Genetic Engineering of Horticultural Crops: Potential Versus Reality©

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INTRODUCTION

During the last decade as biotechnology has become more commonplace, horticultural businesses and industry associations are increasingly being approached with propositions that they support projects that involve genetic engineering. Although most often the basic science that is being proposed is sound and of practical value, what often is missing is a realistic appraisal of the total framework, both economical and political, which will determine the ultimate success of the project. My goal in this paper is to offer some perspectives that may be useful in such situations. Although the emphasis will be ornamental crops, the ideas are applicable to most any crop. The opinions offered here are totally my own and have been formulated during more than several decades of work in this field.

WHAT IS GENETIC ENGINEERING?

First, let's make sure we understand what we are discussing. This paper discusses only one aspect of plant biotechnology — genetic engineering. There are roughly six steps that are required to produce a genetically engineered organism (GEO):

1) The gene (DNA) coding for the desired trait ("trait gene") must be obtained. In the near future, there will be a vast array of genes becoming available as the rapidly developing science of "genomics" advances.
2) Next the gene is modified or "engineered" using techniques that fall under the general rubric of "molecular biology". Usually during this step, other genes are added to the original trait gene. These additional genes allow this whole process to work with plants and also control the functioning of the trait gene in the final plant product.
3) This modified DNA is inserted into a plant cell, a process called "transformation". Two general methods of transformation include using a bacterium to vector the DNA into a plant cell or to simply mechanically insert the DNA into a cell, the most common process being particle bombardment ("the gene gun").
4) Now the cells containing the new genes must be coaxed to divide and eventually differentiate into whole plants. This is where microculture (tissue culture) plays its lead role.
5) Once plants containing the new genes are recovered, then they must be tested. Such testing usually involves greenhouse studies, to make sure the genes are functioning, followed by field tests. The field tests determine if the new traits are a valuable addition and also make sure that other major traits in the crop have not been inadvertently modified during any of the above steps.

6) Finally, the plant must be marketed. Part of this marketing involves patenting the plant and possibly any of the previous steps that are novel. If the market places a high value on the new trait, then the costs of all this work can be recovered through value-added pricing, royalties, etc. Most likely, there will be multiple patents that apply to each GEO and thus there will be multiple hands in the cash tray.

POTENTIAL OF HORTICULTURAL GEOS

Even with all the hype surrounding biotechnology, the fact that it is a real and fantastic revolution is unmistakable. Much has been and is being written on its potential and I will not repeat that here. Several examples involving ornamental plants should suffice. Increased disease and insect resistances are always high on the list. Pest resistance has been one of the most common traits engineered into agronomic crops so far. The same potential applies to ornamentals, however some of the major problems may not be so important. For example, the worry about pests developing mechanisms to circumvent the engineered resistance is probably much less of a concern with ornamentals than with agronomic crops; ornamental plants are seldom used in the monoculture-type situations that promote the development of resistance problems.

Changing plant form is also emerging as a realistic goal as newly discovered genes become available. In particular, making a particular cultivar that is more pyramidal or more dwarf is increasingly feasible.

One trait, not yet widely available, that excites me is the potential to modify the fertility of an ornamental plant. In particular, making an already highly useful plant selection sterile can have wide benefits. Rhododendrons and phlox that do not produce fruit would eliminate the need for the labor-intensive task of deadheading and thus promote annual flowering while eliminating the generation of unwanted and inferior seedlings. Even more importantly, making an invasive, but highly useful ornamental plant sterile would go a long way to improving the environmental ethics of the landscape industry. A case in point is Norway maple (*Acer platanoides*) which is spreading into urban park woodlands at an embarrassingly rapid rate.

OBSTACLES TO USING GENETIC ENGINEERING FOR HORTICULTURAL CROPS

Too Many Cultivars? Most of the large firms specializing in the genetic engineering of plants have decided that ornamentals are not a viable target. This decision is based heavily on economics. We in the industry, and especially in I.P.P.S., relish the vast diversity of selections and all their differences. However, economically speaking, the best crops as targets for genetic engineering are those where there is a minimum of different selections important in the market. Even though genetic engineering is become simpler and cheaper to conduct, the effort and cost to successfully accomplish all six steps is considerable. Reasonable rates of payback require that a GEO command a significant share of the total market. If there are many important selections contributing to the market, then the likelihood of a suitable economic return on the genetic engineering investment is considerably lessened.

Another aspect of the wide diversity of ornamentals is that it is difficult to decide which few will be engineered. For example, of all the 1000s of successful rhododendron cultivars in the market, which 2 or 3 are to be chosen to receive the sterility gene? On the other hand, if the few cultivars that are engineered become extremely successful and do come to dominate the market, do we really want to move away from diversity and increase the monoculture aspects of our industry? How will such a trend be viewed by those who already criticize the industry for overuse of non-natives, cloning, etc? Such uncertainties contribute to questions about the economic viability of an ornamental genetic engineering project.

There are strategies that nicely circumvent some of the above diversity impediments. For herbaceous ornamentals where breeding can be relatively rapid, genetically engineering parental lines that will then be used to generate an array of selections seems more feasible. Likewise, genetically engineering rootstocks that will be used with a diversity of scions overcomes some of the marketing limitations.

Consumer Acceptance. A recent study (Gaskell et al., 2000) of European public attitudes toward biotechnology found that there was support for uses involving medicine and environmental cleanup while strong opposition was apparent for uses involving food and foodcrops. Public perceptions in the U.S. are moving toward those in Europe. How will genetically engineered ornamentals be viewed? Until this question is answered with a number of widely marketed examples, the uncertainty of consumer acceptance of a GEO is a major obstacle to the full use of this aspect of biotechnology.

Availability of the Technology. One of the more frustrating impediments to the full use of genetic engineering is the array of proprietary rights that envelop most any project. Once an engineered plant is obtained, an assortment of patented technologies can encumber many facets of its birth:

- Each of the trait genes utilized may have one or more patents associated with its use.
- The genetic elements driving the expression of the genes are often patented.
- The process of gene insertion can be patented and may carry certain rights to *any* plants created with that process.
- The total process of transformation and regeneration, if a unique sequence, may carry patent protections.
- The resulting plant itself probably will be patented.

Thus in order to be able to commercially utilize a GEO, agreements must be worked-out with the holders of all the applicable patents. Not only can this be a costly and lengthy process in itself, but also the total royalty streams necessary to meet the multiple demands may drive the market price of the GEO beyond reason. Problems can often arise when most all of the patent holders enthusiastically work-out agreements, but one party denies the right to "use" that patented technology on a commercial basis (although permission to use it on a "research and development" basis may have been granted previously). It is not unusual for "hidden" parties to be uncovered during the full patent search that is done prior to commercialization; such parties may not wish to be "bothered" with this new development involving a minor crop. Further uncertainty arises when there are questions as to who has the legal rights to a particular technology. Rights to many of the "hot" genes and concepts have undergone years of litigation. Even when ownership is clear, the company that once gave permission for use may become part of another larger company, which has no interest whatsoever in your use of their newly acquired patents. In any case, without agreement from all parties involved, the product is essentially dead.

SOME SUGGESTED PRECAUTIONS TO CONSIDER

When asked to consider a proposal to participate in a genetic engineering project, a number of ground rules are valuable during the evaluation:

- Projects looking at only technique development should be viewed with skepticism. The techniques to actually perform genetic engineering on plants are now quite well developed. Thus compared to the 1980s and 1990s, there is less need for projects that just look at perfecting a single step of the six-step process. Any project must be evaluated as to the feasibility and reality of the total process that would be needed to bring the product to commercial fruition.
- No genetic engineering project should be seriously considered (and certainly not begun) *before* all rights to the technologies involved are obtained from the known patent owners and for this specific use.
- Potential genetic engineering projects should include an environmental, economic, and political analysis. Such analyses generally include discussion of questions involving what might happen when the genes escape into wild populations of plants, what is the economic risk (lawsuits) of any release of the genetically engineered plant, and whether the new plant is truly "consumer friendly" or just benefits growers/patent holders.

Although it may seem that these guidelines can strongly squelch innovation and experimentation, there is nothing that more effectively dampens enthusiasm than not being able to use an exciting new product that demanded considerable time and money to generate. Hopefully adhering to guidelines like the ones above can minimize such mistakes.

CONCLUSION

Biotechnology, especially genetic engineering, is an incredible revolution. The opportunities for enhancing and improving our horticultural plants are almost boundless. However, this potential must be balanced by the realities of legal, environmental, and political constraints surrounding the ultimate deployment of such engineered plants. A company or an organization supporting a project without first requiring that these issues be addressed up-front is risking a frustrating failure.

LITERATURE CITED

Gaskell, C. (with 22 others who are all members of the International Research Group on Biotechnology and the Public). 2000. Biotechnology and the European public. Nature Biotech.18:935-938.