Journal of Agribusiness 23,2(Fall 2005):203–205

BOOK REVIEW: Steven H. Strauss and H. David Bradshaw, editors. *The Bioengineered Forest: Challenges for Science and Society.* Washington, DC: Resources for the Future, 2004, xxv + 245pp., $45 hardcover. ISBN 1-891853-71-6.

The Bioengineered Forest presents a compelling and realistic assessment of the current state of tree genetic engineering (GE) technology and challenges it must successfully address before becoming widely implemented. The book contains an updated selection of papers presented at the 2001 symposium on bioengineered tree plantations held in Stevenson, Washington. Its authors include many of the lead scientists in the field, who present wide-ranging scientific, ethical, ecological, and environmental views. The editors themselves are the leaders in genetic tree research. Steven Strauss is a professor of molecular and cellular biology and genetics and the director of the Tree Genomics and Biosafety Research Cooperative at Oregon State University. David Bradshaw is a professor in the Department of Biology at the University of Washington with research interests in the genetic basis of adaptive trait evolution in natural populations. The issues discussed are directly relevant to the *Journal of Agribusiness* audience. Forestry represents a major land use and supplies a major manufacturing industry. It also has begun to embrace modern biotechnology, including genetically engineered trees. Forestry assumes more and more characteristics of agriculture, and there are many similarities between the implementation of the forest and agricultural biotechnologies.

Genetic engineering of trees involves the physical isolation, modification, and asexual transfer of genes. Genes can be manipulated within the same species or manipulated and transferred across species. Without a doubt, the direct manipulation of genetic material makes this the most controversial of forest biotechnology tools. Yet the promise of genetic engineering of trees is enormous.

Genetic engineering of trees and their widespread deployment on plantations can dramatically change the global forestry sector (Sedjo, chapter 3). Faster growth rates will allow us to produce more wood on a smaller land base which, in certain situations, may relieve harvesting pressures on natural forests. Faster growth rates are also important for increasing forest carbon sequestration and mitigating climate change. Genetic engineering will help to lower wood production costs on forest plantations and increase the availability of wood products. Lower lignin-content trees can generate great savings and reduce pollution in paper manufacturing. Herbicide resistance may generate savings of up to $1 billion annually. Moreover, genetic engineering may enable the development of novel forest products that better meet our various needs.

While focusing on production forestry, we should not forget the potential environmental benefits. Genetic engineering may be the only tool that would allow restoring tree species which are largely absent from American forests today, including American elm, Frasier fir, and American chestnut. It will also foster the use of trees for cleanup of polluted soils and waters and for neutralization of harmful chemicals. Genetic engineering may open new areas to forestry where it currently cannot be practiced because of adverse growth conditions, such as high salinity or arid soils.

Despite its vast potential, the commercial deployment of genetically engineered tree plantations is still far away. The reasons for this are numerous, ranging from the technology itself, to the development costs, its perception by a society, and ecological unknowns (Strauss and Brunner, chapter 6). The major research and technological obstacle is the lack of ability to quickly transform and regenerate genetically engineered trees, primarily tissue culture systems that would allow the regeneration of whole trees from single cells containing inserted, desirable genes. In combination with the long growth cycles of trees, this makes research and technology deployment difficult. Further, much work is still required to develop actual commercial crop trees. These difficulties can be overcome through well-designed, large-scale research programs. However, this type of research is extremely expensive, and funding is limited.

As is the case with many other technologies, the success or failure of genetic engineering depends on a range of factors, and the road to the marketplace for genetically modified trees presents many challenges (Doering, chapter 8). The future of bioengineered trees will depend on how the technology is first applied, who benefits, who makes decisions, and society's acceptance. Society will accept genetically engineered trees if they offer greater utility, are designed for environmental safety, and are well tested for ecological impacts. One needs to state clearly the benefits, costs, and risks associated with genetic engineering. Science and technology do not always imply beneficial outcomes, and society has the right to request reliable information about new technologies. There are many process similarities to the commercialization of agricultural biotechnology, and forestry can learn from these experiences.

Environmental safety is one of the major concerns associated with the deployment of genetically engineered trees. These concerns include the risk of altering natural populations of trees and the possibility of major unintended and negative ecological outcomes. It is apparent, however, that as long as genetically modified organisms are evaluated based on their biology rather than their production technology (genetic engineering), the risks are no greater than those posed by organisms existing in nature. For example, genetically modified plants were never found to be more invasive than their antecedents. The risk of gene pollution can be reduced by using exotic species or by controlling flowering and other methods of propagation. Also, human health risks related to genetically engineered trees have not been substantiated. Still, given the long life cycles and the complexity of natural ecosystems, one cannot conclude that these risks are nonexistent. Clearly, these risks are also difficult to assess. While research may provide some answers, current support favors relatively short-term, controlled environment experiments that do not necessarily fully represent the complexity of natural ecosystems. Improved modeling efforts will likely yield some answers. Although these risks cannot be entirely eliminated, they can be managed. Further, since no undertakings are without risks, the decision should be made with respect to what risks are acceptable.

Another major challenge to the rapid development and deployment of genetically engineered trees is the lack of strong economic pressure. While forest destruction is widespread in certain parts of the world, we do not face scarcity in timber supply. Further, should scarcity develop, we are able to substantially increase wood production using classical intensive silviculture approaches that still may be more acceptable than genetically engineered trees. Apart from increasing production, we may limit our consumption of wood products or substitute some wood products with other materials. We can also develop new manufacturing technologies that allow us to use available wood more efficiently, or develop novel wood products to meet our needs while using readily available lower wood grades. The dramatic rise in paper recycling rates illustrates how available wood resources can be used more effectively.

Furthermore, our wood manufacturing technologies were generally developed for tree resources already in place. We have learned how to transform what is readily available into things that can be used for our benefit. Now, the focus would shift to modifying the raw wood supplies as well, which represents a certain change in industrial development patterns. Long production periods and large volumes needed for industrial operations make this transition even more difficult, and would require a change in industry culture and investment policies.

Despite these challenges, the promise and potential of genetically engineered trees is so great that one day they will indeed be used on a commercial scale. And while tree biotechnology has not yet passed the proof-of-concept threshold for either risk or benefit, it eventually will. *The Bioengineered Forest* offers a compelling reading about the complexity of problems remaining to be solved by the genetic engineering of trees before it becomes commercially viable. On a positive note, it recognizes that many of the problems related to genetic engineering of trees can be effectively solved. More importantly, there are actions which can and should be taken today to ensure the introduction of genetically engineered trees is accomplished in a manner that generates the highest benefits to society—both economic and environmental.

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