1. Genetic engineering

The new techniques and their potential

Carole P. Meredith
Assistant Professor, Viticulture and Enology, Davis

In one sense, genetic engineering of plants is really nothing new. Since the beginnings of agriculture, when crop species were first domesticated, people have modified plants to suit their needs. In saving seed from only their best plants, ancient farmers practiced genetic selection. Systematic and scientific plant breeding began about 200 years ago and has evolved into a powerful technology. Crop plants are now deliberately improved through controlled pollinations to achieve defined objectives. But although genetic engineering is in a way as old as agriculture itself, in current usage the term refers collectively to a number of very new techniques for changing plants genetically—techniques that do not rely on pollination, but instead involve genetic manipulations at the cellular and molecular levels. This technology promises to be a powerful adjunct to modern plant breeding.

The history of the new technology is very brief, beginning around 1970. At about that time plant protoplasts were shown to be capable of regenerating entire plants. Other aspects of plant cell and tissue culture, such as mutant selection and protoplast fusion, were also developing rapidly, and plant scientists were beginning to recognize the potential of cultured plant cells for genetic research.

Recombinant DNA

Simultaneously, breakthroughs in molecular biology led to the development of recombinant DNA techniques by which a gene could be isolated from one kind of organism and introduced into another organism, permanently changing the genetic makeup of the recipient. Within the last few years, plant molecular biologists have been able to isolate specific important plant genes and study their structure and regulation. Research with several plant pathogens has contributed significantly to the development of techniques for transferring genes into plant cells. The simultaneous advances in all these areas are rapidly bringing together the components necessary to genetically engineer crop plants.

But what does the new technology offer that existing plant breeding technology does not? In quantitative terms, great savings in time and space are foreseen. It will become possible to engineer, in one step, a specific genetic change that would require several generations in a breeding program. Whereas existing breeding programs commonly require considerable amounts of land for planting and evaluating the progeny of each cross, plant scientists employing the new technology can grow and evaluate 100 million cells, each a potential plant, in a single small flask.

Obstacles remain

The most awesome aspect of the new technology is certainly the vastly extended range of genetic variability that will become available to the plant breeder. No longer will a breeding program be limited to those characteristics that already exist within a species or its very near relatives. Protoplast fusion, for example, permits a breeder to use desirable traits from other species that are related to the crop, but not closely enough to permit standard crossing. Other techniques, such as mutant selection, can generate new genetic variants within a crop species. The rapidly developing recombinant DNA technology may ultimately enable us to use genes from any other organism to improve a crop.

These are dazzling notions, certainly, but the new technology is still in its infancy, and a number of major obstacles must be overcome before genetic engineering can become generally useful for crop improvement. At present, most of the new techniques are limited to very few crop species—those in which plants can be regenerated from single cells. Progress in this area is steady, however, and the list of tractable crops is growing. Genetic changes other than those being sought often arise in regenerated plants. We don't yet know how to control this phenomenon. Some important traits—yield and flavor, for example—are extremely complex and are the net result of many interacting components. It will no doubt be quite some time before we understand these traits well enough to orchestrate them successfully at the cellular and molecular levels. Even many less complex aspects of plant function are still not well understood.

The ultimate practical value of genetic engineering will vary from crop to crop. Some major agronomic crops, such as corn, can already be engineered quite effectively as a result of highly sophisticated breeding technology that has developed around them. Genetic engineering, in the cellular and molecular sense, will be an alternative only for specific breeding objectives that cannot otherwise be achieved. At the other end of the spectrum are the crops that are difficult to breed by existing techniques, typically the large woody perennial plants. Their size, genetic complexity, and long generation time severely restrict breeding progress. With these crops, genetic engineering may become the method of choice for many breeding objectives.

Prospects for crop improvement are expanding, not only because of cellular and molecular techniques, but also as a result of advances in breeding technology. New cytogenetic strategies enable breeders to move specific chromosomes into crop species. Crosses between distant relatives are facilitated by novel embryo rescue techniques. Isozyme technology is emerging as a powerful analytical tool for several aspects of plant breeding.

An exciting time

Impressive as all these new techniques are, they are not likely to replace conventional plant breeding. They will instead be combined with the existing methods in an integrated approach to crop improvement, each technique being used when it is the most effective and economical means to an end.

The prospects for manipulating plants genetically have spurred plant scientists to unprecedented levels of activity. As the following articles illustrate, University of California scientists are playing a significant role in development of this new technology. They are involved at all levels, from discovering new knowledge about plant genes to assessing agricultural needs. New techniques are being integrated with old in a wide range of specific crop improvement programs. For agricultural research, it is indeed an exciting time.