Designing Plants with Rare Genes

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By means of gene-transfer technology important crop plants may someday be enhanced through the shrewd transfer of genes from rare and threatened species

Science is a communal enterprise; it makes significant progress only when findings from diverse avenues of investigation are shared and consolidated. Nowhere is this more apparent than in modern biotechnology, the utilization of living systems (plant, animal, and microbial) for practical purposes. In fact, it can be said that the recent success of plant biotechnology has been built on a foundation of earlier progress in such varied areas of botany as anatomy, biochemistry, ecology, genetics, morphology, physiology, and systematics. In the future, plant conservation, with its emphasis on the preservation of rare and endangered species, will undoubtedly also have a significant impact.

The most spectacular recent innovations in biotechnology involve improved technology for genetically modifying plants and producing individuals with new characteristics. Based on so-called "gene-transfer methods," these novel techniques for plant genetic engineering are currently being accomplished by two different procedures. The first procedure exploits a pathogenic bacterium known as *Agrobacterium tumefaciens*, which normally causes the crown-gall disease, characteristic tumorous overgrowths on infected plants, to transfer desired genes (DNA) into plant cells. By an as-yet undefined mechanism, *Agrobacterium* can mobilize, or transfer, virtually any DNA sequence via its Ti plasmid (a tumor-inducing ring of DNA) into cells in which the sequence becomes stably attached to the plant's own DNA, perpetuated, and expressed as new genetic material. The second gene-transfer method, known as electroporation, utilizes a mixture of plant protoplasts (cells that have had their cell walls removed by enzymatic digestion) plus purified DNA incubated in the presence of a strong electric field. This treatment apparently opens channels in the membranes of protoplasts, enabling DNA to enter cells and to be inherited. Even though electroporation is a less efficient means of transferring genes than is crown gall, its advantage is that it avoids the complex biochemical manipulations required to produce inactivated Ti plasmids that are capable of transferring DNA but are inactive as producers of tumorous crown galls. In addition, electroporation is a more versatile technique than is crown gall, which apparently can be used only on dicotyledonous plants and a few conifers.

Up to this time, the success of plant genetic engineering has consisted primarily of careful demonstrations of the gene-transfer principle with model experimental plants.

A salt-tolerant biotype of Lycopersicon cheesmanii *Riley (left foreground), a species of tomato endemic to the Galapagos Islands of Ecuador. Of some fifty-five biotypes collected from the shoreline to the highest elevations of the island, only this one was salt tolerant. Photograph by Charles M. Rick. Courtesy of the photographer*

Less emphasis, therefore, has been placed on the kinds of genes that are being manipulated or, for that matter, on the plants that are being transformed. Tobacco plants, for instance, have been produced that are resistant to the medicinal antibiotic kanamycin, but this characteristic has no obvious agricultural value. Nonetheless, experiments such as these are significant in setting the stage for important advances in the future. Because of the progress that has already been made, it now appears theoretically possible that practically any characteristic of a plant could be transferred to any other plant, provided the characteristic can be defined at the gene level. Once the gene (or genes) involved is identified, it can be isolated and purified from the donor plant. Then, it can be incorporated by means of gene-transfer technology into the genetic makeup of a recipient cell. Finally, tissue-culture methods involving phytohormones can be used to regenerate plants with the new characteristic, starting from single, genetically modified cells.

What kinds of characteristics will be exploited by plant biotechnology? Obviously, the possibilities are numerous, some in the near future and others in the long term. One promising approach involves the development of herbicide-resistant plants. The Monsanto Company in the United States, for example, is attempting to produce soybean cultivars resistant to glyphosate (trade name, Roundup), an agriculturally important, non-selective herbicide. Significant, practical gains could be realized from this research project in the next ten years. Other bioengineering objectives, on the other hand, are farther in the future. Disease-resistant or cold-hardy plants probably won't be produced for another twenty-five years, and effective transfer of nitrogen-fixing abilities are at least fifty years away, even according to the most optimistic observers.

At this very moment, several rare and endangered plants undoubtedly harbor genetic characteristics that would be of tremendous potential significance to biotechnology. Many of them probably have not even been discovered yet; some, in fact, may become extinct before their value is appreciated. Fortunately, at least a few valuable endangered plants are the subject of intense conservation efforts.

Potential Economic Uses for Rare Plants

The following paragraphs describe a few of the potentially valuable characteristics or chemical compounds that endangered species might someday contribute to human welfare through genetic-engineering techniques.

Pharmaceuticals. It has been estimated that, on the average, for every one hundred twenty-five plants closely examined for valuable chemicals, one eventually will become an important source of prescription drugs. Since about two thousand plants are expected to become extinct in the United States alone by A.D. 2000, one pharmaceutically significant species will be lost every year for the next fifteen years. Conservation measures, of course, could dramatically change this serious possibility.

Oilseed Crops. Long-chain fatty acids from plants are used as lubricants in steel production and to make plastics for gear wheels and electrical insulation. Although these fatty acids currently are obtained from imported rapeseed (*Brassica* species) oil, researchers with the United States Department of Agriculture are actively pursuing work with other potential sources. One of these, *Limnanthes alba* (meadowfoam), is a rare and endangered species native to northern California. Research with this plant currently focusses on the development of suitable parent strains for seed production and on possible economic uses of the seed oil.

Salt Tolerance. Lycopersicon cheesmanii is a rare species of tomato found only on the

Potentilla robbinsiana *Oakes, the dwarf cinquefoil, an endangered species endemic to the White Mountains of New Hampshire. Known only from the Monroe Flats on Mount Washington,* Potentilla robbinsiana *is adapted to one of the harshest environments of North America. Photograph by Bruce A. Sorrie.*

shores of the Galapagos Islands in the Pacific Ocean. A variety of this endemic species thrives in a coastal habitat barely five yards from salty ocean water. At the University of California–Davis, researchers have been working for nearly ten years on *Lycopersicon cheesmanii* to evaluate its salt-tolerance characteristics at the biochemical level and to incorporate the genes involved into commercial tomato varieties. If this work is successful, not only will it improve the vigor of tomato plants in agriculture, it should extend the range of soils and irrigation practices that can be used to grow tomatoes, thus increasing growers's flexibility in producing one of the most important crops in the United States.

Cold Hardiness. The dwarf cinquefoil, *Potentilla robbinsiana*, has been listed as a Federally endangered species for only the past five years. As a native inhabitant of the alpine regions of Mount Washington in New Hampshire, this endangered rare member of the rose family (Rosaceae) displays an extraordinary degree of cold tolerance, surviving, as it does, in one of the harshest environments of North America. Because of this, *Potentilla robbinsiana* could be of tremendous value as a source of genes for improving the cold hardiness of commercially valuable species of Rosaceae, such as strawberries, raspberries, and apples.

These examples illustrate only a few of the plant characteristics that might be exploited in biotechnology. Science has only just begun to appreciate the treasures that exist on a global scale in the world's flora. If one keeps this important fact in mind and recognizes that technological advances depend on setting long-term goals as well as on using integrated approaches, it is easy to see how crucial plant conservation is to the future. As more is learned, the value of plants—even rare and endangered species—becomes more and more evident.

Sources

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