating with universities, public and private laboratories and seed companies to develop wheat varieties tolerant to imidazolinone herbicides. Imidazolinone herbicides are flexible, environmentally friendly and provide contact and residual control of weeds common to wheat production, including ones not controlled by currently registered wheat herbicides.
- **IMI™Rice Seed** (American Cyanamid) – American Cyanamid is cooperating with universities and public and private seed companies to develop rice varieties tolerant to imidazolinone herbicides. Imidazolinone herbicides are flexible, environmentally friendly and provide superior contact and residual control of weeds.
- **IMI™Sugar Beet Seed** (American Cyanamid) – American Cyanamid is cooperating with universities and seed companies to develop sugar beet varieties tolerant to imidazolinone herbicides. Imidazolinone herbicides are flexible, environmentally friendly and provide superior contact and residual control of weeds.
- **Insect Protected Tomatoes** (Calgene, LLC, unit of Monsanto Company) – These tomato plants will require less chemical insecticides to achieve higher yields.
- **High Sweetness Tomato** (Calgene, LLC) – Tomato plants that produce high flavor tomatoes.
- **Genetically Engineered Fruits and Vegetables with Longer Post-Harvest Shelf Life** (Agritope, Inc., a wholly owned subsidiary of Epitope, Inc.) – Using ethylene-control technology, Agritope, Inc., has created delayed-ripening, longer-lasting tomatoes, raspberries and strawberries.
- **Virus Resistance Tomatoes** (Calgene, LLC) – These tomato plants will be resistant to infection by certain plant viruses.

Agricultural Biotech Products Expected on the Market Within Six Years –2–

- **Ripening-Controlled Cherry Tomatoes** (DNAP Holding Corporation) – Using the same technology as in its Endless Summer™ fresh market tomato, the company has developed cherry tomatoes with longer market life, improved flavor and better harvest traits through ripening control.
- **Firmer Peppers** (DNAP Holding Corporation) – This sweet pepper has been modified using Transwitch® technology to remain firmer after harvest. Pepper plants are currently in field evaluations.
- **Sweeter Peppers** (DNAP Holding Corporation) – This pepper has been modified to be sweeter and tastier by overexpressing a gene for sweetness. Pepper plants are in early stages of seed increase and field evaluation.
- **Ripening-Controlled Bananas and Pineapples** (DNAP Holding Corporation) – Using the same ripening control technology as in its Endless Summer™ tomato, the company is developing banana and pineapple varieties with extended market life.
- **Strawberry** (DNAP Holding Corporation) – The company is improving the market life of fresh strawberries by using Transwitch® technology to keep fruit firmer after harvest and adding genes to resist disease.
- **Messanger™** (EDEN Bioscience) – This is the first of a series of products based on the Harpin Protein technology. Harpin Proteins induce disease resistance and promote increased yield in a broad range of agriculture and horticulture crops. Harpin Proteins induce the natural disease immune system and growth pathways inherent within each plant.
- **High-Solids Potato** (Monsanto) – Monsanto has developed a higher-solids (or starch content) potato by introducing a starch- producing gene from a soil bacteria into a potato plant. With the reduction in the percentage of water in the genetically improved potato, less oil is absorbed during processing, resulting in a reduction of cooking time and costs, better-tasting french fries and an economic benefit to the processor.
- **Roundup Ready® Canola** (Monsanto) – Roundup Ready canola allows growers to apply Roundup® herbicide over-the-top of the crop during the growing season, for superior weed control with enhanced crop safety.
- **Roundup Ready® Sugar Beets** (Monsanto) – Roundup Ready sugar beets are tolerant of Roundup® herbicide and provide growers with a new weed-control option while the crop is growing.
- **NewLeaf® Plus** (Monsanto) – Insect- and virus-protected potatoes. These potatoes are protecting themselves against Colorado potato beetles and potato leaf roll virus.
- **New-Leaf® Y Insect-and Virus-Protected Potatoes** (Monsanto) – These potatoes protect themselves against the Colorado potato beetle and the potato virus Y.

Agricultural Biotech Products Expected on the Market Within Six Years –3–

- **Second-Generation Bollagard® Insect-Protected Cotton** (Monsanto) – This cotton controls insect pests, like the original Bollagard cotton, but using a different mode of action to help growers manage insect resistance concerns.
- **B.t. Sunflower, Soybeans, Canola and Wheat** (Mycogen Corp.) – These crops will express a protein toxin providing protection against various caterpillar and beetle pests.
- **Fresh Market Tomato** (Zeneca Plant Sciences) – Zeneca is modifying the tomatoes for enhanced flavor, color and increased antioxidant vitamin content.
- **Banana** (Zeneca Plant Sciences) – Zeneca is developing an inherent resistance to Black Sigatoka and modifying ripening characteristics in bananas. This will reduce the need for chemical fungicides, as well as improve the agronomics of production and the quality to the consumer.
- **Modified Lignin in Paper Pulp Trees** (Zeneca Plant Sciences under separate agreements with Shell Forestry and Nippon Paper) – By making lignin easier to remove from cellulose—the primary ingredient in paper—papermakers can make high-quality paper with less energy and bleaching, which benefits both the paper processor and the environment.