RESEARCH

Genetically modified plants: Problem or solution?

Research reveals promise, protesters emphasize problems.

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KEY POINTS

- Today's transgenic modification techniques allow faster development of new plant varieties than traditional breeding methods permit.
- Transgenic modifications allow scientists to take desirable traits from animals, microorganisms and plants and impart them to other organisms, including turfgrasses.
- Resistance to salts, disease, heat and cold, insects or herbicides could be enhanced in turfgrasses by transgenic modification.

Genetically engineered crops and the debate over their use have produced promises of plenty and predictions of plague:

- Researchers say plastics and antibiotics can be produced in crop plants.
- Health experts explore delivering vaccines in bananas to children.
- Florists and gardeners await the first blue rose.
- Lexicographers wrestle with new words such as "Frankenfoods," "Farmageddon" and "Farmaceuticals."
- Protesters dress as monarch butterflies and are tear-gassed and arrested at World Trade Organization meetings in Seattle.
- Vandals strike a private seed research farm in Oregon.

This controversy has implications for everyone, and the questions are confusing and complex. Are the health and environmental risks serious? How will genetically engineered turfgrasses change turf management and the game of golf? Is this technology really a major departure from traditional breeding activites?

Limits of breeding

In conventional plant breeding, natural reproduction is manipulated by researchers to produce a more desirable outcome than nature alone might provide. For example, improved bermudagrass varieties such as Tifgreen and Tifway were created by breeding common bermudagrass (*Cynodon dactylon*) with African bermudagrass (*C. transvaalensis*). The bermudagrass varieties that resulted contained superior genes from both parents: Common bermudagrass contributed its aggressive growth habit, and African bermudagrass contributed finer texture, increased density and pest tolerance. The process also eliminated some undesirable genes.

Yet despite the tremendous progress that plant breeding has produced, there are some serious limitations:

- In conventional breeding, gene exchange is typically possible only between closely related organisms. Bentgrass and bermudagrass cannot be bred with one another. Therefore, breeders cannot access most beneficial traits in the plant and animal kingdoms.

- Breeding projects take many years to produce improved varieties, and there is no guarantee an ideal variety will be produced at all. Each plant contributes multiple characteristics — most of which do not interest the breeder.
- Among the scores of unique offspring are many undesirable new plants, and chances are low that all of the parents' desirable qualities can be found in one plant. The only way to increase the odds of breeding the ideal plant is to evaluate hundreds and thousands of new strains — a time-consuming and laborious process.

Overcoming limitations

Transgenic modification relies on a series of sophisticated short cuts to transfer genes from one organism to another — even between completely unrelated organisms. Scientists at the University of Arizona (5) have identified an antifreeze protein produced by cold-water fish. Using conventional breeding, it would be impossible to transfer the gene from fish to plants. Using transgenic manipulation, however, the fish gene has been transferred into tobacco, and the cold hardiness of the resulting plant is being evaluated.

Similarly, scientists at the University of Toronto announced last year (1) that a salt-tolerance gene from a small weed in the mustard family (*Arabidopsis*) had been identified and transferred to a variety of unrelated plants. Although no turfgrass was among the experimental plants, the possibility exists for developing more salt-tolerant turf varieties.

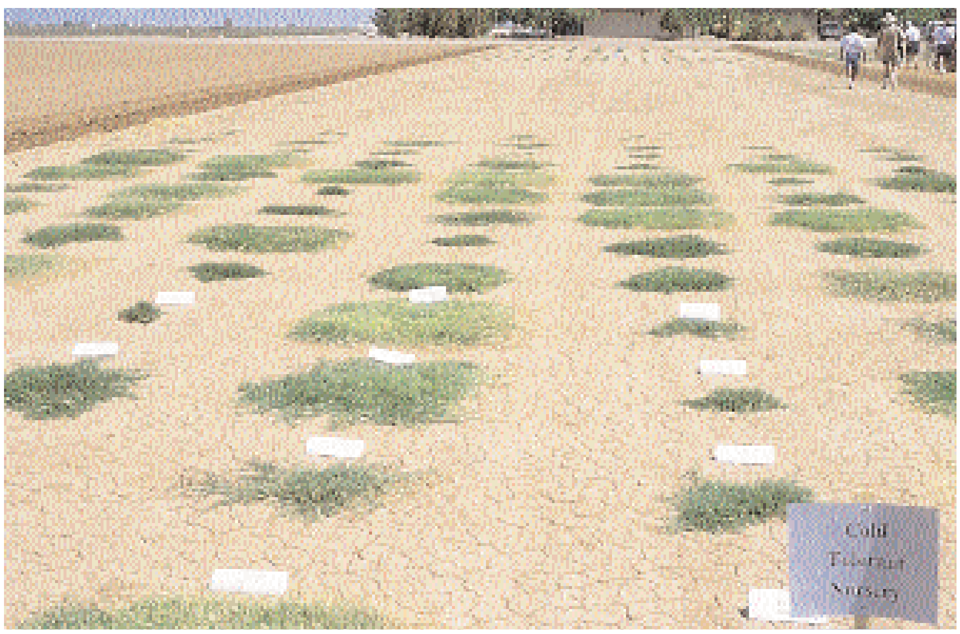
Herbicide resistance

The Scotts Co. may be first to commercialize transgenic turf. Through collaboration with Rutgers University and Monsanto Corp., the company has gained marketing rights for bentgrass that can survive applications of glyphosate (Roundup), even when the turf is sprayed with four times the labeled rate. Although the first Roundup-resistant bentgrasses (commercially available perhaps by 2003) will be for fairways only, greens-quality varieties may follow soon after.

Why herbicide resistance? With current technology, keeping *Poa annua* out of bentgrass greens involves hand labor, herbicide applications, seeding programs and ultimately — once *Poa annua* inevitably wins the battle — the massive costs and downtime of replanting or rebuilding the green.

But with herbicide-resistant bentgrass, a few well-timed herbicide applications per year should keep bentgrass free of all weeds, including *Poa annua*. And because the herbicide resistance is in the genes of each bentgrass plant, these benefits presumably cannot "wear out," or be mown off — the plant should be able to survive herbicide applications in perpetuity.

Sound too good to be true? Well, there are a few potential problems. It is possible (but not inevitable) that some strains of *Poa* will develop resistance to Roundup over time, erasing the benefits of the resistant cultivar and lending *Poa* another competitive advantage. Scotts and turf experts are likely to promote resistance-avoidance programs, recom-



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Using traditional methods, breeders develop cold-tolerant grasses by growing many different types of a few closely related species, then crossing the most tolerant with more attractive types. With transgenic modification, scientists can add cold tolerance to a species by injecting genes from a completely unrelated organism.

mending judicious use of herbicides in combination with other cultural weed management practices.

Another problem may be public acceptance. With any new technology, people are usually wary of new risks. To deal with both the real risks and unfounded fears, we must keep ourselves informed, and keep golfers informed, about both the benefits and the risks of this technology.

Staying informed will also help us to deal with additional advances in turf biotechnology. In the next five to 10 years, expect to see turf modified to resist diseases and insect damage, to survive drought and salinity, or even to remediate soils polluted with heavy metals. The possibilities are truly exciting to contemplate.

Food

Although modified turfgrasses remain in the lab for now, most of us have probably consumed some type of genetically engineered crop during the past few years. Many crops grown commercially (including roughly 50 percent of all corn, soybeans and cotton planted in the United States) have been genetically modified.

- Corn, cotton and potato varieties produce an insecticidal protein originally found in a bacterium — *Bacillus thuringiensis*. Though safe for humans and animals, the protein kills caterpillar and beetle pests after they eat plant tissue.
- Many modified corn, cotton, canola and soybean varieties can survive applications of Roundup.
- Modified papaya and squash can resist infection by diseases, including viruses.
- New canola and soybean varieties can produce oils for use in soaps and processed foods, and to reduce unhealthy polyunsaturated fats.
- Modified tomatoes boast enhanced flavor, storage and processing properties.

Issues

Technical difficulties may be the least of the hurdles that genetically engineered crops face during the next few years. A growing movement of public opposition — in Europe and more recently in the United States — may slow or even halt work on these crops — at least temporarily. The public's concerns cover a large gamut: from religious issues, to scientific questions, to pure, unreasoning fear of the new and unknown.

Ethical issues. Prince Charles of Britain has stated that gene modifications are not just an extension of conventional plant breeding, but instead probe "areas that should be left to God." Proponents of transgenic modifications

For more information

With rapid changes in biotechnology, new developments and issues are constantly surfacing. Several sources of information provide current and reliable updates, as well as relatively unbiased analysis:

- *Science Magazine*'s July 16, 1999, issue is devoted to plant biotechnology, and provides a good technical overview. *Science* is available at almost all public and college libraries.
- The USDA Agricultural Biotechnology Information Center's Web site (www.nal.usda.gov/bic) offers a wide range of information and references on transgenic crops.
- Information Systems for Biotechnology Web site (www.isb.vt.edu) provides documents and searchable databases pertaining to the development, testing and regulatory review of transgenic plants, animals and microorganisms in the United States and abroad.
- The U.S. State Department Web site (usinfo.state.gov/topical/global/biotech/) also provides general information on transgenic crops.

argue that humans have been manipulating plant genetics for centuries. In their view, genetically engineered modifications are just an extension of conventional breeding.

Safety concerns. Many people speculate that altered foods are not being tested rigorously enough prior to market introduction, and may therefore be unsafe to eat. The potential presence of allergens is of particular concern. Still others are concerned about unanticipated environmental damage, such as toxicity to beneficial or protected insects.

The question of whether a "superweed" could arise as a result of gene movement from crops to weeds has received significant attention. This is possible in crops such as oilseed rape (*Brassica napus*) (4) if, for example, pollen from a genetically engineered insect-resistant rapeseed plant fertilized a nearby field mustard (*B. rapa*) weed, perhaps conferring the insect resistance to the weed.

Researchers have proposed a variety of clever solutions, including production of modified crops that contain the new, "foreign" genes in cell components (such as chloroplasts) that are not present in pollen cells (3).

Is regulation adequate? Although modified crops are regulated by a variety of federal agencies — including the U.S. Department of Agriculture — critics claim that not enough is known about the crops to develop an effective testing and review process before commercialization. Many environmental groups are calling for a halt in commercialization of modified crops until more information is available, and even industry groups such as the Turfgrass Breeders Association and the American Society of Landscape Architects (2) have called for stricter regulations on releases of modified plants.

Political and social issues. The continuing consolidation of the agrichemical and crop seed industries puts control of potentially valuable genetically engineered crops into fewer and fewer hands, leading to concerns about inflated seed and food prices, manipulation of supplies and limited accessibility to the improved seeds.

Consumer choice. Consumer advocates are protesting that genetically engineered foods are now commonplace in the supermarket, but consumers cannot necessarily tell which foods are modified and which are not. They are demanding that genetically engineered foods be labeled (federal legislation was recently proposed, but hasn't yet been approved) — an idea that some seed companies are resisting.

Clearly, the future of genetically engineered crops and grasses is largely in the hands of the public. Their concerns are sure to produce restrictions and regulations on future development and marketing of transgenic crops. Yet these products can offer important advantages to the public and to golf course superintendents. Continued research will help us all determine which products offer the greatest benefits with the least risk. ■

Literature cited

1. Apse M.P., G.S. Aharon, W.A. Snedden and E. Blumwald. 1999. Salt tolerance conferred by overexpression of a vacuolar Na^{+}/H^{+} antiport in *Arabidopsis*. *Science* 285:1256-1258.
2. Barbosa, D. 2000. Suburban genetics: Scientists searching for a perfect lawn. *New York Times* July 9, p. 1.
3. Daniell, H., R. Datta, S. Varma, S. Gray and S.B. Lee. 1998. Containment of herbicide resistance through genetic engineering of the chloroplast genome. *Nature Biotechnology* 16:345-348.
4. Hauser, T.P., R.B. Jorgensen and H. Ostergard. Fitness of backcross and F_2 hybrids between weedy *Brassica rapa* and oilseed rape (*B. napus*). *Heredity* 81(4):436-443.
5. Songer, J.G. 1993. Antifreeze transgenes increase cold tolerance and freeze protection. *Information Systems for Biotechnology Report* October.

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