Plant Biotechnology: A Global Overview of Problems and Potentials

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INTRODUCTION

In this session on plant biotechnology, I have been given the charge to address the subject on a more global scale. This is not an easy task considering the complexity of not only the science involved but also the diversity of perceptions of the commercialization of that science. My approach is to breakdown the topic into a number of questions, many of which I find are of common concern throughout the world.

WHAT ARE THE COMPONENTS OF PLANT BIOTECHNOLOGY?

One of the oldest commercial plant biotechnology processes, micropropagation, grew out of the need for more rapid and dependable propagation methods. As you all are well aware, micropropagation has been entrenched in commercial plant propagation for more than three decades. Is the wide use of this form of plant biotechnology highly controversial? How many groups have demonstrated for more governmental control of micropropagation? Beyond some fears of increasing monocultures, micropropagation was a part of biotechnology that was commercialized with little negative fanfare.

Another form of plant biotechnology that has been quietly used for years is embryo rescue. Embryo rescue employs microculture techniques to recover viable embryos from seeds that would otherwise be incapable of maturing or germinating. For example, we are using embryo rescue to recover interspecific hybrids of *Viburnum carlesi* and *V. lantana* in a breeding program designed to create a more ornamental and useful landscape plant (Hoch et al., 1995). Again, even though embryo rescue is used to help "create" plants that would not be generated in the wild by "natural" means, it is used without controversy.

Other aspects of plant biotechnology have grown out of the science of molecular biology. Genomics is a part of biotechnology that focuses on identifying the genes that make up an organism. For example, all the genes that constitute the research "guinea pig" and mustard relative, *Arabidopsis thaliana*, have been determined. An even newer form of biotechnology, proteomics, seeks to identify all the proteins of an organism. Genomics and proteomics promise to give us knowledge and tools that will continue to revolutionize biology, including the human organism, and how we use plants.

However, as already discussed by the previous speakers, the most controversial form of biotechnology is genetic engineering. Genetic engineering (GE) entails the creation of new plants by inserting specific genes coding for desirable traits. Unlike all the other forms of biotechnology, GE has gained the most interest of the public and thus is now acting as the surrogate for all of biotechnology. Let's discuss why genetic engineering has become such a controversial part of plant biotechnology.

WHO IS USING GENETICALLY ENGINEERED PLANTS?

The simple answer is “a lot of people”. Since the major introduction of GE crops in the mid 1990s, there has been a steady increase in the number of hectares devoted to growing GE crops (Table 1). The crops grown as GE plants are almost totally agronomic with the greatest percentage of planted GE area being devoted to soybean (Table 2). Although most of the area is in the U.S.A. and Canada, Argentina and China also grow significant amounts of GE crops. Thus GE crops have been rather widely accepted by farmers; in fact, historically, the adoption of this form of plant biotechnology has been faster than comparable rates of adoption of other major innovations in agriculture.

Table 1. Global area planted to transgenic crops (2000 growing season). From James, 2000.

Year	hectares (millions)
1996	2
1997	11
1998	28
1999	40
2000	44

Table 2. Relative global use of genetically engineered (GE) strains of major agronomic food crops (2000 growing season). From James, 2000.

Crop	Total area planted to GE strains (millions of hectares)	Total area planted to crop using GE strains (%)
Soybean	25.8	36
Maize	10.3	7
Cotton	53	16
Canola	2.8	11

Another answer to this question is that only a few companies (especially Monsanto, DuPont, and Novartis) are major players in commercializing plant GE. These companies not only own much of the technology, but they also market the plants and associated products (such as the agrochemicals needed to grow them). This extreme concentration of plant GE in the hands of a few international firms is one the sources of the controversy surrounding GE.

WHY ARE FARMERS USING GE PLANTS?

By far the most common reason to grow GE crops is to utilize herbicide-tolerant plants. More than 70% of all the area devoted to GE crops is planted to herbicide-tolerant plants (Table 3). What is so attractive about herbicide tolerance? One answer is demonstrated by soybean. Previously, up to four herbicides were often used to grow soybeans. Now with GE soybean, only one herbicide, glyphosate or Roundup™, is used. Often only one application is required and unlike previously, the herbicide can be applied at the best time to control weeds without worrying about crop injury. Crop rotation is easier as there is no soil carryover of glyphosate. An unexpected benefit of herbicide-tolerant GE crops has been a wider acceptance and use of minimum tillage because the weed pressure is now so easily controlled by glyphosate that the need for tillage is minimized.

Table 3. The relative global area planted to genetically engineered crops (GE) modified with specific traits (2000 growing season). Adapted from James, 2000.

Trait to GE crops	Total area planted (%)
Herbicide tolerance	74
Insect resistance	19
Mix of above	7
Other (e.g., virus resistance)	<1

The second main reason to use GE crops is for insect resistance. For maize, corn borer was mostly untreated prior to GE corn as the burrowing pest was difficult to impact by insecticides. Now maize genetically engineered with Bt genes effectively controls this pest without pesticide applications. For cotton, GE pest resistance has resulted in more effective control of pests and a marked reduction (measured in millions of pounds of insecticide) in the amount of pesticide applied and in the number of applications necessary for control of all cotton pests. In addition, other non-pest insects, previously impacted by broad-spectrum pesticide applications, are now present in the cotton fields.

Probably the overall primary answer to the question of why GE crops are being used is that it is just much easier to grow soybean, cotton, and maize when using GE plants. Other effects such as less impact on the soil, the surrounding environment, and the farmer’s health are side benefits.

SO WHY IS THE USE OF GENETICALLY ENGINEERED CROPS SO CONTROVERSIAL?

There is no escaping that the use of GE crops has generated an enormous amount of controversy. Groups ranging from medical associations to whole countries have called for moratoriums or bans on the growing and use of GE crops. In a recent survey of the public attitudes in European Union (EU) countries (Gaskell et al., 2000), a number of interesting opinions were highlighted. The use of biotechnology for medical reasons (genetic testing, cures) or to clean the environment was supported, often very strongly, while the uses of GE for food was strongly opposed. The reasons for the public concern about plant biotechnology centered on the technology being “unnatural”.

So are these negative reactions to the use of GE for our foods unreasonable? Many forms of biotechnology, especially GE, are indeed revolutionary. GE has given us the ability to move genes between organisms with unprecedented speed and freedom. A plant breeder is no longer limited by such “natural” barriers as not being able to sexually combine a fish and a plant, a bacterium and a plant, etc. So viewed in the broadest sense, the EU public’s view of GE as “unnatural” is not without merit. GE, genomics, and the impending proteomics are revolutionary in nature. They promise to change our relationship with other organisms in the world (as well as change us biologically). This revolution, as have been all the other major revolutions in the past, can be scary.

The biotechnology industry itself deserves considerable credit for some of the negative perceptions toward plant biotechnology. The first major products of plant biotechnology brought to market were anything but consumer friendly. The traits of herbicide tolerance and pest resistance in agronomic crops directly benefit the growers of these crops and the companies selling the seed and the associated chemicals. How many of you have gone into your local food store and requested soybean or corn oil derived from herbicide-tolerant plants? The emphasis on these agronomic and grower/industry friendly traits has done very little to give the average consumer something in which they can believe. Quite to the contrary, many feel that these technologies have been “pushed” on them without their participation in that decision. Thus it has been remarkably easy for the anti-biotechnology sentiment to take hold in public attitudes toward plant biotechnology.

Another aspect of the industry that leads to mistrust is its monopolistic character. Over the last decade, major consolidations (buy-outs) have been the norm in the industry. Now less than five major international firms control the technology. This control is in the form of ownership of the patents necessary to make the technology work as well as ownership of many of the seed firms distributing the GE plants themselves. Is it healthy to have many of our major food genetic resources tied up in the hands of only a few major international firms? What are the consequences for those growers and nations that cannot afford to pay the premiums to access these genetic resources? Can such large, profit-motivated entities be trusted to make decisions that have environmental and social well-being motives as well as economic benefits? These and other issues just add to the “scariness” of plant biotechnology.

Finally, there are real environmental threats that have yet to be fully addressed by either industry or governmental monitoring agencies. GE pest resistance should be looked at as nothing more than another form of pesticide application. Historically, overuse and abuse of pesticides has always led to the development of pest populations that are no longer susceptible to the pesticides, thus making these agrochemicals much less effective. GE plant pest resistance, if misused, will suffer the same fate. Unfortunately, strategies to control such misuse have not been that convincing.

Other environmental issues are more unique to genetic engineering. The cross contamination of foods with GE products is an obvious example. Most definitions of “organically produced foods” do not allow the use of any form or product of genetic engineering. However, how does one stop pollen moving by wind or insect from GE crops to fields of organically grown food, thus contaminating that organic seed with genes from plant biotechnology? If it becomes desirable to separate GE products from non-GE products, how does one really do that with our huge, interdependent, international commodity markets? Some of these issues become so large and seemingly so insoluble that the tendency is for the public to decide to simply say "no" to plant biotechnology, even though the benefits may be considerable.

WHAT ARE THE POSSIBILITIES AND OBSTACLES FOR THE USE OF GENETIC ENGINEERING FOR THE ORNAMENTAL AND PROPAGATION INDUSTRIES?

I have already addressed this topic in a paper presented at the 2000 Eastern Region, North America I.P.P.S. meeting (McCown, in press). Even though there are exciting potential uses of plant GE for modifying plant form, increasing pest and disease resistance, and controlling fertility of our ornamental crops, major obstacles including unfavorable economics and lack of availability of the technology for ornamental corps are apparent. What ornamental crops have in their favor is that most of the traits that would be engineered into such crops would most likely be "consumer friendly". Thus acceptance and even proactive demand for GE ornamentals may offer an exciting alternative to what has occurred with agronomic food crops.

In utilizing plant biotechnology, the ornamental and propagation industries would be wise to not make the same mistakes that have been so resplendent in the use of GE for agronomic food crops. In particular, GE projects should include an environmental analysis of the product before the project is begun. In such an analysis, questions of the impact of gene escape and the consumer friendliness of the final product should be of paramount importance. In doing such "do-diligence", our industry can continue to be viewed as the "green industry".

LITERATURE CITED

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