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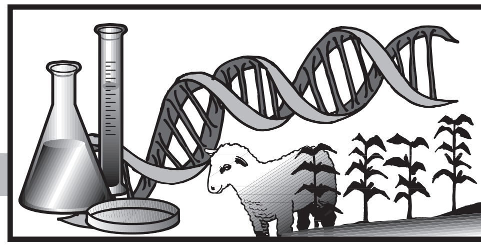

Biotechnology Information

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Biotechnology and the Environment

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Products developed through modern day biotechnology could benefit the environment in many ways. This publication will highlight some applications of biotechnology that relate to the environment and point out associated benefits and concerns.

Effects of Biotechnology on Agricultural Chemical Use

Biotechnology has the potential to reduce the application of agricultural chemicals for pest control and fertilization through the utilization of genetically modified microorganisms, plants, and animals.

Insecticidal plant proteins

Through the use of biotechnology, scientists have developed plants that produce a naturally occurring protein that is toxic to certain crop-damaging insects. The most common examples are the "Bt" plants, which include corn, cotton, and potatoes. These genetically engineered plants produce a protein normally found in the soil bacterium, *Bacillus thuringiensis* (Bt). Commercial sprays that contain *Bacillus thuringiensis* have been available for decades as an alternative to chemical insecticides. The Bt protein is toxic to certain crop-damaging insects, but is harmless to humans. Researchers are also searching for other insecticidal and antimicrobial proteins that are appropriate for use in crops.

Because these plants produce insecticidal proteins, they provide at least partial protection from damage caused by certain insects, which results in reduced chemical insecticide use in the environment. Another possible advantage to the environment is reduced fuel consumption by farm equipment as a result of fewer chemical applications.

An important concern associated with the release of a genetically engineered plant into the environment is its potential negative effect on non-target organisms. In 1999, a group of scientists working in a laboratory setting reported that the Bt protein was toxic to monarch caterpillars after some Bt plants had already been approved for commercial use. In the wake of the report, the United States Department of Agriculture organized a large investigation, funded by both government and industry, to address the effects of Bt corn on the monarch butterfly. The conclusion from that study was that Bt corn posed a "negligible" risk to monarch caterpillars in field situations. However, most scientists agree that continued monitoring of these plants is prudent to determine their long-term environmental effects.

Herbicide-tolerant plants

In conventional farming, weed growth is controlled through a combination of plowing and chemical herbicide application. Plowing leaves the soil exposed to wind and rain, which results in significant erosion of the land. In "no-till" agriculture, plowing of the soil in preparation for planting a new crop is eliminated. Remainders of the previous crop and a cover crop are left undisturbed on the soil surface while the new crop is planted directly into the crop residue. Herbicides are applied to kill any weeds that may be present. A 2001 Virginia study, conducted by The Colonial Soil and Water Conservation District, used rainfall simulation to investigate the effects of a no-till system on ten experimental plots. The study found that when no-till planting was used, there were 99, 75, 95 and 92 percent reductions in the loss of sediment, runoff, nitrogen, and phosphorus, respectively. There is currently a nationwide movement to increase the use of no-till agriculture. A key ingredient to success will be weed control.

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Tree Biotechnology

The process of making paper from trees requires the use of highly toxic chemicals that are harmful to the environment. The requirement to degrade the tree's lignin is a major reason for the use of the harsh chemicals. Scientists have recently used biotechnology to reduce the lignin content of aspen trees by 45%, potentially making it easier to prepare the pulp. These trees had the additional benefits of faster growth and an increased cellulose content, which is the component needed to produce paper. It is hoped that trees such as these may one day prove beneficial to the environment, but further studies are needed on the possible adverse effects that they could have on complex environmental ecosystems.

Through modern biotechnology, plants have been developed that are tolerant to certain herbicides (herbicide tolerant, HT), which allows farmers to use a broad spectrum spray for weed control without killing the crop they are growing. In the United States, the HT traits are available in a number of crops including canola, corn, cotton, and soybeans.

The biggest environmental advantage from using HT crops is that farmers can more easily implement a no-till system. Furthermore, because a broad-spectrum herbicide is applied, fewer types of herbicides are used. This practice reduces the amount of soil lost to erosion, provides additional protection for the seedlings, and reduces farm equipment usage.

In 2001, the American Soybean Association conducted a Conservation Tillage Study and found that 73% of soybean growers were leaving more crop residue on the soil surface than they did in 1996, meaning that there was an increase in no-till agriculture. More than half of the 452 growers surveyed attributed this increase to the use of HT soybeans. The effect of HT crops on herbicide use, including the type, amount, and associated costs, is currently being evaluated.

One concern of this technology is the possibility for the HT trait to be naturally transferred to plants in the wild, rendering them tolerant to commonly used herbicides and potentially allowing them to grow unchecked. This occurrence depends on the ability of the HT plant to breed with other plant species and its mechanism of pollination. Transfer of the HT trait to wild plants has not been shown to be a problem to date. However, it has been documented that the HT trait can be transferred between different varieties of the same plant species once the plant is in the field. For example, a Canadian farmer unintentionally developed a canola plant that was resistant to three herbicides by growing different varieties of canola in close proximity to one another. This allowed the three HT traits to be transferred among the canola varieties as a result of natural pollen movement. This incident underscored the need to use good crop management practices in conjunction with these types of plants.

Biopesticides and biofertilizers

Biotechnology may also reduce the use of agricultural chemicals through development of genetically engineered biological agents that protect crops from disease and insect destruction, and that promote growth. Scientists are currently investigating viruses, bacteria, and fungi that have beneficial properties for plants, which could be enhanced through genetic modification. These microorganisms would then be applied to plants or the surrounding soil. However, there are issues associated with releasing genetically modified microorganisms into the environment and their potential effects on non-target organisms.

Reducing phosphorus in farm animal waste

Manure from certain animals including swine and poultry contains high levels of phosphorus because the phosphorus in grain-based diets is in a chemical form that the animals are unable to metabolize. To meet animal nutrient requirements, additional phosphorus is added to animal diets, which results in even higher concentrations of phosphorus in the manure. When the manure is applied to the land to improve soil fertility, excess phosphorus can become an environmental pollutant through storm runoff into streams and rivers.

If these animals could utilize phosphorus in grains, additional phosphorus supplementation could be minimized and the amount of phosphorus in animal wastes would be reduced. For this to occur, animals need an enzyme called "phytase." Researchers recently developed several methods to potentially supply animals with phytase:

- Phytase was purified from a microbial source and used as a feed additive. Currently, its use has not been widely adopted.
- Canola, which was genetically modified to produce phytase, was subsequently used as a feed source, resulting in reduced phosphorus in manure.

- Scientists from Canada and Denmark collaborated to develop transgenic swine that produced phytase in their saliva. The swine secreted enough phytase to reduce excreted phosphorus by up to 75 percent.

Bioremediation

Bioremediation is the use of biological agents such as bacteria, fungi, and plants to remove, degrade, or detoxify pollutants from contaminated environmental sites. This technology is appealing because of the enormous costs and environmental disturbance that are associated with current clean up methods.

Scientists are identifying naturally occurring organisms that may be useful for bioremediation. They are also genetically modifying these organisms as a way to expand the list of treatable contaminants and to maximize their efficiency and safety.

Environmental contaminants that are targets for bioremediation include:

- organics (petroleum products and other carbon-based chemicals)
- metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, zinc)
- radioactive materials

Research is ongoing to determine if bioremediation represents a viable option both environmentally and monetarily. Although some success has been achieved in the laboratory, it is much more difficult to test and monitor the utility of these organisms in field settings.

Assuming the scientific obstacles are overcome, the safety of releasing these genetically modified organisms into the environment is being discussed. To avoid any unforeseen problems, one strategy under investigation is to make the organism dependent on the contaminant for life; therefore, when the contaminant has been successfully removed from the environment the organism will die. Another option is to take contaminated soil and water to contained facilities for biological decontamination, a much more expensive proposition.

Bioremediation using *Deinococcus radiodurans*

The United States Department of Energy estimates that the use of current methods to decontaminate the 3,000 sites in this country that have been used for nuclear weapons production will cost approximately $250 billion.

The bacterium, *Deinococcus radiodurans*, may one day be used to reduce these costs. Through a mechanism that continues to both intrigue and puzzle scientists, the bacterium is able to grow normally after being exposed to 1.5 million rads of radiation. A dose of 500-1000 rads is lethal to the average person. Although interesting, the ability to withstand deadly doses of radiation is not by itself useful. However, scientists are currently trying to genetically modify *Deinococcus radiodurans* so that it is able to sequester or detoxify radioactive compounds, toxic metals, or organic chemicals that may be present at contaminated sites.

Environmental Biosensors

The development of new biosensors, systems that use living organisms to detect environmental contaminants, has the potential to change the way in which environmental quality is monitored. Currently, environmental samples must be collected and taken to a laboratory where contaminant concentrations are determined. This is an inefficient, labor-intensive process that can result in contamination going unnoticed for a critical period of time. Plants and microorganisms are being developed that exhibit a quick, detectable response to low levels of contamination. These biosensors can be maintained on-site where they can monitor conditions constantly. For example, biosensors could be used in the soil or water outside of factories to ensure that discharge from the factory was acceptable at all times or at nuclear reactor sites to make certain that radioactive materials were not being released into the environment.

Biosensors may one day be used to detect forgotten landmines in war-torn countries by genetically modifying plants to be responsive to the explosive TNT, which is present in the soil near landmines. The United Nations estimates that worldwide there are approximately 110 million unexploded landmines, which kill or maim approximately 26,000 people per year. The theory is that by sowing, maintaining, and monitoring these TNT-detecting plants using planes or helicopters, it will be possible to identify the location of landmines. It is hoped that this method would replace the current procedure used in developing countries to locate landmines, which uses individuals with sticks to search suspected areas.