The Success of Tree Breeding in the Southern US

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Nowhere in the world have tree improvement and silviculture had a bigger impact on forest productivity and value to landowners than in the southern US. The economic impact from almost 60 years of tree improvement in the southern United States has been staggering. For example, over 300,000 hectares are planted each year with seedlings from the breeding efforts with loblolly pine (*Pinus taeda*) by members and staff of the North Carolina State University Cooperative Tree Improvement Program. The present value of continued genetic gains from traditional tree improvement efforts is estimated to be $2.5 billion USD to landowners and citizens in the southern US.

Keywords: Forest genetics; Genetic gains; Breeding; Genomics

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Tree Improvement and Plantation Forestry

The U.S. South can boast of the productivity, quality, and value gains realized from plantation forestry that silviculturists and tree breeders have developed over the past 50+ years. From the beginning of tree improvement programs in the region, the focus has been on selecting, breeding, testing, and planting trees that provide landowners with the greatest return on their investments. The agrarian culture, available land, favorable political and social attitudes towards production forestry, productive soils, and a moderate climate all favor the growth of plantation forestry in the South. The trend in recent years has been for increasing intensity of forest management of these lands. With global demand for timber products increasing at the same time as the area of the world's forests is decreasing, increased productivity of southern plantations has local, regional, national, and global implications. These plantations help provide timber to meet increasing demands while simultaneously reducing the environmental footprint of industrial forestry by growing more wood on less land area.

Foresters in the southern United States are responsible for over 75% of the nation's tree planting, and over 95% of these seedlings are genetically-improved loblolly and slash pines (*Pinus elliottii*). Deployment practices such as planting only the best open-pollinated families or specific crosses to the best sites are resulting in dramatic increases in productivity. Increased resistance to fusiform rust disease, especially in slash pine, has also had major impacts on plantation yields.

All of the genetic gains made to date in operational pine plantations in the southern US have come from traditional tree improvement practices. Tree breeding includes selection of superior-looking parent trees; breeding these candidate trees together and testing their progeny to see which parent trees are indeed superior; measuring the progeny for traits that improve plantation value to landowners (*e.g.* stem size, stem straightness, disease resistance, adaptability, and wood properties such as wood density and bending strength); selecting the best parent trees and establishing them into production seed orchards; managing these seed orchards to produce tons of seed and hundreds of millions of seedlings that are planted on about 500,000 hectares each year throughout the South.

Traditional tree improvement is inherently slow even with some of the new "tricks of the trade" that shorten the time to flowering and crossing from 8-10 years to 3-5 years and reduce the selection age from 10-12 years to 4-5 years. Despite the challenges that we face, genetic gains in loblolly pine over the past 40+ years have been comparable to those made in other crops. Gains in volume production have averaged 5% to 10% per generation over three generations, but the most productive families are 1.5 to 2 times better than the average families. The incidence of fusiform rust disease can be reduced to very low levels by planting the most resistant families on high-hazard sites. The most dramatic gains have been made in stem straightness. Wild or non-improved loblolly pine is naturally crooked. However, improved families have stem straightness comparable to slash pine and even longleaf pine (*P. palustris*) and are routinely used for high-value sawtimber, poles, and pilings. To maintain and continue this genetic gain for decades and centuries to come, breeders maintain a very large and diverse genetic base with over 800 different parent trees being bred in the 4th cycle of breeding in the NC State Cooperative Tree Improvement Program.

New "Tricks of the Trade"

Tree breeders are always trying to improve the efficiency and effectiveness of their efforts and will use whatever tools are available to increase genetic gain. Since breeding cycles for loblolly pine are at least 10 to 15 years (reduced down from 15 to 25 years in the first cycles of breeding), a reduction of even one or two years can have dramatic economic impacts. The promises of enhanced gains from the new genomic sciences and biotechnologies are so great that tree breeders are investing resources into developing these tools. Using large genomic data in plant and animal breeding is a new frontier, and genomic breeding is expected to be a paradigm shift in tree breeding programs. With the use of molecular marker data, our hope is to identify genetically-superior individuals within a few weeks or months of the life of a tree as opposed to a few years. These technologies have worked especially well in cattle and other animal breeding programs, and there is every reason to believe that they will work in tree breeding programs. Additional investments into developing cost-effective marker systems and analytical techniques are still needed before the methods can be scaled up and routinely implemented into operational breeding.

The future of tree improvement in the southern United States is as bright now as it ever has been. Through both the traditional methods of selection, breeding, and testing and the hoped-for benefits from new genomic sciences, landowners should expect continued, steady genetic gains in productivity, disease resistance, stem form, and wood properties for decades and centuries to come. If genetic gains continue at the rate that has been realized across the South the last decade or so (about 1% gain in value per year), the present value of those gains is about \$2.5 billion. With better tools and improved rates of gain to a modest 1.1% gain in value per year, the present value would be \$2.8 billion. If the promises of genomics can be realized, gains per year should be much higher, and the financial benefits much greater.