



Biotechnology in Forestry

Considering the Costs and Benefits

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The economic benefits resulting from the introduction of forest biotechnology will be lower costs and increased availability of wood and wood products. Important environmental issues, including rehabilitation of habitats altered by disease and the overuse of natural forests for industrial wood, may also benefit from biotechnology solutions.

Forestry today is on the threshold of promising change as biotechnology is introduced into its operations. Sophisticated tissue cultures for cloned seedlings and genetically modified organisms portend many benefits as more of the world's industrial wood is being produced on planted forests. In many cases biotechnology in forestry is simply an extension of agricultural innovations, such as herbicide resistance. However, biotechnology also has applications unique to forestry, such as fiber modification, lignin reduction and extraction, and sterility, which is an important factor to prevent modified genes from "leaking" into the natural environment.

The economic benefits from the introduction of biotechnology to forestry will be lower costs and increased availability of wood and wood products. Additionally, innovations in forest biotechnology have the potential to address important environmental issues, including the rehabilitation of habitats altered by disease, like the American Chestnut blight, or invasive exotics. Moreover, the increased productivity of tree plantations may free large areas of natural, or primary, forest from pressures to supply industrial wood and thus improve their ability to preserve biodiversity. And as trees are modified to grow in previously unsuitable areas—such as arid lands or saline soils—the new forests could not only produce more wood but also enhance watershed protection and sequester carbon for climate change mitigation.

Some History

The planting of forests for timber began in earnest in the 19th century in Europe and about the middle of the 20th century in North America. Over the past 30 years, industrial plantation forests have become a major supplier of industrial wood, largely because of the higher productivity of planted forests and the higher costs of extracting timber from natural forests under more stringent environmental standards.

The traditional breeding techniques practiced in forestry have followed the model of other agricultural crops. Early improvements in trees involved identification of superior trees with desired traits and attempts to capture offspring having those traits. The planting of genetically improved stock began about 1970. In the 1990s, modern biotechnology, including tissue culture and genetic modification, began to be undertaken in forestry in earnest. As more of the world's industrial wood is being produced on planted forests, the potential benefits from introducing desired genetic alterations into the seedling utilized in planting have become obvious.

Benefits will be found, first, in lower costs of wood production, which in turn will result in lower costs to consumers of wood and wood products. And second, biotechnology in forestry has the potential to address important environmental issues. On the cost side, how-

ever, concerns relate to potential genetic transfers between transgenic and wild trees, and the potential implications for the natural environment.

Biotechnology in Forestry

Biotechnological innovation in forestry falls into three main areas: the use of vegetative reproduction methods; the use of genetic markers; and the production of genetically modified organisms (GMOs), or transgenic trees. Most of the biotechnologies used in forestry today involve vegetative reproduction through tissue culture and molecular marker applications. However, GMOs are also likely to play a major role in forestry. Using techniques adapted from agriculture, selected foreign genes are introduced into the plant genome. In one such approach, specific genes are identified and modified to affect biochemical pathways and the resulting phenotypes. For example, the promise of controlling the lignin—cells that impart strength to the tree's structure but that must be removed in papermaking—depends on the ability to identify and modify lignin genes, thereby altering the amount, type, and form of lignin that is produced in the tree. The ease of gene transformation varies with different species, generally being more difficult in conifers than in hardwoods.

Benefits of Biotechnology

Economic benefits. A distinguishing feature of the introduction of technology is increased productivity—that is, output per unit of input. Alternatively stated, technology can be either cost reducing or yield (output) enhancing. For society, more output for the expenditure of inputs means a societal increase in efficiency. For the consumer, technology typically means that relative prices of the desired good fall compared with what they would have been in the absence of the innovation. Plantation forestry has enjoyed success in recent decades in part because its associated cost-reducing technology has given wood from planted forests a competitive advantage over that harvested from natural old-growth forests. Furthermore, the opportunities for the application of cost-reducing biotechnology to forestry appear substantial.

Tree improvements can take many forms. These include increased growth rates (wood volume yields), improved tree form (straight trunks with minimal branching), and disease resistance. Efforts to improve resistance to disease and pests may target problems common in the growth of particular species or extend the

climatic range of certain species.

Besides ensuring establishment, survival, and rapid growth of raw wood material, tree improvement programs can also focus on wood quality. Some characteristics are valued not for their utility in the final product but for how they affect the production process. In pulpmaking, for example, desirable traits would be the easy breakdown of wood fibers and the removal of lignin during chemical processing. Desired traits also vary by end product. Wood quality may involve one set of fiber characteristics for pulping and paper production and another set of characteristics for milling and carpentry. Paper production, for instance, requires fiber with adequate strength to allow sheets to be produced on high-speed machines, an attribute determined by the wood fiber characteristics. To the extent that the raw material can be customized to meet the requirements of producers, wood values increase.

Environmental benefits. In addition to the direct market benefits, forestry biotechnology could also be used to generate a number of desired environmental outputs and objectives, summarized in Table 1.

One nonmonetary benefit of biotechnology in forestry has been the substitution of plantation wood for that of primary forests, which has reduced commercial logging pressure on natural forests that have value for biodiversity and wildlife habitat. Biotechnology also offers the potential to assist in ecosystem restoration and repair by, for example, saving species that have been essentially destroyed by disease, such as the American chestnut. Similarly, biotechnology may help deal with invasive exotics, which have in many places threatened indigenous species. Modified tree species also prove useful in providing environmental services in areas where trees now have difficulty surviving, such as arid or drought-prone areas and areas with saline soil or frost zones.

Another application of biotechnology involves biological sinks—a potential tool to mitigate the buildup of greenhouse gases associated with global warming. Regions not currently forested could grow carbon-sequestering plantations of transgenic trees.

Costs of Biotechnology

Transgenic biotechnology has become controversial when applied to agriculture and some of the controversy appears to be spilling over to forestry. The controversy centers on a number of issues.

Table 1. Environmental Benefits

Biotechnological innovation	Environmental output
Plantation wood substitutes for wood from natural forests at lower costs.	Pressure to log primary forests can be reduced.
Trees are genetically modified to grow in arid or saline conditions.	Protection forests can be established on degraded lands.
Trees are genetically modified to adapt to traditionally unsuitable sites.	Carbon-sequestering forests can be established on sites previously not suitable for forestry.
Cold-tolerant species of a desired genus are developed.	The range of desirable trees can be extended.

One involves the effects of biotechnology—particularly the introduction of transgenic plants—on human health. The food-safety issue is not generally raised for plants such as trees or cotton, which are not usually a food source. However, cellulose is increasingly being used as a filler in food products, and the food-safety issue could become a concern.

A second issue is the effect of transgenic plants on the natural ecosystem, should there be genetic exchange between domestic and wild populations. In cases where plantation tree species are an exotic, genetic “outcrossing” to the natural environment would not be a factor. Where genetic exchange could be a problem, planting sterile trees or varieties with reduced or delayed flowering would lessen the likelihood of their “escape.”

If modified genes do escape, how serious are the expected consequences and the worst-case consequences? In the case of the herbicide-tolerant gene, the consequences of release into the wild are probably small. Herbicides are unlikely to be applied to most of the natural environment, and where necessary, other types could be used to which the escaped genes do not confer tolerance. In the intermediate and longer term, the herbicide in question will almost surely be replaced periodically in the normal course of product change and development. Thus the presence of that modified gene in the natural environment appears unlikely to constitute any serious environmental problem, either short- or long-term. For genes that affect tree form or fiber characteristics, release into the natural environment is similarly unlikely to provide a competitive advantage in survival and therefore unlikely to have significant or adverse consequences.

However, the consequences could be different if a survival gene is involved. For example, the release into the wild of a gene for *Bacillus thuringiensis* (Bt), which makes a plant toxic to certain pests, could constitute a more serious problem if it altered

the comparative competitive position of wild vegetation in dealing with pests. Ultimately, the seriousness of this problem depends on the probability of the transfer of a survival gene into the wild, the scale of the transfer, and the comparative change in the competitive balance within the natural habitat. To the extent that pests adapt via natural selection to modified genes, however, the long-term impact of the release of the modified gene into the natural environment will be mitigated.

That effect of biotechnology on the pest population brings up another concern. Pests would adapt to genetic pest controls through natural selection, and wild populations would gradually become resistant to the Bt gene, thereby undermining its longer-term effectiveness. The long period of tree growth would likely exacerbate that problem because it would allow insect populations many generations to develop resistance mechanisms. An approach to extend the life of transgenic pest control would be to establish “refugia,” places planted in trees without the Bt gene, thereby diluting the ability of pests to develop resistance through natural selection.

Conclusions

The benefits of biotechnology in forestry go beyond economic advantages—including increased production, lower costs to consumers, and trees modified for easy processing or specific production values—to such environmental benefits as helping to preserve biodiversity and mitigate global warming. But biotechnological innovations also raise concerns about biosafety and the effects of transgenic plants on the resistance of pathogens and on the natural ecosystem, particularly the question of genetic exchange between domestic and wild populations.

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