The Promises, Pitfalls and Ethics of Genetic Transformation of Turfgrasses

By Dr. John C. Stier, Department of Horticulture, University of Wisconsin-Madison

Mankind began genetically transforming plants over 10,000 years ago when two types of a species were planted in close proximity to one another to achieve gene transfer between plants. For the last 300 years we've called this process breeding. Biotechnology offers another means to achieve this end. While not necessarily faster than conventional breeding, laboratory-based genetic transformations become part of the breeding process and allow genes to be introduced into a plant that might normally not be possible (genetic transformation was described in the previous issue of the Grass Roots, Vol. XXX(1).) Once transformed, the genetically altered plants still have to go through field screening trials to ensure the plants grow as expected, seed yield is adequate, and the desired trait(s) is/are passed on to successive generations.

The permitting process.

Genetic transformation of crops is highly regulated by federal groups including the United States Department of Agriculture (USDA), the Environmental Protection Agency (EPA), and in some cases the Food and Drug Administration (FDA). Applications for field testing of genetically modified organisms (GMOs) must be submitted to the Animal and Plant Health Inspection Service (APHIS), a division of the USDA. APHIS conducts an environmental assessment (EA) to determine the potential environmental impact of a GMO. Permits are issued when a Finding Of No Significant Impact (FONSI) is determined. Field tests of certain organisms (e.g, tomato, corn, soybean, etc.) are subject to lesser standards known as "notifications". As of 7 February 2001, there were 6931 notifications and release permits for field tests. This is more than twice as many as existed in 1997 (Johnson and Riordan, 1999).

Sponsors (owners of the GM products) may petition APHIS for deregulation following appropriate field test results. This is a necessary step towards commercialization of the product. To date, fourteen organisms have been deregulated, primarily edible commodities. No turfgrasses have yet been deregulated.

The Promises.

Over 100 permits have been issued for genetic transformation of turfgrass species. Creeping bentgrass was the first species to get a permit (1993) and has the largest number of permits listed (Table 1). Most of the permits were issued for genes involved in drought and salt stress tolerance. As the availability of high water quality and quantity decrease both drought and salt stress issues will become extremely important to turf managers. Heat tolerance genes will allow bentgrasses to be grown across the South and should improve performance in the North during periods of high temperatures. Even more exciting in the short term is the potential for development of dollar spot and brown patch-resistant turfgrasses. As the Food Quality Protection Act and other regulations such as the proposed NR151 rules in Wisconsin (see the President's article in this issue) increasingly restrict fungicide applications, development of disease-resistant grasses will become essential for golf course maintenance. Such an

Table 1. Types of permits issued for field testing of genetically-altered turfgrasses as of 7 February, 2001.

	Bermudagrass	Creeping bentgrass	Tall fescue*	Kentucky bluegrass	Perennial ryegrass
	# permits				
Trait	5	82	4	17	2
Aluminium tolerance		X			
Drought tolerance	X	X		X	X
Heat tolerance		X			
Salt tolerance	X	X		X	X
Glyphosate resistance		X		X	
Sod webworm resistance		X			
Rhizoctonia resistance (brown patch)		X		X	
Sclerotinia/Dollar spot resistance		X			
Growth regulation		X		X	
Genetic markers		X	X		

* This was most likely for forage, not turfgrass, cultivars.

advance will also reduce budget allocations for fungicides.

Glyphosate (Roundup) tolerance is likely to be the first genetically transformed turfgrass product available commercially, perhaps as soon as 2002-2003. Herbicide tolerance has worked well in row crops: in 2000, approximately 60% of the soybean crop in the U.S. carried the gene for glyphosate resistance. Weed control in turf can become a no-brainer: simply spray visible weeds in a glyphosate-resistance turfgrass with glyphosate at any time of the year and the problem can be solved. This allows control of weeds for which there is not a good selective control such as annual bluegrass and quackgrass.

The Pitfalls.

The greatest problem facing the use of genetically modified turfgrasses is a common theme in science—lack of public understanding. In order for GMO technology to be useful, the following issues will have to be addressed sooner rather than later.

Public antipathy and legislation. Perception is reality. Advocacy groups lobby hard to prevent the use of GMOs in our society. Extreme groups go so far as to sabotage laboratories and businesses engaged in research with GMOs. One of the most stunning events occurred on a research farm of Pure Seed Testing, Inc. in Oregon last summer. The Anarchist Golfing Association destroyed greenhouses and field plots on June 5, 2000, causing over $300,000 worth of damage because the company was involved in research using GM turfgrasses (RB, 2000). The AGA opposes turfgrasses because they are grown for profit "and the pleasure of the rich and have no social value". The irony of the case was that Pure Seed had been testing GM turfgrasses to determine the biological and environmental impact of GM turfgrasses. Furthermore, the plants the group destroyed were developed by traditional breeding techniques, not through biotechnology. What the group's actions amount to is eco-terrorism. Of all possible GMO problems, terrorism has got to be the scariest aspect of all.

From a turf management perspective herbicide-resistant turfgrasses could lead to increased reliance on herbicides. This could make turf managers "lazy", allowing them to resort to herbicides to control weeds rather than correct underlying causes (compaction, poor drainage, etc.). Since the actions of any facet of the turf industry are reflective upon the industry as a whole this could reduce credibility of the turf industry. For example, if parks and recreation departments increase their herbicide usage because herbicide-resistant turfgrasses are being used, the public may cry "foul", and golf courses will be looked at in the same light. Increased use of specific herbicides such as glyphosate could lead to cancellation of these products because of public perception and laws such as FQPA which regulates pesticides based partly on the quantity used. While glyphosate's use will likely be limited to spot treatments, FQPA and the EPA does not necessarily use or in many cases have good data in decision-making. When bensulide came up for review under FQPA recently the report published in the federal register assumed the herbicide was used on golf courses across the country for *Poa annua* control; its use actually was largely limited to putting greens in certain geographic regions. Alar, a plant growth regulator once widely used for ripening apples, was cancelled after the public became aware and concerned about its widespread use (Meryl Streep, the famous actress, was involved in Congressional hearings to aid in getting Alar cancelled). Until science, not politics, dictates EPA actions these types of concerns have to be addressed by the suppliers and end users through lobbying and public education.

Development of resistance in natural weed populations. Some concern exists that herbicide-resistant turfgrasses will result in the development of herbicide-resistant weeds. One possibility is that pollen from GM turfgrasses would pollinate wild relatives. While the potential for this exists (Wipff and Fricker, 2000), the problem is mostly an issue in seed production areas. In turf situations mowing largely prevents seedhead formation. Even if hybridization does occur the extent to which it would become a problem is unknown. Weediness is usually a combination of many factors, including competitiveness during vegetative growth, production, dissemination, and longevity of propagules (seed, rhizomes, etc.). It is unlikely a single gene for herbicide resistance could increase competitiveness, and the trait may fail to be expressed in the absence of occasional herbicide application (Johnson and Riordan, 2000). Genes that confer tolerance to biotic stresses (drought, heat, etc.) could potentially increase weediness potential, but turfgrasses require a multitude of inputs in order for them to thrive. Technologies are being developed that can prevent transformed plants from becoming established in unwanted areas. "Terminator" genes can be added to kill a plant unless certain treatments are given. Research is also being conducted to control "promoters", those parts of DNA which determine when a gene will actually be expressed.

Some species have very limited ability to become cross-pollinated:

Kentucky bluegrass, for example, is largely apomictic and cross-pollination is rare; other species such as *Poa annua* are self-fertile and the eggs are not always receptive to pollen blown from another plant. Of greater concern is outcrossing into other turfgrass seed production fields. If pollen from GM turf fertilizes even a few plants in a field which is not intended to be GM, the entire crop may be considered "contaminated". This could interfere with sales to locales or countries which have banned transformed plants. The European and Japanese public are especially anti-GMO.

A greater likelihood for development of herbicide-resistant weeds exists due to natural selection. Herbicide resistance of weeds has been documented for years in agricultural settings. In turf, *P. annua* is probably the most likely candidate to develop herbicide-resistant populations. *P. annua* is a relatively young species with many biotypes and it is quite possible some plants already exist which are naturally resistant to an herbicide such as glyphosate. If glyphosate is used exclusively a glyphosate-resistant population could develop. Unlike other grasses, *P. annua* is capable of forming seedheads at low mowing heights and pollen can be transferred between plants. In Australia, a ryegrass species (*Lolium rigidum*) has already been reported to be resistant to glyphosate (Johnson and Riordan, 2000). Resistant weeds will require alternate control strategies which may be as simple as switching to another herbicide.

One of the most ungrounded fears which is getting great press from the natural and native plants groups is that transformed, non-native species will move into "natural" areas and displace native species. This is unlikely because turfgrasses have been developed to require intensive care: regular mowing, fertilization, and irrigation. Transformed turfgrasses are unlikely to become a problem in conventional row cropping systems because they will quickly be shaded by the crops, the fields are routinely cultivated, and irrigation and fertility are generally limited.

To the end user the greatest problem may be lack of transformed turfgrasses for use. Since genes which are likely to be used in turfgrasses will probably be con-

trolled by only a few companies, transformations will be limited to those varieties owned by those companies or to those varieties owned by companies which will enter into a contractual agreement with the gene-owning company.

The Ethics.

Ethics in science has always been subject to intense public scrutiny. In medieval times persons experimenting with science were deemed necromancers and witches. Conventional breeding of turfgrasses has been occurring for years: how is this different than using biotechnology to transfer genes? One could argue its not "natural" compared to conventional breeding which crosses genes within or between closely related species. Yet for years irradiation has been used to mutate plants, with over 1550 cultivars developed from this "unnatural" process (Rodgers and Parkes, 1995). People's perceptions vary widely. This past autumn I surveyed the advanced turf class students to determine their perceptions on biotechnology in turf. Keep in mind this is a group of well-educated students preparing to graduate, many of whom were in the top percentage of their high school class. The questions and response rates are listed in table 2. While all the students were comfortable with the idea of transferring genes between cultivars and species within a genus, not all were comfortable with genes being transferred between genera within a kingdom. Transfer of genes between plants and animals was unacceptable to 60% of the students. Only 30% of the students were comfortable with a hypothetical transfer of a gene from a plant into a human (some day humans may need to carry genes for chlorophyll production to exist in a crowded world). Ultimately the public determines what practices are ethically acceptable and this depends to a large degree on their state of knowledge.

Table 2. Response of upper-level turf students to questions regarding genetic transformations of turfgrasses, University of Wisconsin-Madison, 2000.

Question	Percent responding with a "yes"
Is it OK to insert a gene from one cultivar into another cultivar?	100
Is it OK to insert a gene from one turf species into another (e.g., Kentucky bluegrass into supina bluegrass)?	100
Is it OK to insert a gene from one turf genus into another (e.g., Seashore paspalum into creeping bentgrass)?	90
Is it OK to insert a gene for drought tolerance from the African lungfish into creeping bentgrass?	40
Is it OK to insert a gene from creeping bentgrass into humans to detoxify pesticide residues (over 50% of the genes are the same in plants and animals already)	30

Conclusion.

Despite public concerns over real and imaginary issues genetic modification of turfgrasses will proceed. It will not solve all problems, and will likely create some additional problems. In the end, it will provide some useful benefits, and the utility of turf and turf management practices will be etched up yet another notch from its humble beginnings centuries ago. What is needed now is a directed effort to gain public acceptance to minimize the public antipathy which is already occurring. It is incumbent on the turf industry to build public relations through education and to demonstrate the utility of GM turfgrasses. It is critical to provide clear answers to questions and concerns from the general public and the turfgrass manager. History shows that societies that embrace new technologies move ahead and prosper, while those that cling to the old ways wither and vanish (Diamond, 1997).

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