Genetically Engineered Crops: The Problem or the Solution?

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Bottom line: Genetic engineering is a tool that has the potential to dramatically change agriculture, and in so doing to address many of the world's most pressing problems – including hunger, malnutrition, and environmental pollution. In the world of golf course management, genetically engineered turfgrasses that survive attack by insects and diseases, or that are tolerant of herbicides, salts, heavy metals or drought are expected in the marketplace in the near future. However, there are many technical, safety, regulatory, political and even ethical questions that are unresolved. It is imperative to stay educated about this technology so that we can make the most informed decisions possible about its use on golf courses, and in our lives in general.

Plastics and antibiotics produced in crop plants. Vaccines delivered to children in bananas. A blue rose. The introduction of new words such as "Frankenfoods", "Farmageddon" and "Farmaceuticals" into our vocabularies. The planting of genetically engineered cotton, corn and soybeans on approximately 100 million acres worldwide. Protesters dressed as monarch butterflies, being tear-gassed and arrested at the World Trade Organization meetings in Seattle last month.

These are some of the enduring images produced by the use of genetically engineered crops, and by the escalating debate over their benefits and risks. The technology has become so controversial that *Science* magazine named genetically engineered foods as the "Controversy of the Year" for 1999.

The outcome of this controversy has important implications for everyone, and the questions raised are confusing and complex. Can genetic engineering really reduce world hunger through production of higher yielding, increased nutrition crops, as its promoters claim? Are the health and environmental risks really as serious as its critics allege? Should genetically foods be labeled so that consumers can choose whether they want to buy these products? And on a topic of more immediate relevance – how will the use of genetically engineered turf change turf management practices, as well as the game of golf?

It is easy to become overwhelmed by the complexity, strange language and rapidly changing nature of genetic engineering. If you feel this way, you're not alone! But the topic is not as complicated as it seems at first glance. In this issue of *PACE Insights,* we will provide you with some of the basic information that will help you to navigate around this confusing, important and vastly interesting topic.

Conventional plant breeding: an important technology with some important limitations

In conventional plant breeding, the natural process of plant reproduction is manipulated by human beings to (hopefully) produce a more desirable outcome than Nature alone might provide. In its most fundamental form, conventional breeding is based on the principle that crops with improved traits (for example, higher yields, better flavor, improved pest resistance) can be created by selecting plants that possess one or more of the desired traits, and forcing them to breed with one another. If the procedure is a success, the new plants will contain desirable genes from both parents, resulting in a plant with better performance than either parent. For example, improved bermudagrass varieties such as Tifgreen and Tifway were created by breeding common bermudagrass (*Cynodon dactylon*) with African bermudagrass (*Cynodon 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), while at the same time eliminating some of the undesirable genes from each.

The crops that we rely on today for food and fiber were all created using this type of conventional breeding approach. Yet despite the tremendous progress that plant breeding has produced, there are some serious limitations.

1. Conventional breeding is restricted to closely related plants that can breed with one another – the two different species of bermudagrass discussed above, for example. When plants are too unalike, they cannot reproduce. For example, bentgrass and bermudagrass cannot be bred with one another. There will be no offspring, because the pollen of one plant is simply unable to fertilize the other plant. This means that breeders are unable to take advantage of the majority of beneficial traits that are present in the plant and animal kingdoms.
2. Conventional breeding projects usually take many years to produce the desired outcome, and there is never a guarantee that the ideal new

plant variety will be produced at all. This is because each plant contributes a multitude of characteristics – most of which the breeder has no interest in whatsoever. Thus, the majority of new plants produced via conventional breeding are undesirable, and the chances that all of the desirable qualities can be found in one plant is low. 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.

Genetic engineering: overcoming some of the limitations of conventional breeding

Genetic engineering relies on a series of sophisticated short cuts to transfer genes from one organism to another. These short cuts give plant breeders the tools to overcome the limitations to conventional breeding that are described above.

Unlike conventional plant breeding, where reproduction (pollination, fertilization, etc) is required in order to transfer genes from one organism to another, genetic engineering bypasses these complex, and sometimes time consuming processes with a series of rapid steps. Because traditional reproduction is not required, genes can be transferred between completely unrelated organisms. For example, in their attempts to increase the cold hardiness of plants, scientists at the University of Arizona (Songer, J.G. 1993. Plant Molecular Biology, p.377-385) have identified an antifreeze protein produced by marine fish that live in cold waters. Using conventional breeding, it would impossible to transfer the gene for these antifreeze molecules from the fish to the plant, since these two organisms cannot breed with one another (unless you're having some terrible nightmare!). However, using genetic engineering, the fish gene has been transferred into tobacco, and the cold hardiness of the resulting plant is now being evaluated.

Similarly, scientists at the University of Toronto announced just this last August (Apse et. al., 1999) 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 turfgrass was not one of the experimental plants, the exciting possibility of more salt tolerant turf varieties for the future now exists.

Herbicide resistant bentgrass: the first genetically engineered turf

The Scotts Company (Marysville, OH) will probably be the first company to commercialize genetically engineered turf. Through a three way collaboration among Scotts, Rutgers University and Monsanto, the company has gained access to the technology and the marketing rights for bentgrass that is genetically engineered to survive applications of glyphosate (Round-Up), even when the turf is sprayed with four times the labeled rate. While the first Round-Up resistant bentgrass to be released (commercialization is expected by 2002-2003) will be bentgrass varieties bred for fairway use only, Scotts expects that greens quality varieties (with performance similar to the "A" and "G" series) will follow soon after.

If these new varieties perform as expected, greens management practices will take a huge step forward. Imagine being able to maintain bentgrass without the worry, the labor, the cost and the pesticide applications that are now standard operating procedure because of invasion by annual bluegrass – *Poa annua.* With our current technology, keeping *Poa* out of greens involves hand labor, herbicide applications, seeding programs, and ultimately – once *Poa* inevitably wins the battle, the massive costs and downtime involved with resurfacing or re-building of the green. But with herbicide resistant bentgrass, a few well-timed herbicide applications per year are all that should be required to keep bentgrass free not only of *Poa,* but of all weeds. And because the characteristic of herbicide resistance is embedded in the genes of each bentgrass plant, these benefits cannot "wear out", or be mown off – the plant will be able to survive herbicide applications perpetually.

Sound too good to be true? Well, there are of course a few potential problems. First, it is possible (though by no means inevitable) that over time some strains of *Poa* will develop resistance to Round-Up. If this occurs, the benefits of Round-Up resistant bentgrass will be largely erased. To avoid this scenario, it is expected that Scotts will promote resistance avoidance programs, including judicious use of herbicides in combination with other cultural weed management practices. The second issue involves public acceptance. With any brand-new technology, people are usually justifiably wary of the risks. There is only one way to deal with this effectively, we believe, and that is to keep ourselves informed, and to keep golfers informed, on 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 ten years, expect to see turf engineered 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.

What about genetically engineered food?

Moving from turfgrass to edible crops, most consumers are surprised when they learn that they have probably consumed some type of genetically engineered crop during the past few years. Although many of the applications of genetic engineering (such as cold or salt tolerance) are years away from commercialization, there are many crops now grown commercially (roughly 50% of all corn, soybeans and cotton planted in the U.S.) that are genetically engineered including:

- Corn, cotton and potatoes genetically engineered to produce an insecticidal protein from a bacterium – *Bacillus thuringiensis.* The protein, which is safe for humans and animals, kills caterpillar and beetle pests once they eat a small amount of plant tissue. The resulting reduction in the number of insecticide applications made has been one of the benefits of these crops.
- Corn, cotton, canola and soybeans genetically engineered to survive applications of Round-Up. This feature lets farmers effectively manage weeds without the fear of damaging their crop plants. In addition to greatly simplifying weed management programs, seed companies claim that by allowing farmers to time their herbicide applications more effectively, the amount of herbicide used per year should be significantly reduced.
- Papaya and squash engineered to resist infection by plant diseases, including viruses.
- Canola and soybean engineered to produce oils suitable for use in the manufacture of soap and processed foods, and to reduce unhealthy polyunsaturated fats
- Tomatoes engineered to enhance flavor, storage and processing properties.

There's always something! Issues surrounding genetic engineering

Despite their potential, there are many potential barriers to the utilization of genetically engineered crops. Surprisingly, technical difficulties may be the least of the hurdles that genetically engineered crops face during the next few years. Instead, it is a growing movement of public opposition – in Europe and more recently in the U.S., which may slow or even halt work on these crops – at least temporarily. As with most new technologies, the public's concerns cover the gamut – from religious issues, to scientific questions, to pure, unreasoning fear of the new and unknown. Some of the most commonly voiced concerns include:

Ethical issues: Some people object to the process of genetic engineering itself, primarily on ethical grounds. This viewpoint was voiced recently by Prince Charles of Britain who believes that genetic engineering is not just an extension of conventional plant breeding, but instead "takes us into areas that should be left to God". In contrast, proponents of genetic engineering argue that humans have been manipulating plant genetics, via conventional plant breeding, for centuries. In their view, genetic engineering is just an extension of conventional breeding.

Safety concerns: Others object to the products of genetic engineering because they are concerned that the altered foods are not being tested rigorously enough prior to market introduction, and may therefore be unsafe to eat. The presence of compounds that might provoke allergic reactions in highly sensitive individuals is of particular concern. Still others are concerned about unanticipated environmental damage, such as toxicity to beneficial insects (such as the monarch butterfly).

The possibility that a "superweed" could accidentally be produced via transfer of genes from engineered crops to weeds, is a technical issue that has received much attention recently. It appears that this is indeed a possibility for a certain select group of crops -- crops such as oilseed rape that are grown in regions where closely related weeds are also present. If, for example, an rape oilseed plant that has been genetically engineered to be resistant to insects somehow pollinates a nearby weed, the weed could now theoretically produce progeny that can also resist insect damage. This would allow the weed to survive better, to spread and to become a more serious pest. To deal with this problem, researchers have proposed a variety of clever solutions, including production of engineered crops that contain the new, "foreign" genes in the plant, but not in the pollen (Daniell et. al., 1998). The feasibility of this and other approaches has not yet been tested on a broad scale, however.

Is regulation adequate? Although engineered crops are in fact regulated by a variety of federal agencies, including the Food and Drug Administration, the Environmental Protection Agency and the US Department of Agriculture, critics claim that not enough is known about the crops to develop an effective testing and review process prior to commercialization. Many environmental groups are calling for a halt in commercialization of engineered crops until more information is available.

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 accessibility of the improved crops to poor farmers in the developing world.

Consumer choice: Consumer advocates are incensed that genetically engineered foods are now commonplace in the supermarket, but that consumers have no way to tell which foods are engineered, and which are not. They are demanding that engineered foods be labeled (federal legislation was recently proposed, but hasn't yet been approved) – an idea that most seed companies are resisting.

For more information

Staying on top of all of these issues simultaneously would be difficult for all but the most committed, but if you do have questions, it's nice to know that answers are available from a variety of relatively unbiased (no one is totally unbiased!) sources, including:

Science Magazine's July 16, 1999 issue (volume 285, no. 5426) 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 website at **http://www.nal.usda.gov/bic** offers a wide range of information and references on genetically engineered crops.

Information Systems for Biotechnology website provides documents and searchable databases pertaining to the development, testing and regulatory review of genetically modified plants, animals and microorganisms within the U.S. and abroad. **http://www.isb.vt.edu/**

The US State Department information website also provides general information on engineered crops. **http://www.usia.gov/topical/global/biotech/**

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