Improvements in Stem Form and Growth of Elite Genotypes in Loblolly Pine

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Improving the value of our forests in the southeastern United States is becoming increasingly important to the stability and long term productivity of Cooperative members as well as the industry as a whole. The North Carolina State University – Cooperative Tree Improvement Program has made significant gains in volume, rust resistance, and stem straightness through two generations of tree improvement (Li, McKeand et al. 2000). Increasing the value and amount of sawtimber from each acre of forest plantation is one opportunity for adding value to forest landowners in the South. With sawtimber prices nearly 5 times greater than pulp prices ("Timber Mart-South" 2007), even small increases in the proportion of sawtimber can significantly increase the value of timber. Previous research found that stem form and crown traits influenced the quality of sawlogs, but volume was the major influence in the value of sawlogs (Busby 1983). While it has been widely observed that variation exists among families, it has not been characterized within loblolly pine (*Pinus taeda* L.) breeding populations. Over the last year, the Cooperative has made efforts to assess the variation in traits thought to influence sawtimber quality.

The Lower Gulf Elite population was a joint effort between the North Carolina State University-Cooperative Tree Improvement Program, the Western Gulf Forest Tree Improvement Program, and the Cooperative Forest Genetics Research Project formed in the mid 1990's with elite material from the Atlantic Coastal Plain, Florida, and Livingston Parrish/East Texas provenances. At the time it was created, this was the most elite material from these provenances considered to be suitable for the development of a land race for the lower Gulf Coastal Plain of the United States. This combination of provenances provided an excellent population to quantify the variation in growth and sawtimber quality in loblolly pine. The objectives for this research effort were to 1) estimate genetic parameters for age 6 year growth and stem form traits and 2) determine potential gains in sawtimber quality by family selection.

The experimental design consisted of six 8-tree, disconnected diallels that resulted in approximately 128 crosses. Four tests in Alabama, Florida, and Georgia were measured for this; each test was a 20 replication single tree plot design. Data were analyzed using a mixed model approach performed in ASReml. A total of ten traits were measured in the LGE diallel tests: Height, DBH, Volume, Rust, Forking, Sweep, Branch Angle, Branch Diameter, Branch Frequency, and Sawtimber Potential (on a 1-4 scale with 1=high sawtimber potential, 4=cull).

Individual-tree heritability estimates ranged from 0.08 for sawtimber potential up to 0.24 for tree height (Table 1). The half-sib family-mean heritability estimates ranged from a low of 0.71 in branch angle to a high of 0.97 for branch frequency. Full-sib family mean heritability estimates were lower than half-sib estimates ranging from 0.66 for branch angle to 0.91 for rust incidence. While some individual tree estimates seemed low (below 0.10), the half-sib family mean

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heritability estimates suggest there is genetic variation at the family level that could be utilized for population improvement.

While branching characteristics were found to be heritable, it is perhaps most encouraging that the more subjective sawtimber potential score was heritable at the half-sib level at 0.85. The potential to grade a progeny test tree for multiple stem form characteristics with a single score could make sawtimber potential assessments rapid and cost-effective for tree improvement programs. Based upon correlations among parental breeding values for growth and stem form traits (Table 2), there are no relationships that would prevent the improvement of stem form and growth in the Lower Gulf Elite population. Sawtimber potential was most highly correlated (between breeding values) with volume and height (0.54 and 0.53, respectively) but was not highly correlated with any branching traits (Table 2). A relationship between growth and sawtimber potential was expected since above-average growth was a criterion for sawtimber grading. The modest correlations suggest that volume was not unfairly weighted for sawtimber evaluation. In addition to growth traits, sawtimber potential was also negatively correlated (favorable) to sweep (-0.52) and rust infection (-0.38). Both of these relationships are favorable as lower sweep values indicate straighter trees and rust is scored as a binary variable (0 = no rust, 1 = rust). These traits are also factors in sawtimber potential scoring since stem rust disqualified a tree from being a potential sawtimber tree and large sweep (>3") penalized a tree from being potential sawtimber. These relationships will be further explained through the development of a predictive model for estimating sawtimber potential from existing Cooperative breeding values.

In addition to the potential improvement of sawtimber quality in breeding populations, gains in sawtimber quality can also be captured through the deployment of select first- and second-generation parents. Figure 1 demonstrates the range in sawtimber and volume growth by full-sib family means. Since correlations were not high between growth and sawtimber potential it is important to quantify both the growth and sawtimber quality of each family. Selecting only on volume for deployment will not always result in the families with higher proportions of potential sawtimber trees. This consideration is also seen in Figure 2 where the top fifteen parents for volume show a range in sawtimber potential from less than 40% to greater than 70%. Selecting parents with high volume and sawtimber potential breeding values will be important not only for deployment decisions for reforestation now, but also for decisions in population management and the improvement of elite germplasm in the Cooperative for future breeding efforts.

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Table 1. Heritability Estimates for traits measured in four Lower Gulf Elite tests.

Trait	h^2_i	h^2_{HS}	H^2_{FS}
Height	0.24	0.95	0.89
DBH	0.12	0.87	0.77
Volume	0.15	0.87	0.78
Rust	0.22	0.96	0.91
Forking	0.15	0.91	0.82
Sweep	0.16	0.94	0.78
Branch Angle	0.16	0.71	0.66
Branch Diameter	0.09	0.91	0.69
Branch Frequency	0.13	0.97	0.71
Sawtimber Potential	0.08	0.85	0.70

Where h^2_i is narrow-sense individual tree heritability, h^2_{HS} is narrow-sense half-sib family mean heritability, and H^2_{FS} is broad-sense full-sib family mean heritability.

Table 2. Parental Breeding Value Correlations (and p-value) among selected growth and stem form traits in four Lower Gulf Elite tests.

	Height	Volume	Sweep	Branch Angle	Branch Diameter	Branch Frequency	Rust	Sawtimber Potential	Forking
Height		0.86 <.0001	-0.06 0.68	-0.10 0.48	0.37 0.01	0.52 <.0001	0.00 0.99	0.53 <.0001	0.35 0.01
Volume			0.06 0.67	-0.28 0.04	0.53 <.0001	0.32 0.02	0.00 0.99	0.54 <.0001	0.28 0.04
Sweep				-0.25 0.07	0.35 0.01	0.16 0.26	0.22 0.11	-0.52 <.0001	0.10 0.48
Branch Angle					-0.40 0.00	0.03 0.85	0.11 0.44	-0.11 0.41	0.26 0.06
Branch Diameter						0.36 0.01	0.39 0.00	-0.04 0.79	-0.05 0.73
Branch Frequency							0.11 0.43	-0.01 0.95	0.26 0.06
Rust								-0.38 0.01	-0.01 0.96
Sawtimber Potential									-0.12 0.38

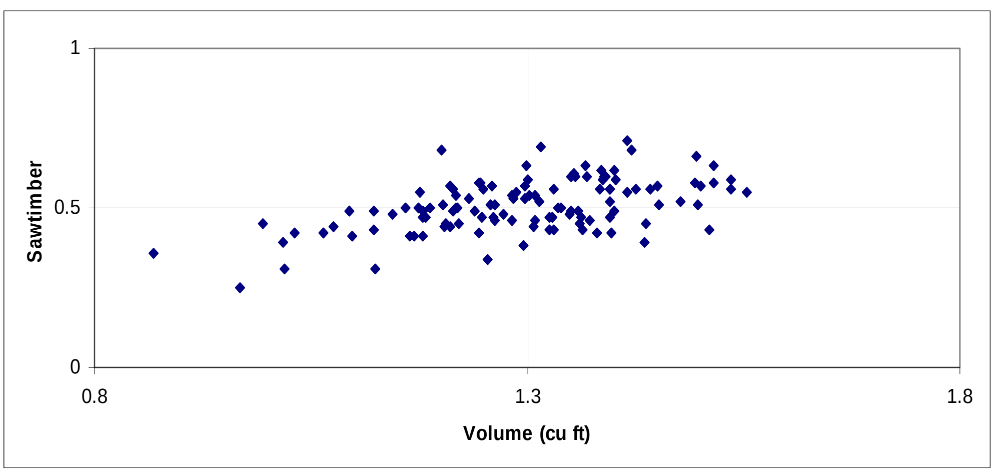

Figure 1. Plot of Sawtimber full-sib breeding values (proportion) vs. whole-tree 6-year volume full-sib breeding values (ft^3).

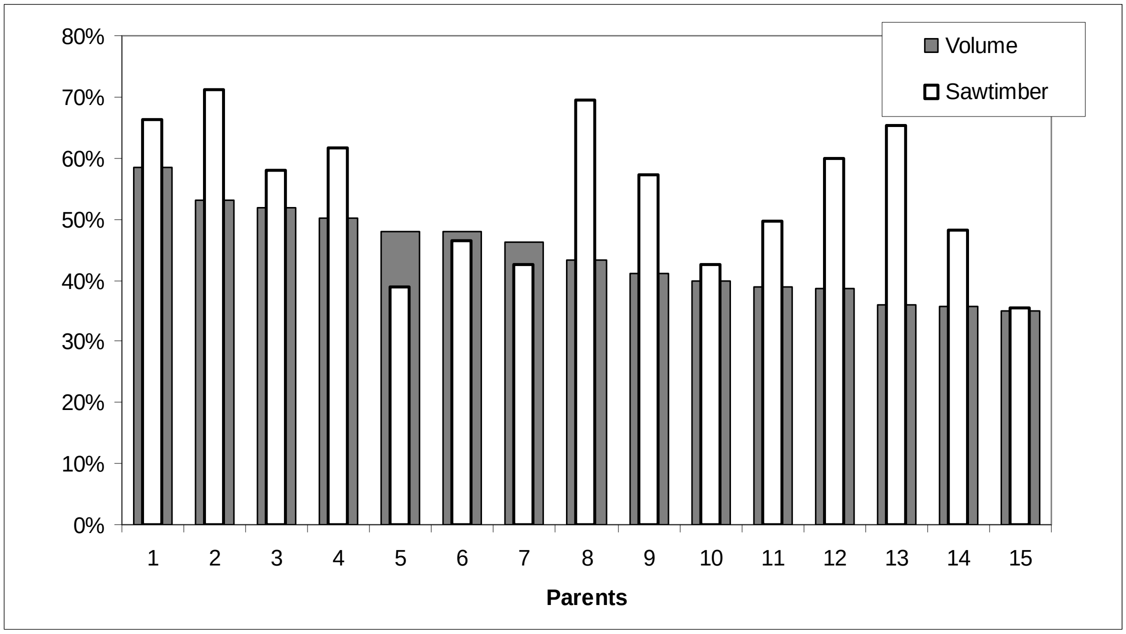

Figure 2. Half-sib breeding values for volume gain (%) and sawtimber potential (%) for the fifteen highest volume.

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