Teaching About Genetic Engineering

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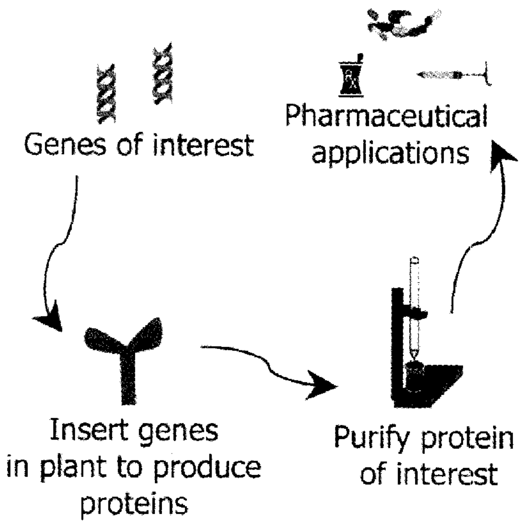


The current world population is 6 billion and the United Nations estimates that by 2030 it will increase to 10 billion (1). Usable farmland will shrink while other land use demands will increase. Some estimates indicate that world food production will have to double on existing farmland over the next 30 years to keep pace with anticipated growth (1). Our food will need to be grown under non-optimal conditions, such as less water and poorer soil, yet it will need to have added nutrition to adequately feed the populace. The biggest question facing agriculture today is how do we provide an increasing population with sufficient quantities of nutritious food while limiting the environmental impact? For agriculture to be sustainable, our food and fiber crops will have to be selected and engineered for optimal efficiency. Genetic engineering is a primary means to accomplish that.

Why Teach About Genetic Engineering?

If you are just now wondering whether you should be teaching about genetic engineering in crop production, you are already too late. According to a recent issue of Science (2), one-half of the 72 million acres of soybeans planted in the U.S. in 1999 were genetically modified. The genie is out of the bottle; the molecular genetic green revolution is here.

So, why teach about genetic engineering of crops in agricultural education? The answer is: because our students represent not only American agriculture, but the American public. The public needs to understand the technology and the implications for the use of this technology in order to make educated decisions regarding these crops and their products. A recent U.S. Senate subcommittee report stated that the Administration, industry, and the scientific community have a joint "responsibility to educate the public and improve the availability of information on the long record of the safe use of agricultural biotechnology products and research activities" (3). The public, including those in agriculture and those who are consumers of agriculture, need to know that:

- genetic engineering of food and fiber crops is being done,
- plants are being used to produce important industrial and pharmaceutical proteins,
- specifically what it is that is being done, how its being done, and what the real concerns are, based on science and reason.

What is Genetic Engineering of Crops?

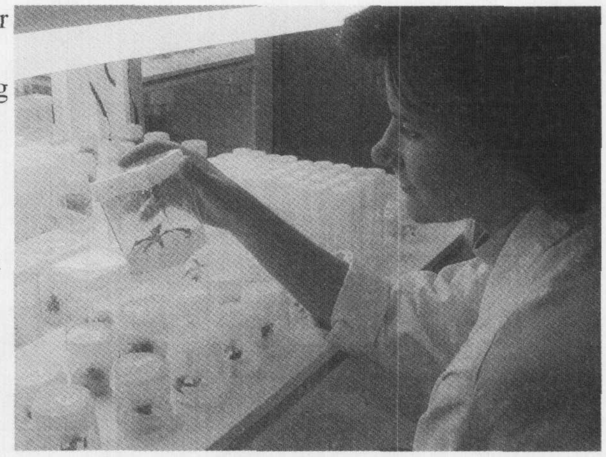
In conventional breeding, plants with desired characteristics are crossed and the characteristics are selected. This may take many generations over many growing seasons. Humans have conducted traditional plant breeding for thousands of years; and every crop available today is a product of this genetic manipulation. It is time-consuming and imprecise, and the breeder may have little control over the outcome. Plant biotechnology consists of techniques that allow scientists to identify, isolate, and transfer specific genes (DNA fragments) into plants to create desired traits or effects in the plant; it is a very precise genetic modification.

Biotechnologists follow specific steps to create a genetically modified (GM) or engineered plant (See above). The first step is to identify the trait, phenotype or characteristic to be manipulated. Examples include insect resistance or the ability to metabolize excess lead from the soil. Genes for these traits define which particular proteins are made and when, and the proteins cause the desired effect in the plant. Biotechnologists identify the gene that encodes for the desired protein from a source, then clone it (copy and purify it) as a DNA fragment. After the gene is cloned, it must be put into the plant for expression. While there are different ways to accomplish this, the common method of "transformation" of the recipient plant cells is to use a bacterium, Agrobacterium tumefaciens, to temporarily infect the plant. The bacteria delivers the gene into the plant genome.

Once the plant has gone through the transformation process, those plant cells, which do carry your gene of interest, must be selected. The biotechnologist can select for plants that successfully received the genetic material using antibiotic or herbicide resistance marker genes. Marker genes have been inserted into the plant with the gene of interest and any plant that can grow in the presence of antibiotics, for example, is also highly likely to carry the desired gene. After different lines of plants carrying the gene of interest have been generated, these primary transformants are grown for multiple generations to confirm stability and continued transmission of the modified trait.

What are the Benefits of Genetically Engineered Crops?

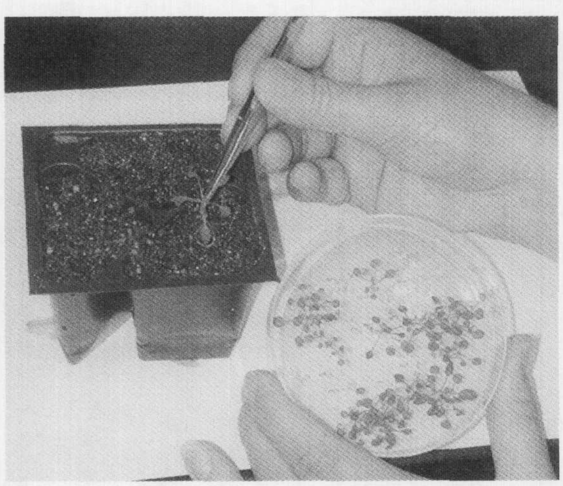
The potential for impact of GM plants is tremendous with benefits to farmers, consumers, and the environment. Crops with genetically engineered herbicide, disease and insect resistance, along with integrated pest management, have been shown to result in decreased herbicide and insecticide use and less crop loss (3). Carlson et al. (4) reported that GM Bt cotton required 72% fewer insecticide applications versus conventional cotton and had an increased yield of 11%. The increased yields permit the farmers to produce more per acre, conserving land (3). Resulting changes in farming practices include conservation tillage programs, improved pest control, and decreased soil erosion (3).



Various plants in tissue culture.

Genetic engineering can modify plant biochemistry for improved plant survivability under non-optimal conditions such as drought, high salinity, and heat/cold extremes, and to permit plants to absorb nutrients from poor soils. This can allow farmers to tailor plant choices to match specific environments for optimal productivity. Potential benefits for animal production from plant biotechnology include altering feed composition by altering the oil and protein content of corn, and by creating grains with low phytate amounts for decreased phosphate excretion into the environment.

Genetically modified crops may be used to increase human health and nutrition. New plants with "nutraceutical" properties may help prevent disease with increased vitamin, mineral, protein, amino acid content, and decreased or altered fat content. Vaccines, both edible and injectable, along with pharmaceuticals that will be used as protein-based drugs are being produced in plants. The production of GM plants for medicine will provide value-added crops for farmers. Crop foods with enhanced attractiveness, better taste, and foods that are hypoallergenic are also being produced.



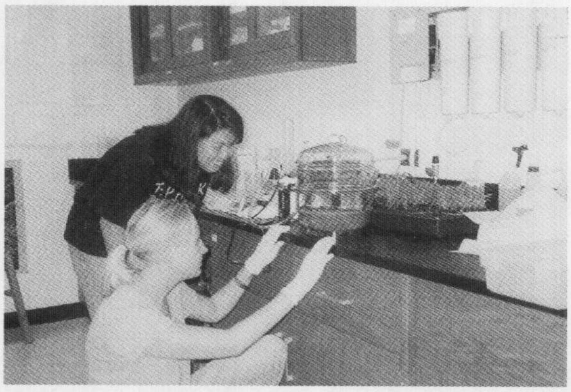
After selecting for genetically engineered plants on antibiotic media, survivors are moved to soil to set seed.

Plants will not be just sources of food, feed, and medicines, but also serve as factories for the production of industrial enzymes, alternative sources of plastics and fibers, and as aids in cleaning up the environment. Recently, plant proteins that can sequester or transform heavy metals into non-toxic forms have been identified. This allows researchers to modify plants to perform bioremediation of toxic metals such as mercury, copper, and cadmium (5).

Are There Risks of Genetically Altering Crops?

No unique risks from directly transferring genes from other organisms into plants, as is currently done in modern plant biotechnology, have been found. The potential for risks associated with GM plants are similar to those associated with plants modified with classical breeding. In fact, the new technology consists of more precise genetic manipulation than with conventional techniques, and that allows developers and producers to assess safety more easily (3,6). Genetically modified plants result from the specific introduction of a small DNA fragment into the plant genome. It has a precise, easily characterized, effect on the plant. Traditional breeding crosses thousands of genes whose functions are generally not known and the plants are introduced into the food supply with large genetic and phenotypic changes that are not characterized (3,6).

Should we be concerned with the movement of introduced genes to



Genetically engineering rape seed to produce anti-cancer proteins utilizing a vacuum method.

other plants through outcrossing, the transfer of antibiotic resistance to bacteria, or the potential additions of allergens to our food supply? The frequency of outcrossing will be no different between a crop produced by traditional methods and that produced through biotechnology. However, the outcomes of such crosses and the potential effects of possible movement of an engineered gene product to a non-target species need to be addressed with ecological research for each event.

There has been concern raised as to whether antibiotic resistance genes, used to help select for successfully transformed plants, will be passed to bacteria making them resistant to the antibiotic and causing human health threats. Several panels of experts have concluded that the chance of antibiotic-resistance genes getting into intestinal bacteria is exceedingly unlikely and of little concern because the same resistance genes are already present in many of the bacteria (7). Therefore, the risk of a health hazard due to antibiotic resistance genes has little medical significance (3).

Concern exists that GM foods may induce allergic reactions in humans. Many conventional foods already pose similar or higher risks, as plants produced by classical breeding methods may introduce many potential allergens into a product. Additionally, GM foods are tested more rigorously than conventional foods before marketing (3,7).

Should there be alterations to the regulatory process for these GM plants? Perhaps, if only to clarify governmental oversight. At this time, USDA, EPA, and FDA each have responsibilities regulating different aspects of the production and use of GM plants. Plant biotechnology products have been extensively researched and reviewed (more so than conventionally bred products) and there is rigorous governmental oversight of the technology (3).

Our students, as the next generation of agricultural producers, consumers, and scientists, will have to make the educated risk-benefit analyses in regard to transgenic versus conventional crops. While the bottom line for agriculture may be yield and cost, the world's concern is "can we feed the people and feed them safely with reduced environmental impact?" These are especially important questions in light of the likelihood that the world's population will double in the next 30 years or so. Thus, the future of plant genetic engineering is tightly linked to our own future.

References

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