The Impact of Genetics on Forest Productivity

Robert J. Weir
Director, N.C. State University - Industry Cooperative Tree Improvement Program
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Establishing a pine plantation is hard work and it is expensive. The cost of the seedlings planted is only a small part of the total, yet a poor choice of planting stock can frequently reduce the productivity and value of the resulting plantation and in extreme cases, cause outright failure (Lantz and Kraus 1987). Conversely investing in the best available genetic material can provide the opportunity to grow much greater wood volume and value per acre. Good genetics is a corner stone of the foundation on which improved plantation productivity is constructed.

Genetics improvement of pines began in the southern region of the United States in the early 1950's. Forward thinking leaders of major forest products companies initiated genetics research and development coincidental with the rapid expansion of tree planting programs. To insure a continuous supply of low cost raw material for the large pulp and paper mills in the region, these leaders reasoned that they must replant the thousands of acres of timber harvested each year with seedlings that have the genetic potential to grow rapidly, resist disease infection and produce desirable wood. Now more than 1.5 million acres are planted in the southern U.S. each year and all of these acres are planted with genetically improved tree seedlings. The very first plantation established with genetically improved seedings in the 1960's are now being harvested. The promise of increased yield and higher value per acre is being realized.

The development of genetic improvement in the southern region has largely been accomplished through the efforts of three major tree improvement cooperatives. These organizations are a partnership among universities, forest industry and government agencies. Three cooperative tree improvement programs impact the southern region and the State of Mississippi. The Western Gulf Tree Improvement Cooperative works on the genetic improvement of both loblolly and slash pines. This program is run by the Texas Forest Service, and works in close collaboration with scientists at Texas A & M University. The Cooperative Forest Genetics Research Program, at the University of Florida, has a primary focus on the improvement of slash pine. The N.C. State University - Industry Cooperative Tree Improvement Program is the largest of the three cooperatives, and works primarily on the genetic improvement of loblolly pine. Members of each cooperative provide support for a scientific/technical staff; they breed, test, and select superior trees; develop seed orchards for the production of genetically improved seed; and support research focused on improving the efficiency and benefit to be derived from future genetic improvement work.

The first level of genetic control is to plant the species that survives and grows best, given the soils, rainfall, temperatures and general climate in your area. In the 1950's nearly 80% of all tree planting in the south was with slash pine. The early fast growth of slash pine on a wide variety of sites, along with nearly total resistance to attack from the pine tipmoth, resulted in this species being planted in many areas where loblolly eventually proved to be a better choice. Today loblolly is planted on 80% of the acres reforested (Todd, et al. 1995) and slash pine planting is properly restricted to the wetter "flatwoods" sites in the lower costal plain that commonly have a sandy topsoil over a poorly drained clay subsoil. Loblolly is best suited to the better drained soils in the upper coastal plain and Piedmont, however it does not survive or grow well on very dry, deep sands. Experience has also led to the conclusion that slash pine planted in the interior regions of the south will too often suffer severe damage from cold, ice and snow storms.

Choosing the correct seed source within a species is absolutely critical to the success of pine plantations. Slash pine has very little seed source variation and most any commonly produced source of seed is acceptable in any part of the region where slash pine should be planted. In contrast, loblolly pine has a very wide natural range, extending from Delaware to southeast Texas. Eastern coastal sources of loblolly pine, when moved into Mississippi are usually faster growing yet can be more susceptible to fusiform rust and have lower wood density than sources taken from west of the Mississippi River. Western sources of loblolly may exhibit more drought resistance (Wells 1985). Generally southern sources of loblolly pine will grow faster than northern sources, however care must be taken not to move southern material too far north or cold, ice and snow will cause major losses. Moving seed sources northward from areas with minimum average temperatures that are 5 degrees (F) warmer than the planting site, will give maximum growth gain over local sources (Schmidtling 1992). Seedlings grown from the Livingston parish, Louisiana seed source have exhibited excellent growth rates and strong resistance to fusiform rust when planted over much of the lower gulf coast and south Atlantic coastal areas. Again care must be taken not to move this source too far north.

Genetic improvement of loblolly pine has brought additional gains in volume and value over and above those achieved from use of appropriate wild seed sources. first-cycle seed orchards have produced seed, that when planted in bulk mixture, grow plantations with 8 to 12 percent more volume per acre at harvest (age 25 to 28, depending on site quality) than the trees grown from wild seed (Talbert et al. 1985). The value of genetic based quality improvements (stern straightness, disease resistance, and wood density) are more difficult to assess, but are believed to be at least equal in value to the improvement in growth rate. Second-cycle seed orchards are now producing as much as 50% of the total seed harvest in the region and these orchards are projected to add an additional 4 to 8 percent improvement above the gains from the initial seed orchards established in the early 1960's.

Harvest yields from second-cycle seed orchard bulk seed mixes, the best wind pollinated families, the best specific crosses, and the best clone selected from the best cross, were derived from the reports of Todd et al. (1995) and Frampton and Huber (1995) and are depicted in Figure 1, in terms of cunits (1 cunit equals 100 cu. ft. of solid wood) per acre. Second-cycle seed orchard mixes are projected to produce 29 cunits per acre at harvest which is 16 percent more wood per acre than would be expected from plantations grown from wild seed. With increased seed orchard production, it will be possible to plant seeds from the best wind pollinated families and the yields from such a family block planting system are projected to approach 32 cunits per acre. Developmental work is underway to optimize the techniques needed to mass produce the best specific crosses from parents in second-cycle seed orchards. If this technique were operational today, it is projected that yields could be as high as 36 cunits per acre. Longer term research is focused on developing vegetative propagation methods for the mass production of the best individual tree in the best cross which might yield as much as 40 cunits of wood per acre at harvest.

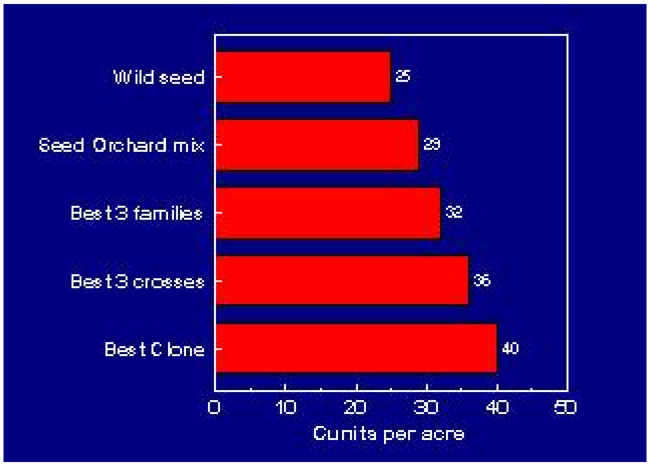

Figure 1. Loblolly pine plantation harvest yields expected from several genetic improvement alternatives.

The marginal cost of developing a tree improvement program for those organizations planting at least 10,000 acres per year is approximately $8 per acre of plantation established. This is true for seed produced as a seed orchard mix and for those planting seed from the best wind pollinated mother trees (a family block deployment system). The value return in today's dollars for the $8 invested will range from $100 dollars per acre to as much as $300 per acre, depending on the level of genetic improvement used. Land owners reforesting limited acreage are not justified in developing their own tree improvement program. However, all southern states and many industries produce genetically improved seedlings for sale to the public. When you buy seedlings grown from seed produced in seed orchards developed from the best available breeding stock, the $8 per acre is part of your seeding costs and depending on the level of genetic development, the benefits depicted in Figure 1 should also be realized.

The cost of more advanced technologies such as mass production of the best 3 crosses, or vegetative propagation of the best clone in the best cross are unknown. The technology for these systems is still being developed as refined through research. Yet the projected increases in yield are substantial and they are expected to offset the costs encountered. Clearly genetic improvement can be a very worthwhile investment.

Cultural treatments can provide yield increases comparable to or greater than those realized from genetic improvement. Response to intensive site preparation, fertilization, and weed control have been well documented (Allen et al. 1990). However, to realize the full benefit from investment in cultural practices such as mechanical site preparation, fertilization and weed control, one must also plant the highest quality genetic stock. Figure 2 depicts the yield response to intensive cultural treatments for families with high, average, and low breeding values. The high breeding value family is projected to have a 7.1 cunit response (age 8 volume) to cultural treatments, while the average and low breeding value families are respectively projected to have a 5.4 cunit and 3.6 cunit response. Clearly to get the most from investments in stand culture, it must be coupled with good genetics. Good genetics and good silviculture must go together.

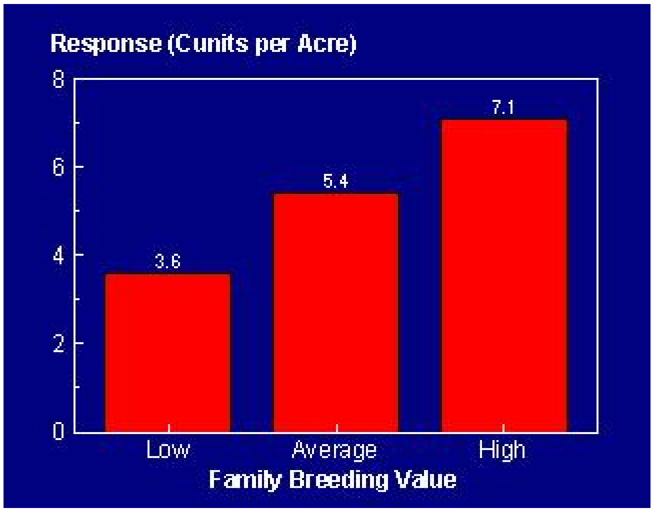

Figure 2. Volume growth response with intensive site preparation, fertilizer, and herbicide treatment for low, average and hight breeding value families.

A substantial investment by the forest science community is being made in forest bio-technology research, in addition to the ongoing research aimed at improving the efficiency of traditional tree improvement, mass production of outstanding specific crosses, and vegetative propagation. Biotechnology research involves basic science investigation at the molecular genetics level and may well revolutionize genetic improvement in the years and decades ahead. Already substantial progress is being made in describing the underlying genetic control of economically important traits. Regions of loblolly pine DNA have been mapped and a marker for a single gene having major control of fusiform rust resistance has been identified (Wilcox 1995). Work is underway to locate additional resistance genes and to understand the frequency of these genes in pine breeding populations. Across the nation various research laboratories are working on lignin and cellulose production pathways, molecular control of growth rate, water stress, herbicide tolerance, reproductive sterility, etc. Understanding the genetic control of economically important traits at the molecular level can have several benefits. Initially it may change the way tree breeders design and develop their breeding programs. Subsequently it may be possible to develop alternative and improved selection methods where it would be possible to select trees in the laboratory based on their DNA configuration rather than in long term field tests. Such systems can only be developed if we have a greatly improved understanding of the genetic control mechanisms for tree growth, wood formation and disease infection.

The ultimate system would involve developing cell cultures from pine trees into which important genes could be inserted, and these altered cells would then be manipulated so as to grow many thousands of tree seedlings, all having an "engineered" change in their genetic makeup. Genetic engineering is certainly a powerful tool that may someday be used to make important and valuable changes in our southern pines, yet substantial barriers exist that prevent the implementation of this technology today. The potential for desirable change is great, yet it may well be a long time before this technology makes a difference in the trees we grow and how we grow them.

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