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BIOTECHNOLOGY in FORESTRY: The promise and the economic reality

Forestry biotechnology promises major benefits for the forest products industry. Getting the economics right is the key to success.

IN THIS ARTICLE YOU WILL LEARN:

- Weyerhaeuser Company's background in forest biology.
- The combination of disciplines needed to produce benefits from forest biotechnology.
- Why manufactured seed is vital to the future of forest biotechnology.

ADDITIONAL RESOURCES:

- For more information on Weyerhaeuser's forestry programs, go to: http://www.weyerhaeuser.com/environment/

Photo: The author with seedlings produced through Weyerhaeuser's biotechnology program. Photo courtesy of Weyerhaeuser Co.

"We will hereby be launching on a program of growing trees." With those words in 1936, executive vice president, Phil Weyerhaeuser, completed decades of work toward sustainable forestry and prepared the Weyerhaeuser organization for a new era of conservation and reforestation. Many people in the pulp and paper industry and many Weyerhaeuser managers and loggers were skeptical. The idea of holding and reforesting land was a departure from industry practice.

In 1937, the company unveiled its "Timber Is a Crop" ad campaign designed to change the prevailing opinions about managing a commercial forest. It soon became the Weyerhaeuser trademark and signified a dramatic shift in how wood products companies managed their land.

Weyerhaeuser Company has had an active research program in forest biology for more than 70 years. The organization takes pride in its expertise in converting technical innovation in the laboratory into valuable commercial practice in the woods.

I am not surprised that people ask when the industry will begin to realize the benefits of biotechnology research. We hear about commercial advances in biotechnology so frequently in agriculture and medicine that we wonder when can we expect to see them in forestry, wood products, and pulp and paper.

WILD TREES

Behind these questions is some impatience. Is biotechnology for forestry only hype? Why is forestry taking so long compared with agriculture and medicine? The first obstacle is that we start with essentially wild trees. Unlike agriculture, our most domesticated stock would have no trouble surviving in the wilderness. Three generations of Weyerhaeuser employees have said "timber is a crop," but we are using only second-generation seed Traditional breeding that incorporates knowledge from the public domain is reaping great rewards. Even relatively "old" technologies such as cloning face tough competition from classical genetics in delivering value. That is not the case in agriculture today where clones are commonplace and genetically modified organisms are on the leading edge.

The second challenge is the value returned for the technical effort expended. In pharmacology, entrepreneurs are driving innovation with expensive products produced in relatively small facilities. Large drug companies pay for the innovations and then bring them to market. The extraordinary value created in the market for health products covers the costs of commercialization.

The forest products industry faces very different circumstances. This industry consists of large, traditional firms fighting for cost-competitiveness in mature product markets. The cost of commercialization must be spread broadly over diverse market segments. The raw material attributes that might delight one segment could be detrimental in others.

Biotechnological innovations may be valuable, but the products themselves are inexpensive per pound. Production of the material uses large manufacturing units that might require expensive process changes to extract the product values. In sum, the potential change in product rev-

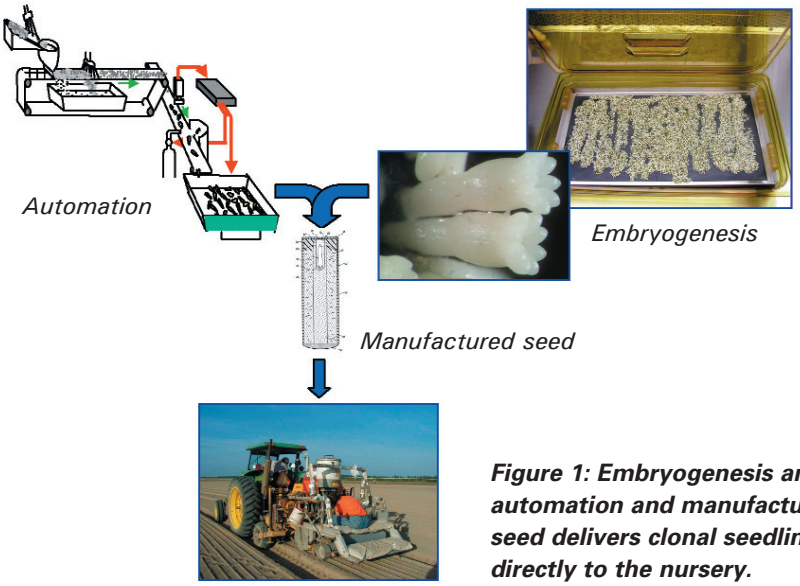

Figure 1: Embryogenesis and automation and manufactured seed delivers clonal seedlings directly to the nursery.

enue is small compared with the technical effort. Making innovation succeed at the scale of a single company is difficult.

The final challenge is time. Conifer genomes are complex. Certain facts of life in forestry stymie the powerful techniques that are leading to advances in human health and agriculture. The human genome work builds on a solid knowledge of physiology. We have been perfecting agriculture for thousands of years. Tree farming is in its infancy. New genetic knowledge is hard to turn into revenue. After the approval of a product, the farmer can gain the margin improvement in the next crop—the forester must wait many years for the harvest.

When will the benefits of biotechnology begin to have an impact on our sector? I believe these benefits will occur only when the combination of somatic embryogenesis, manufactured seed, and the automation technologies linking them produce clonal seedlings at a cost approaching that of orchard seedlings. Before estimating when this might occur, let me review our current thinking on biotechnology.

The breeding and growing of genetically select populations of parents is the foundation for advances in biotechnology. Weyerhaeuser has been breeding loblolly pine since the 1950s. That work is the platform for sophisticated biotechnology applications of the future. Weyerhaeuser has realized an average increase of 7%–10% in the growth rates of our trees from each generation of breeding.

We maintain active breeding and field testing programs in both our loblolly pine and Douglas-fir regions. In loblolly pine, we are entering the fourth generation of breeding. In Douglas-fir, we are entering the third generation. Weyerhaeuser has developed numerous lines of germplasm broadly adapted to the soils and climates on our land base. These possess varied attributes–such as fast growth–and unique wood properties. We have carefully maintained genetic diversity in these programs. This genetic diversity is an invaluable resource base for breeding and cloning applications and represents greater diversity than many other commercial programs.

VEGETATIVE PROPOGATION

Cloning via vegetative propagation has already provided substantial benefits in several forest species that are easily rooted, such as poplar species, some Eucalyptus, such as *E. grandis*, and a few conifers, such as radiata pine and slash-caribaea pine hybrids. These benefits will soon extend to several other conifers via a process called somatic embryogenesis—in vitro enhancement of natural production of embryos from vegetative cells. Following discoveries in the middle 1980s that immature embryos from Norway spruce seeds could be propagated or cloned in culture using somatic embryogenesis, we started a well-funded research and development program using this technology for both loblolly pine and Douglas-fir.

We have increased the scale of our cloning program. Producing clones economically at a large scale is a complex process requiring good biology and good engineering. Although the importance of the biology cannot be overstated, the engineering for handling embryos is at least equally important.

Our research and development program has developed the technology required for the selection, orientation, and delivery of somatic embryos from the bioreactor to insertion into a manufactured seed where germination will occur. This system will be completely automatic so that human hands will no longer be necessary to handle cultures, embryos, or manufactured seeds directly. **(See Fig. 1)**.

MANUFACTURED SEED

Clones carefully selected for growth and wood properties will offer great benefits at harvest. Most foresters and landowners will nevertheless decide which seedlings to buy based primarily on cost. The reality of the long-term investment in growing timber dictates this choice even for large corporations such as Weyerhaeuser.

The importance of up-front cost and cash flow is very important when implementing a regeneration technology—even for forest biotechnology where the rewards at harvest are so promising. Clonal seedlings that cost significantly more than orchard seedlings will become an obstacle to the implementation of any cloning technology. This economic reality cannot be ignored.

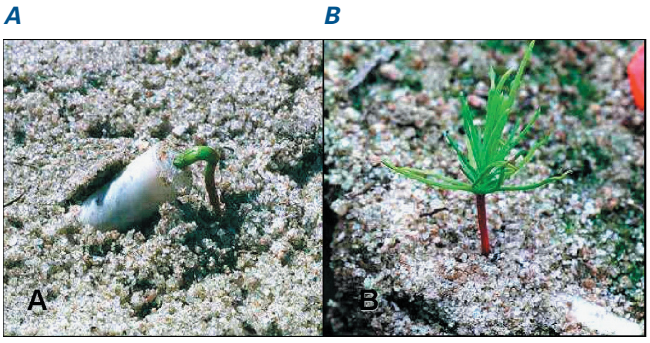

Figure 2: Germination of embryos from manufactured seed. A, root emergence. B, fully emerged seedling.

The biotechnology program at Weyerhaeuser has always been driven by the goal of producing clonal seedlings at a cost competitive with orchard seedlings. The company began its biotechnology research in the early 1970s using the organogenesis technology common in commercial horticulture. The seedlings from this technology proved too costly for large-scale implementation. The company also tested rooted cutting technologies in Douglas-fir and loblolly pine and reached the same conclusion. When it began an embryogenesis program in the late 1980s, the company focused on developing a cost-effective vehicle to deliver somatic embryos to nurseries.

Henry David Thoreau noted in *Faith in a Seed,* "Though I do not believe that a plant will spring up where no seed has been, I have great faith in a seed. Convince me that you have a seed there, and I am prepared for wonders."

Weyerhaeuser uses several approaches to delivery systems. These include germinating low numbers of embryos placed by hand in Petri plates and then transplanting to soil for use as rooted cutting hedges. Other approaches include various forms of sterile or non-sterile embryo germination in soil-based media using various types of automation. Although many of these approaches are creative, the final seedling cost at implementation remains unclear—early testing and scale up phases may be priced much more competitively.

After careful review of cost structures, Weyerhaeuser made a strategic decision that the only way to approach orchard seedlings costs was to create a manufactured seed. A manufactured seed contains a somatic embryo. Nursery sowing equipment can plant it in a bare root nursery that allows the somatic embryo to germinate just like a natural seed. See **(Fig. 2)**.

Because the company started research into this technology very early using creative scientists, we possess a very broad and complete intellectual property position in this area. We have also completed a proof-of-concept test of manufactured seed in a nursery in the Southeast. Our development effort focuses on scaling up automation to deliver millions of somatic embryos through this technology. We are bringing these technologies to fruition through a fully automated set of machinery and plan further nursery testing within the next year.

Our company is receiving questions about whether we will offer our embryogenesis, automation, manufactured seed, and scale-up technology to others or keep it proprietary. Our intention is to sell or license the complete technology package after proving it during pilot production. Like drug companies, we need to recover our R&D costs.

Weyerhaeuser views genetically engineered tree species as a longer-term bet for commercial application. Consequently, the company does not conduct active genetic engineering R&D. Genetically engineered trees may eventually provide benefits to the forest industry. Commercial implementation will require a receptive regulatory environment, more field-testing, and sensitivity to environmental issues.

TODAY AND TOMORROW

We have completed proof of concept testing for somatic embryogenesis, manufactured seed, and the automation required to link these technologies. The challenge is to lower costs and scale up to commercial application. We are beginning pilot scale testing and foresee cost-effective scale technology in a few years as we identify elite clonal selections.

Weyerhaeuser envisions scale production facilities capable of producing over 100 million seedlings of Douglas-fir and loblolly pine per year. These facilities will link somatic embryogenesis to manufactured seed via automation seamlessly into our existing nursery system and produce sufficient seedlings to meet our internal needs. The company believes that growing superior trees on its lands produced through cost-effective vegetative propagation will provide a substantial return to the company.

When sustainable forestry was in its infancy, Weyerhaeuser was a pioneer for its early adoption of concepts such as tree farming. The notion was that grandchildren would reap the benefits of what the company was sowing. With the pace of scientific progress today, the benefits of forest biotechnology are not only for our children and grandchildren; we get to enjoy them, too. **S!**

About the author: *George H. Weyerhaeuser Jr. was elected senior vice president, Technology, in 1998, and is responsible for purchasing, transportation, and research and development. He joined the company in 1978. Weyerhaeuser received his bachelor's degree in philosophy/mathematics from Yale University in 1976, and a Master of Science degree from the Sloan School of Management, Massachusetts Institute of Technology, in 1986. Weyerhaeuser's great-great grandfather was Frederick Weyerhaeuser, one of the founders of Weyerhaeuser Company.*