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Impact of Biotechnology on Crop Production, Protection, and Utilization

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Since the beginning of civilization, humankind has modified plants to better fit their needs for production of food, feed, and fiber. Even before the days of modern science, cultivators selected plants with high productivity, the ability to withstand disease, and the size, shape, and color of the seed. The individual preferences of the cultivators led to thousands of different "varieties," particularly in the area where the crop originated.

In China, for example, there are hundreds of different soybean "varieties," each chosen for special characteristics by the farmers that use them. We can say with confidence, therefore, that humankind has for thousands of years attempted to understand and manipulate nature in a way that would better fit society's needs. The innovations that will result from biotechnology are simply a continuation of this desire to manipulate plants in ways that can better serve us. The purpose of my presentation today is to talk about how biotechnology will influence plant production in the future.

Biotechnology represents the application of molecular biology to the development of useful products and processes. One can trace the roots of biotechnology to the discovery by Gregor Mendel in the late 1800s that living cells contained heredity factors that are passed from one generation to another. That discovery ultimately led to modern plant breeding and provided us with a more intelligent means of manipulating plants to develop the products that we wanted. Without ever seeing the gene or knowing how it operated chemically, plant breeders were able to improve numerous characteristics of plants including seed yield, nutritional characteristics, disease resistance, insect resistance, standability, adaptability to mechanical harvest, and a host of other important traits.

Since the discovery of heredity factors by Gregor Mendel, that we now refer to as genes, scientists have wanted to know the chemical makeup of a gene and how genes are expressed in the formation of a living organism. A major step in this discovery process was the research by Watson and Crick in the 1950s that identified deoxyribonucleic acid, DNA, as the basic chemical molecule that makes up a gene. Since their discovery, scientists have learned the sequence of nucleic acids that make up a number of important genes, how genes are triggered to express themselves, and how the message of the gene ultimately becomes a leaf, stem, or seed. The manipulation of genes at the molecular level is an essential component of what we refer to as molecular biology. It is the chemical manipulation of the gene to produce a useful product or process that we refer to as biotechnology.

When the term biotechnology was first used, there were those who suggested it was a passing fad or a flash in the pan. Those who expressed that
view, however, did not realize that biotechnology was simply the application of a wealth of biological knowledge that was being developed. The only way that biotechnology could not impact on plant production would be if we stopped biological science and tore up the textbooks of the last 20 years. Biotechnology is here to stay, and it will have a profound impact on the plants that are produced in the future.

One of the most profound changes that will occur from biotechnology is in the ability of scientists to produce plant products that more closely fit the needs of the consumer. Plant breeders have always been able to manipulate plants to produce a variety of products, but they have been limited in the diversity of the products that were possible. The limitation is the genes available in the species with which they are working or in related species that can be hybridized with the species of interest. An additional tool sometimes used successfully is the application of mutagens to seeds or other plant parts with the hope of creating genetic changes of a desired type. Mutagenesis is carried out with chemicals and physical agents. It is a random process which I refer to as the "spray and pray" method because there is no assurance that a breeder will obtain the genetic change that is desired.

Plant breeders have utilized the available genes to make major changes in plant products. One of the most notable is the development of a low erucic acid, low glucosinate rapeseed known as carrola. With mutagenesis, soybeans have been developed with oil characteristics that are unique to any natural germplasm that has been evaluated in the world. These soybean oils can serve as a useful model for understanding how profoundly plant products will be changed in the future.

In the late 1960s, Earl Hammond, a colleague of mine in the Department of Food Technology at Iowa State, was approached by a major company about the possibility of developing a soybean with a lower percentage of linolenic acid. Linolenic acid has been identified as the fatty acid responsible for the tendency of vegetable oils to be less stable than desirable. Through the oxidation of linolenic acid, off flavors develop that are undesirable for the consumer. Commercial soybeans grown today have about 8% linolenic acid.

Research in the '60s had indicated that it would be necessary to lower the percentage of linolenic acid to about 3% to appreciably change the stability of the soybean oil. Earl and I decided that we would embark on a project to develop a lower linolenic acid soybean as a means of increasing the value of the crop. As a part of that effort, we found it necessary to utilize chemical mutagens in an attempt to create the genetic changes that we desired. By looking at thousands of progenies from treated seeds, we were able to identify a genetic type with about 3% linolenic acid. We also found types that we were not looking for, including some with unusually high stearic acid or high palmitic acid. Through this process, therefore, we had created soybean oils that before were not available to processors, manufacturers, and consumers. We have transferred the genes controlling low linolenic acid into high-yielding varieties and intend to have at least one million pounds of low linolenic acid oil available by the harvest of 1991. We also are transferring the genes for high stearic acid and high palmitic acid into high-yielding varieties. In a short time, therefore, we will no longer grow generic soybeans.
Instead, we will have new crops that look like soybeans, are planted and harvested like soybeans, but each of which has unique characteristics.

Non-generic soybeans will extend well beyond different oil types. In our breeding program at Iowa State University, we have for many years been interested in developing soybean varieties with unique characteristics for different food products. For example, there are three Japanese food products, all of which can be made with generic soybeans, but each of which can be made more satisfactorily with soybeans with unique characteristics. Miso is most satisfactorily made with a soybean with unusually large seed; for tofu, a soybean with high protein gives the most desirable product; and for natto, a soybean with unusually small seed is preferred. In our program at Iowa State University, we have been developing highly productive varieties for each of these markets. These varieties look like soybeans, are planted and marketed like soybeans, but differ from generic soybeans in important characteristics for the end user. In my state of Iowa, non-generic soybeans have the potential of being major "new crops" in the future.

All of the research I have just described have not involved biotechnology. We have not known the chemistry of the gene with which we have been working. We only know that the genes we want are present because the seeds possess the characteristics that we want. Biotechnology will add a new dimension to the development of the non-generic crop because scientists will have the ability to intelligently manipulate genes in the laboratory to produce products that are not possible by traditional breeding or with the use of chemical mutagens.

The list of potential new products is limited only by the imagination. There are numerous biotechnology journals and trade magazines today, all of which propose a wealth of new possibilities. It is impossible to say how many of these possibilities will become a reality because even though we may be able to isolate a gene and manipulate it, we cannot be certain that the gene will express itself in the plant in the way we desire. We must wait until success or failure has been realized to be certain of the outcome of the current speculation. Although all of the potential possibilities will not be achieved, we can be assured that a wealth of new types will be available in the market place.

As I indicated earlier, we can find lists of possibilities for new products in numerous publications. For example, the October 1987 issue of Genetic Engineering News has an article written by William Netzler entitled "Plant Biotechnologists Reorchestrating Native Gene Expression Systems." In the article, he lists the following products that are under scientific development:

- Tolerance to herbicides obtained by selecting among cells in tissue culture;
- Insect resistance in plants obtained by transferring a gene from bacteria into a plant;
- Approved uptake of phosphorous by plants to be achieved by chemically turning off the gene that limits the amount of phosphorous that a plant can absorb from the soil;
- Improving the quality of seed protein by eliminating components of limited
nutritional value and increasing those components of higher nutritional value. This would be done by chemically turning off the genes of little value and enhancing the expression of those of greater value;

Developing plants that would express in leaf and stem tissue the same level of high protein that is expressed in seed. At the present time, seeds often have a chemical composition that is markedly different from that of the rest of the plant. By chemical manipulation, the genes expressed only in the seed would be expressed also in the plant tissue. This would increase their value for forage;

Improve carotinoid synthesis in tomatoes to increase their nutritional value;

Modification of the fatty acid composition of seed oil;

Production of pharmaceutical chemicals by plants by introducing genes from micro-organisms and animals.

The question often asked is when will these products be available in the marketplace. A few of them are relatively close and others remain only possibilities. Herbicide resistance in plants has already been achieved and plant breeders are incorporating the new genes into future varieties. Improved insect resistance in plants also is close to becoming a commercial reality.

There are those who have suggested that all biotechnology research is unnecessary because we already have abundant food supplies in the world. Those who make that comment have not carefully looked at the list of new possibilities that scientists are considering. Many of the new possibilities relate to increasing nutritional value, eliminating chemical processes that are now involved in food manufacturing, and more carefully tailoring the crop to meet the needs of the end user.

Agriculture has an exciting future. Major changes are coming in the way plants will be marketed and utilized. The change from generic crops to non-generic crops undoubtedly will have repercussions on the agricultural production and marketing system. Some people ask if we will be able to deal with these non-generic products. I can tell you from my experience in Iowa with specialty soybean types that farmers and agribusiness persons are fully capable of dealing with the new opportunities. I look forward to participating in this new era of agriculture and I hope you do also.