The Application of Biotechnology to Sustainable Forestry

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Author Henry David Thoreau, well known for his romance with the woods near Walden Pond, had great appreciation for the beauty and majesty of forests. But he also was realistic about the practical value of trees: "They warmed me twice—once while I was splitting them, and again when they were on the fire."

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The challenge of foresters today is to maintain the natural characteristics of forests while meeting society's need for products produced from trees. Forestry products are the third most valuable commodity after oil and gas. Trees supply the bulk of fiber for pulp, paper, packaging and building needs. Some 5,000 products are made from trees. Three billion people depend on wood for fuel. So we must harvest wood. But forests also are an essential component of our ecology. They provide wildlife habitats. They help control erosion. They purify water. They sustain the world's environment by emitting oxygen and sequestering carbon dioxide. And their beauty is unquestioned.

It is, therefore, essential that our forests are managed sustainably for ourselves and future generations. During the twentieth century, wood consumption tripled around the world and continues to grow. The most practical way of preventing this increased demand from further impacting our natural forests is to increase productivity of managed tree plantations.

Silviculture is the agriculture of trees—how to grow them, how to maximize growth and return, and how to manipulate species composition to meet specific objectives. Silvicultural research increased loblolly pine plantation productivity from an average of 10 to 20 tons/acre 40 years ago to 90 tons/acre today on the most productive sites. Advancements in site preparation and selective tree breeding have been the primary contributors to this significant increase. Biotechnology will be another important tool in the sustainable silviculture "tool kit" for stepwise improvements in productivity per acre.

As biotechnology helps to conserve natural forests, it also will give new roles to trees, such as pollution cleanup and restoration of threatened species. It has long been said that people who fail to see the big picture "can't see the forest for the trees." In this case, it is important that we not lose sight of trees' potential by focusing solely on the forest. By improving plantation trees, we can help sustain forests.

How Biotechnology Can Reduce the Impact on Natural Forests

Today, managed tree plantations provide only about a third of the world's need for wood and wood products. The remainder comes from other sources, including natural forests. Clearly, if tree plantations produce more, less will be needed from natural forests.

Genetic research, including biotechnology, holds promise to produce faster-growing trees and to increase the cellulose content of individual trees.

For example, loblolly pine—the major pulp species in the southeast United States—has a rotation of about 25 years. A 5-year reduction in time to harvest would have a tremendous impact over time on total cellulose production per acre. Genetic research, including biotechnology, holds promise to produce faster-growing trees and to increase the cellulose content of individual trees. Eucalyptus, another major source of pulp for paper manufacture, has been manipulated to grow faster through advancements in tree biotechnology.

In the Pacific Northwest, by crossing the eastern cottonwood with the region's indigenous black cottonwood, University of Washington scientists have attained yields five to ten times greater than from trees in the wild. Oregon State University has produced poplar trees capable of reaching 60 feet in height in 6 years.

Biotechnology can also reduce threats to tree health. Research is showing promise in the introduction of traits that confer resistance to pests and pathogens that weaken or kill trees. Improvements through tree biotechnology may also improve weed control, enabling young trees to get a head start over nutrient-robbing competitors. Trees with these traits will improve the competitiveness of the United States forestry industry in international markets for forest products and will improve productivity of lands intended for pulp production.

Other Potential Benefits of Biotechnology

Tree biotechnology promises benefits beyond increased productivity, including:

- Restoration and preservation of heritage trees. Research is underway at several institutions, including the State University of New York, the University of Georgia and the University of Tennessee to develop disease-resistant varieties of important and desirable tree species that are threatened with extinction due to blight. Biotechnology provides the best hope to save and restore species such as American chestnut, American elm, flowering dogwood and various oak species, which have been so important to our culture and the beauty of our cities and woodlands.
- Cleanup of toxic waste and Superfund sites. It may be possible through biotechnology to develop trees capable of absorbing specific toxins from the soil. This has the potential to reduce by millions of dollars the amount of money spent on cleaning up toxic sites. The University of Georgia is among several institutions conducting research with trees for phytoremediation.
- Improvement of water quality. Just as trees can be engineered to absorb toxic metals, they also can be modified to absorb excess nitrogen, which contributes to water pollution and algal blooms in waterways. Rutgers University is pioneering research in this area.
- Biofuels. The US Department of Energy is researching the potential for trees to provide clean, sustainable fuels. One possibility is to convert the cellulose in wood to ethanol as transportation fuel. Biotechnology can play a vital role in producing wood better suited for the production of ethanol, which can reduce our reliance on foreign oil.
- Decreased lignin content for pulping. Biotechnology can reduce the amount of lignin in trees intended for paper manufacture. Lignin—which gives wood its strength—must be removed in the pulping process. Trees that have less lignin or more-extractable lignin are more readily pulped, allowing mills to reduce the chemicals and energy required to purify cellulose (the basis for paper, packaging and many absorbent products) from wood. Thus, pulp mills are expected to better achieve their ambitious environmental objectives while reducing inputs and costs.
- Better lumber. Biotechnology may also produce straighter trees with fewer limbs, resulting in increased production of better-quality lumber.

Continued research in biotechnology may address and solve other issues, such as why some woods resist rot and others do not and why some species are susceptible to insects and others are not. Through this continually expanding knowledge will come advancements that will maximize the value and efficiency of trees.

Techniques Used

While people may think of biotechnology as involving the transfer of genetic material from one species into another, in fact transgenic research is only one of the multiple methods involved. Current applications of tree biotechnology include techniques that identify genes or alleles within a species that contribute important traits. By identifying these genes, researchers can select and breed better genotypes. This work currently is directed towards improving the growth, health and quality of trees grown in plantations. Methods employed include molecular marker-assisted breeding and the selection and asexual propagation of elite trees. These research areas have been applied relatively recently to the genetic improvement of plantation forestry species, with the most advanced applications practiced in eucalyptus plantations in Latin America and Australasia, and in plantations of Monterey pine in New Zealand, Australia, and Latin America. Further research seeks to apply the technology to additional plantation species such as loblolly pine, spruce and poplar species and hybrids.

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Technologies to improve loblolly pine will rely on the development and commercial application of cost-effective mass propagation techniques (such as ArborGen's ArborGenabled® process) for specially selected elite genotypes. Once these genotypes have been identified, they will be the foundation for the introduction of value-added traits through gene-insertion technology. These genotypes, in addition to being the best of their species, will impart the various benefits discussed above, such as wood-quality improvements, disease and stress tolerance, and bioenergy and bioproduct applications. ArborGen currently is focused on faster growth and altered lignin content.

Field Testing and Deregulation

Several institutions, including ArborGen, have made significant progress in introducing and testing genes that improve wood-volume gains as well as in reducing lignin content. These trees are currently in multiple field tests to determine trait expression and to ensure overall tree performance in plantation conditions. ArborGen has multiple field sites for testing trees in geographies and environments in which industrial forestry is practiced for these species. Some of the trees currently under evaluation will be selected for further product development and future commercial sale.

Commercialization will require that genetically engineered trees go through the regulatory process that has a proven track record for agronomic crops, such as soybean, corn and cotton. The regulatory framework has been successful in its current risk-assessment approach in regulating field tests and commercial deployment. The system under which APHIS has regulated biotechnology since 1987 is effective and protective, as evidenced by the fact that more than 10,000 field trials have been done and more than sixty biotech products have been commercialized without adverse effects on human or environmental health.

This science-based approach allows assessment of risk on a case-by-case basis for a particular trait in a particular crop of interest. This approach is equally applicable for many of the new products under development, including plantation trees. The significant knowledge base that already exists for plantation species must be considered in the regulatory process. The academic community will play a critical role in the trial and testing phases of product development.

The regulatory process should be similar to the coordinated framework currently used for agronomic products, which operates on a case-by-case, trait-by-species basis.

Summary

In summary, tree biotechnology will have many environmental and societal benefits. Faster-growing trees, developed through biotechnology, will contribute significantly to sustainable silviculture by diminishing the demand for wood harvested from old growth and natural forest stands. Many other benefits are possible, including restoration of heritage tree species, such as American chestnut and American elm; cleanup of toxic wastes; nitrogen absorption; biofuels; and lignin modification to improve the production of paper. A robust, science-based regulatory system is essential to bring these improvements to market. The regulatory process should be similar to the coordinated framework currently used for agronomic products, which operates on a case-by-case, trait-by-species basis. Biotechnology will help the forestry industry advance its goals of providing wood products for society while protecting the natural forests that provide beauty and essential ecological benefits.