GMOs — A Crossroads for the Turfgrass Industry

Traditional breeding methods have brought turfgrass a long way. Is biotechnology now the path to follow?

BY DR. MIKE KENNA

The turfgrass industry is entering the century of biotechnology. Biotechnology refers generally to the application of a wide range of scientific techniques to modify and improve plants and animals of economic importance. In the broadest sense, traditional biotechnology has been used for thousands of years for the improvement of agricultural plants. However, the new molecular methods available to turfgrass scientists will help produce new cultivars with exciting improvements that would be difficult to achieve with traditional breeding methods.

TRADITIONAL PLANT BREEDING METHODS

Traditional breeding methods exchange genes by crosses between the same or closely related species. Depending on the starting point and what trait is meant to be improved, this effort can take considerable time to achieve the desired results. For example, cold-hardy, fine-textured, seed-propagated bermudagrass took 20 years to achieve. In contrast, improving gray leaf spot resistance in perennial ryegrass took only about five years.

Frequently, the characteristics of interest do not exist in any related species. In Figure 1, the progress that can be made with traditional breeding methods is illustrated. The vertical axis measures the frequency of individuals with the desired trait and the horizontal axis measures the level of negative or positive response.

When progeny from a cross are plotted on the graph, it produces a bell-shaped curve. The curve with the dashed line is the original population. The best progeny plants are selected from the tail of the bell curve and crossed to produce the next generation of offspring. After several cycles of selective breeding, significant improvement can be made for the trait of interest. This improvement is indicated in the bell curve with the solid line. The average performance of the improved population is better than the original population.

NEW PLANT BREEDING METHODS

In the 1970s, a series of advances in the field of molecular biology provided scientists with the ability to readily move DNA between more distantly related organisms. Today, this recombinant DNA technology has reached a stage where scientists can take a piece of DNA containing one or more specific genes from nearly any organism and introduce it into a specific plant species.

The application of recombinant DNA technology frequently has been referred to as genetic engineering. An organism that has been modified, or transformed, using modern techniques of genetic exchange is commonly referred to as a *genetically modified organism* or *GMO*. However, the offspring of any traditional cross between two organisms also are "genetically modified" relative to either of the contributing parents.

Turfgrasses generally are transformed using the biolistic gun. External DNA is coated on the surface of small particles of tungsten and the particles are physically shot into plant cells. Some of the DNA comes off the tungsten particles and is incorporated into the DNA of the recipient plant. Those recipient plant cells can also be identified and grown into a whole plant that contains the foreign DNA.

Plants that have been genetically modified using recombinant DNA technology to introduce a gene from either the same or a different species also are known as transgenic plants. The specific gene transferred is known as the transgene. Not all GMOs involve the use of cross-species genetic exchange. For example, recombinant DNA technology also can be used to transfer a benefit between different varieties of the same species or to modify the expression of one or more of a given plant's own genes.

ADVANTAGES OF GENETIC ENGINEERING

The application of recombinant DNA technology to facilitate genetic exchange in plants has several advantages over traditional breeding methods. The exchange is far more precise because only a specific gene that has been identified as providing a useful trait is being transferred into the recipient plant. As a result, there is no inclusion of ancillary, unwanted traits that need to be eliminated in subsequent generations, as often happens with traditional plant breeding.

Application of recombinant DNA technology to plant breeding also allows more rapid development of varieties that contain new and desirable traits. Further, the specific gene being transferred is known, so the genetic change taking place also is known. This is often not the case with traditional breeding methods, where the fundamental basis of the trait being introduced may not be known at all. Finally, the ability to transfer genes from any other plant or organism into a chosen recipient plant means that the entire span of genetic capabilities available among all biological organisms has the potential to be genetically transferred.

A comparision of traditional breeding and genetic engineering is illustrated in Figure 2. On the left, parents are crossed to move resistance genes into a commercial cultivar. Resistant progeny are backcrossed for seven cycles to get back to the original cultivar with the resistance genes. This process may take 8 to 10 years or more. On the right, genetic engineering can precisely incorporate the resistance gene into an existing cultivar. In fact, this diagram shows how three different resistance genes are inserted into a commercial cultivar. The amount of backcrossing would be greatly decreased and the time needed to improve disease resistance would be reduced.

WHY USE BIOTECHNOLOGY?

Whether scientists use traditional breeding or genetic engineering methods, the goal with turfgrass is to reduce pesticide use and make efficient progress on complex traits such as temperature or drought tolerance. A combination of new and old technology also will help increase the adaptation of our turf species to a wider range of environments and help conserve natural resources by reducing inputs such as water and fertilizer.

BENEFITS AND RISKS

One way to look at the benefits and risks of a GMO is to consider the *inherent* and *transcending* risks of the technology. Technology-inherent risks include safety issues and the behavior of a biotechnology product in the environment. For example, gene transfer, weediness, trait effects, genetic and phenotypic variability, expression of genetic material from pathogens, and worker safety need to be considered. In the United States, this process is regulated by the USDA Animal and Plant Health Inspection Service (APHIS), the Food and Drug Administration, and the U.S. Environmental Protection Agency. It is a very rigorous process.

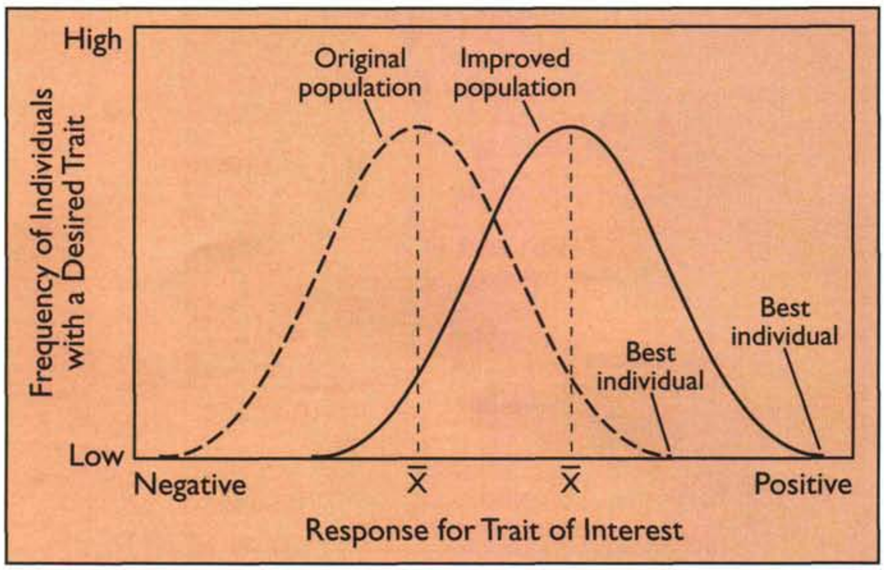

Figure 1. Through traditional breeding methods, progress can be made to improve the frequency of desired traits.

Technology-transcending risks deal with the political and social context in which the technology is used and how these uses may benefit or harm the interests of different groups in society. Will the technology increase the gap between rich and poor countries or small and large companies? Will the technology decrease biodiversity? Will it impose a burden on regulatory systems? And how will the intellectual property issues be managed? No single person, company or government agency can foresee all the benefits and risks, and that is why the process must be transparent and allow time for public comment and debate.

ROUNDUP-READY™ CREEPING BENTGRASS

The USGA Turfgrass and Environmental Research Program was involved early in the development of genetically modified grasses. In 1989, the USGA funded a project at Rutgers

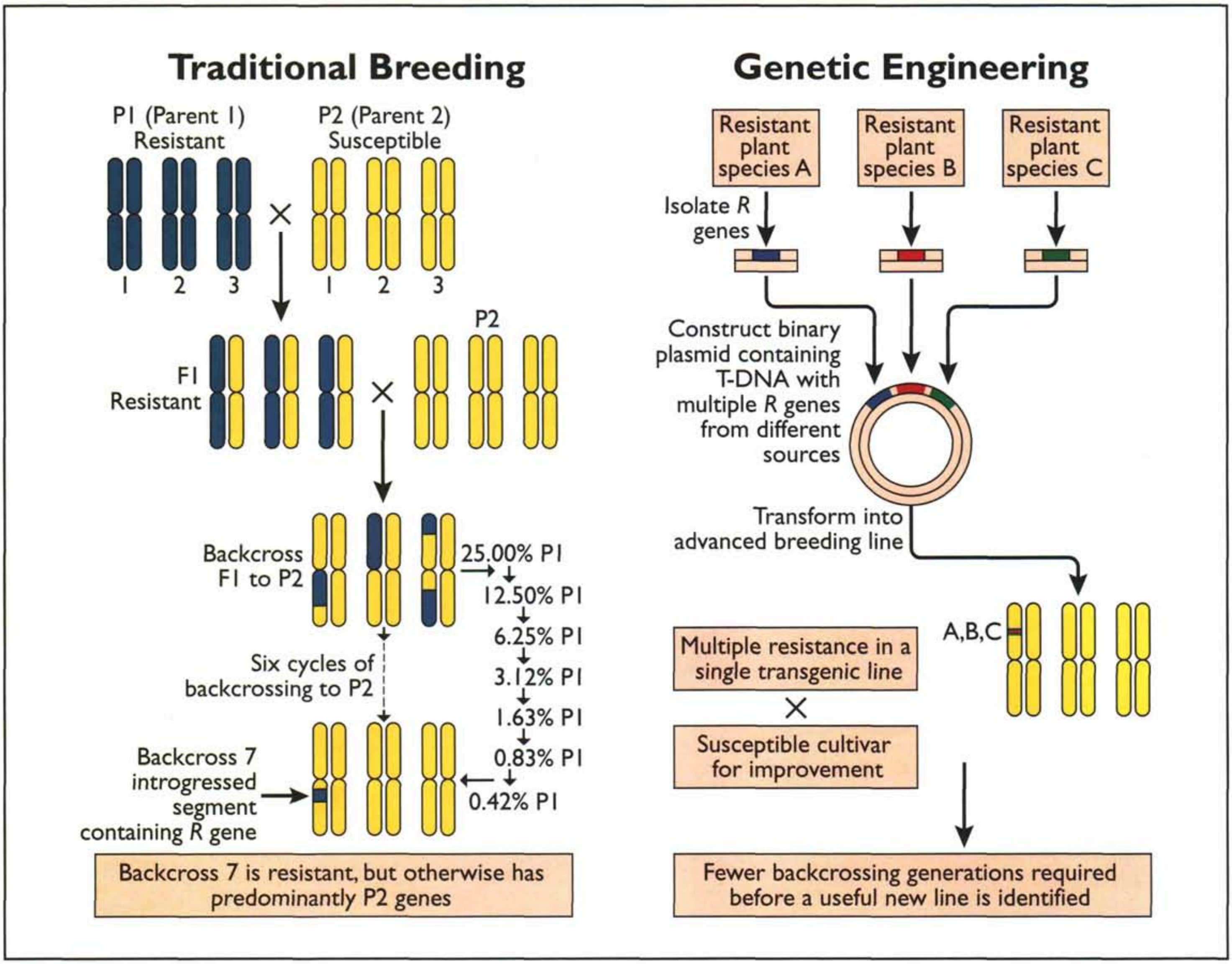

Figure 2. Traditional breeding methods for introducing one or more genes require making crosses, usually within the species (left), followed by a series of backcrosses to return to an acceptable cultivar. A decrease in breeding time and effort is possible using genetic engineering by inserting genes directly into the callus cultures of useful turfgrasses (right). Genetic engineering also allows genes from very different species to be incorporated into turfgrasses.

Adapted from Buchanan, Bob B., et al., 2000. *Biochemistry & Molecular Biology of Plants.* Am. Soc. of Pl. Phys., Rockville, Md.

University to determine if endophytes could be introduced into creeping bentgrass. The thought was that this would increase insect resistance. There was some discussion about using genetic engineering to achieve this goal. By 1991, the prospect of an endophyte for bentgrass seemed remote, so the project direction turned toward herbicide resistance. In 1994, a successful transformation system for bentgrass was achieved and there were a few scientific papers published on the techniques.

In 1996, the Scotts Company became interested in using biotechnology to improve grasses, and by 1998, Scotts acquired 80 percent of Sanford Scientific. This gave Scotts the right to use the biolistic gun for turfgrass and ornamental plant genetic transformation. In 2003, the Scotts Company and Monsanto petitioned the USDA/APHIS to deregulate a GMO bentgrass with glyphosate tolerance, and there was a lot of excitement, but there also were concerns.

In 2004, APHIS decided to conduct an Environmental Impact Statement or EIS. This was the first time APHIS took such an action, and the primary reasons listed were that bentgrass is an open-pollinated, perennial species and that there was concern for gene escape and weed problems. Also in 2004, the EPA pollen study determined that pollen moved farther than scientists originally believed. Last year, in 2005, public hearings were held; in 2006, APHIS will complete the draft EIS, set a time for public comment, and make a final decision at the end of the year.

Roundup-Ready™ creeping bentgrass would be a wonderful addition to the golf course industry, and it is hoped that the USDA/APHIS will approve the deregulation of this particular GMO. I see no reason to delay the release of this technology, especially in light of the APHIS decision to deregulate Roundup-Ready™ alfalfa, which also is an open-pollinated, perennial crop.

The turfgrass industry has been mistreated in the press. Herbicide tolerance would allow our industry to control unwanted weeds and, in the long run, reduce our overall pesticide use. This has already been proven in agricultural crops, and it also would be true for the turf industry. There is a constant stream of anti-genetic-engineering, anti-golf, anti-turf stories in the mainstream media that is quickly picked up by the so-called organic movement that wants to prevent the use of GMOs as well as pesticides.

WHAT IS THE FUTURE?

The USGA will continue to support traditional plant breeding efforts to improve both warm- and cool-season species for several important characteristics. For example, significant improvements in bermudagrass cold tolerance, spring green-up, and resistance to spring dead spot will help our industry to reduce pesticide and water use. The genes involved in heat tolerance mechanisms of bentgrass will be identified in *Agrostis* species selected from thermal soils near hot springs in Yellowstone National Park. Can we move these genes into creeping bentgrass using traditional breeding methods, or will genetic engineering be needed? How will this trait be regulated? Dollar spot resistance will be developed in creeping bentgrass by moving resistance genes from colonial bentgrass, as well as improving dollar spot resistance by selective breeding of resistant genotypes.

The difference in all of these studies is that we are using the new molecular tools to understand the function of the genes that produce the desirable characteristics, whether it is cold or heat tolerance, or resistance to disease. USGA-supported scientists can now locate where the genes are on the chromosomes of our various turfgrass species using genetic linkage maps. There is an expanding tool kit of molecular techniques that allow scientists to understand how genes function in plants, and this information will be used to develop improved cultivars with or without the need for genetic transformation.

Turfgrass scientists also will benefit from the millions of dollars spent on cereal grass genomics. The beauty of Mother Nature is that she does not reinvent the wheel; she only rearranges it a bit. The genes in rice, sorghum, maize, wheat, and oats are all very similar, and the chromosomes of these species also have similarities. Turfgrass scientists will be able to capitalize on what is already known in the cereal grasses so improvements can be made in our important turfgrass species as well.

SUMMARY

In the broadest sense, biotechnology has been around for a long time. Genetically modified organisms or GMOs can be produced in many of our turfgrass species that we use on the golf course. This method is more precise, avoids unwanted traits, and will enable faster improvements. Functional genomics will help us use information from the cereal grass species to more efficiently breed grasses in concert with traditional breeding programs. With GMOs there is a defined regulatory process to examine the benefits and risks, but there also are political and social implications to be considered. In the case of Roundup-Ready™ creeping bentgrass, it is my hope that the USDA-APHIS makes the right decision and allows the turfgrass industry to step forward into the 21st century of biotechnology. Regardless, GMOs are here to stay!

The biolistic gun has been used in the lab to transform turfgrasses. External DNA is coated on the surface of small particles of tungsten and the particles are physically shot into plant cells.

REFERENCES

Lee, Lisa, Cynthia L. Laramore, Peter R. Day, and Nilgun E. Tumer. 1996. Transformation and regeneration of creeping bentgrass (*Agrostis palustris Huds.*) protoplasts. Crop Science. March/April. 36(2):401-406. TGIF Record #37365.

Persley, Gabrielle J., and James N. Siedow. 1999. Applications of Biotechnology to Crops: Benefits and Risks. CAST Issue Paper, Number 12, December 1999, p. 1-9. Ames, Iowa.

Wipff, Joseph K., Crystal Rose Fricker, Crystal Rose. 2000. Determining gene flow of transgenic creeping bentgrass and gene transfer to other bentgrass species. Diversity. 16(1&2):36-39. TGIF Record #67653.

United States Department of Agriculture – Animal and Plant Health Inspection Service (USDA-APHIS). 2005. Environmental Impact Statement; Petition for Deregulation of Genetically Engineered Glyphosate-Tolerant Creeping Bentgrass. Docket No. 03-101-4, Federal Register 70(68):18352-18353.

DR. MIKE KENNA *is director of Green Section Research, based in Stillwater, Oklahoma.*