North Carolina State University – Industry Cooperative Tree Improvement Program

51st Annual Report

Department of Forestry & Environmental Resources
College of Natural Resources
North Carolina State University

May 2007

Tree Improvement Program
NC STATE UNIVERSITY

NC STATE UNIVERSITY

Mass Controlled Pollination at MeadWestvaco

Over 94 million control-pollinated full-sib seedlings have been planted operationally in the southeastern US since 2000.

EXECUTIVE SUMMARY

Tree Improvement at NC State – The Next 50 Years?

There are many questions about the future of the Cooperative's breeding program, but we remain optimistic that the economic value to landowners will be recognized, and continued support for our efforts will come. The value of genetics on the Hofmann Forest is an excellent example of how landowners can benefit from our work. From the productivity increases and very conservative estimates of increased value over "routine" families, our estimate is that the Hofmann Forest realized a net present value at 8% IRR of $437,800 this year alone simply from planting the best genetics possible. The old saying that "knowledge is power" is borne out once again.

SELECTION, BREEDING, AND TESTING

Mainline breeding continues to progress, with 45% of the total PMX breeding complete. An additional 19% is in progress with some seed in hand. In the fall/winter of 2006-2007, a total of 15 PMX tests were established within the cooperative, 10 tests in the Coastal region and 5 tests in the Piedmont region. With the Elite seed collected in 2006, the Coastal region is 85% complete with 90% of assigned crosses being made; Piedmont is 7% complete with 45% assigned crosses made; and Northern is 7% complete with 23% assigned crosses made.

In March 2007, superior individuals were selected from full-sib crosses in the Piedmont Elite Population (PEP) in 8- and 9-year-old field trials. From the two breeding groups of the PEP, a total of 21 superior individual trees from 19 different full-sib crosses were selected and grafted into breeding orchards.

The Loblolly Pine Performance Rating System (*LP-PRS*)

In 2006, the Cooperative released the Loblolly Pine Performance Rating System (***LP-PRS***) as a service to forest landowners, nursery managers, and the tree improvement community. We hope that the ***PRS*** will simplify interpretation of breeding values and make decisions about the value of different seedlings more understandable.

SEED PRODUCTION

Approximately 26 tons of loblolly pine seed were harvested in the Cooperative in 2006. In both the Coastal and Piedmont regions there was an increase in 3rd-generation seed and a decrease in 1st-generation seed.

PROGRESS REPORTS FOR RESEARCH

Marker linked major gene discovery is providing opportunities to integrate biotechnology with clonal forestry to increase forest productivity. Two studies received significant effort this past year that will help us understand the benefits of markers to applied breeding programs.

Wood quality studies to understand variation patterns throughout the tree and to evaluate rapid assessment techniques are in their final stages. Promising results were found in both.

Growth and yield traits and several stem quality traits were assessed at the SETRES2 study. GxE for yield per acre is starting to show up at the provenance level at age 10 years. Detailed quality assessment show strong genetic and environmental effects. Stem and wood quality assessments were made on the Lower Gulf Elite Population trials and will provide valuable data for future breeding.

ASSOCIATED ACTIVITIES, GRADUATE STUDENTS, COOPERATIVE STAFF, MEMBERSHIP

The Contact Meeting in May 2006 held with the Forest Nutrition Cooperative and hosted by Weyerhaeuser was one of the highlights of the year. We have six full-time excellent graduate students studying on a wide array of genetics topics. Sadly, Dr. Bailian Li has left our staff, but remains at NC State as Vice Provost for Academic Affairs. Patrick Cumbie and Fikret Isik have joined the staff full-time, and Tori Batista-Brooks is now our half-time Czar for Administration. Cooperative membership continues to undergo unprecedented changes. MeadWestvaco and Temple-Inland have both announced land sales and management changes that will affect membership.

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Tree Improvement at NC State – The Next 50 Years?

I have been asked many times over the last year about the future of the Cooperative Tree Improvement Program at NC State. Will the Cooperative continue? Do you *really* believe that breeding will progress into the 4th cycle and beyond? Do you *really* think that significant and economically valuable genetic gains will continue to be made in the next 50 years? Do you *really* believe that new forest landowners value genetically improved loblolly pine and will be willing to invest in tree improvement? My unqualified answer to these questions is **YES**! I'll be honest, the next few months and years will test our constitution as foresters, tree breeders, and scientists. I worry that communication about what we do has not been as clear as it could be with landowners, and the result is that many do not fully realize the importance and need to continue the efforts to increase forest productivity via genetic improvement. My optimism comes from a simple, hard, economic reality - tree improvement is an incredibly valuable and wise investment. Why would any informed and intelligent landowner not want to continue the value improvement that has been realized from our effort?

When people approach me with concern about the value of tree improvement with loblolly pine, I point to our recent economic analyses describing the financial returns that planting the best genetics brings to landowners. Our Hofmann Forest is a prime example. For the last 6 years, we have been making recommendations to the NC Forestry Foundation about what genetics should be planted at the Hofmann. Before 2002, the forest manager was purchasing seedlings that were routinely available on the open market. These were very good quality seedlings, but they were not necessarily the best that could be planted. This past planting season, 2038 acres were planted – 106 acres with somatic embryogenic varieties, 1844 acres with full-sib families, and 88 acres with an open-pollinated family. The genetic quality of each of these types of seedlings is THE BEST available for the Atlantic Coastal Plain based on extensive field testing. From the productivity increases and very conservative estimates of increased value over "routine" families, my estimate is that the **Hofmann Forest realized a net present value** (8% IRR) **of $437,800 <u>this</u> <u>year</u> <u>alone</u> simply from planting the best genetics possible**. The old saying that "knowledge is power" is borne out once again. Next year, we will plant even better genetic material, and in 2009 there should be better clones, full-sib families, and open-pollinated families available. The future of the Hofmann Forest has never looked brighter.

Old plantations at the Hofmann Forest are being replaced with seedlings that are genetically much more productive. Even better genetics will be available in the coming years, and the value of the new plantations will increase for decades.

Given these straightforward, favorable economic realities for a modest regeneration program of only about 2000 acres, why wouldn't I be optimistic about the future of tree improvement? Imagine the economic value to a large forestry company whose annual regeneration program is 10, 20, or 30 times larger. Investment in genetics is about as good as it gets in forestry.

The Cooperative has received tremendous support for years from far-sighted foresters, landowners, state forestry agencies, the US Forest Service, forest products companies, and in recent years from institutional investors (TIMOs and REITs), nursery and seed orchard companies, and biotechnology companies. Our challenge will be to educate the new class of landowners and foresters about the value of increased productivity from genetics. Our message is simple and easy to defend; continued investment in loblolly pine tree improvement will reap tremendous economic, ecological, and social benefits for years to come.

Steve McKeand
May 2007

SELECTION, BREEDING, AND TESTING

THIRD-CYCLE MAINLINE BREEDING PROGRESS

Mainline breeding continues to progress, with 45% of the total PMX breeding complete. An additional 19% is in progress with some seed in hand. With seed that was harvested in the Fall of 2006, we were able, for the first time, to send out PMX tests for all 3 regions. As we move towards the half-way mark in PMX breeding, changes in the breeding and testing schedule may become a reality, but 2006 was an excellent year of progress in 3rd Cycle breeding and testing.

We are using a complementary design, with polycross mating for among family selection and full-sib mating for within-family selection. The numbers of completed crosses are summarized in Table 1. The coastal region has made the most progress with 55% of PMX breeding and 64% of Mainline Full-sib breeding complete.

Cooperative members within each region have grafted all parents selected for generating the pollen mix (PMX) for polycross mating. Three third-cycle check seed lots are being created for each of the three regions by using the same 20-parent PMX applied to 10 of the selections as females. Checklot crossing has progressed well in the Coastal and Piedmont regions (Table 1). Sufficient quantity of checklot seeds has been produced for all three regions (Coastal, Piedmont, and Northern) for establishing the PMX tests in 2006. Thanks to breeding efforts over the last two years, checklot seed for the coastal and piedmont regions is complete, while the northern region has made progress.

In addition to the third-cycle checklots, several well-characterized families (common family checks) from the first two cycles of breeding are being crossed with the pollen mix. These families will be included in all tests to contribute to estimates of variance components and provide better family comparisons. Seeds from some common family checks have been collected for each breeding region (Table 1).

Full-sib controlled crossing made excellent progress this year, more than doubling the number of completed crosses reported in 2005 (96 crosses completed as of Fall 2005) (Table 1). Seed production from full-sib cross mating is expected to rise in the coming years as the third-cycle selections produce more flowers. These full-sib crosses will generate seeds for within-family selection for the next breeding cycle.

Table 1. Summary of third-cycle breeding progress, as of Fall 2006

Type of crosses	Breeding Region	# Coop-erators	# of Sublines	Total # Parents	#Crosses producing Seed	#Crosses of Sufficient Seed	% Done Crosses
Polycross	Coastal	9	32	384	251	212	55%
	Piedmont	7	31	364	191	137	38%
	Northern	4	14	177	112	65	37%
Polycross	**Total**	**15**	**77**	**925**	**554**	**414**	**45%**
PMX checks	Coastal	9	--	10	10	10	100%
	Piedmont	7	--	10	10	10	100%
	Northern	4	--	11	11	3	27%
PMX CFs	Coastal	9	--	7	7	7	100%
	Piedmont	7	--	7	7	6	86%
	Northern	4	--	7	7	3	43%
Full-Sib	Coastal	9	32	235	*	150	64%
	Piedmont	7	31	186	*	39	21%
	Northern	4	13	81	*	44	54%
Full-Sib	**Total**	**15**	**76**	**502**	*****	**233**	**46%**

***** No data available

#Crosses of Sufficient Seed: A parental cross is counted here if the "total seed requirement" has been met for that cross

PMX checks: Polycrossed checklot mixes

PMX CFs: Polycrossed Common Family check.

THIRD-CYCLE PROGENY TESTING

Polycross tests

In the fall/winter of 2006-2007, a total of fifteen PMX tests were established within the cooperative (Table 2.). Ten tests were established in the coastal region from two tests series and five tests were established in the piedmont region from one test series. Since the number of tests per series was reduced for all regions; the PMX breeding and testing can move faster as we work together to complete the third cycle breeding and testing. Tests were established in AL, FL, GA, NC, SC, and TN.

In April 2007, seed was sent out to cooperators for the establishment of PMX tests in 2007-2008. A total of 22 tests were sent to cooperative members. For the first time we were able to send out PMX seed for testing in all three regions. Tests will be established in AL, FL, GA, NC, SC, TN, and VA. Thanks to all the cooperative members for their efforts to get these tests in the ground!

Full-Sib controlled cross tests

A small number of Full-sib block plots are being installed and will continue to increase with the availability of full-sib seed. These plots will be a source for selections as the program moves forward. Each member is encouraged not to delay the installation of these tests. Once enough seed is collected from a few crosses, block plots can be installed.

ELITE BREEDING

The expected gains from the Elite Breeding programs make it clear that getting this breeding underway is very important, and the cooperators have made great strides in accomplishing this task. With the Elite seed collected in 2006, the coastal region is 85% complete with 90% of assigned crosses being made; Piedmont is 7% complete with 45% assigned crosses made; and Northern is 7% complete with 23% assigned crosses made.

Table 2. Third-cycle progeny tests to be established through 2008

Region	Test Series	2004-05	2005-06	2006-07	2007-08	Total
Coastal	CPMX1	15				15
Coastal	CPMX2		5	5		10
Coastal	CPMX3			5	5	10
Coastal	CPMX4				5	5
Piedmont	PPMX1		3	5		8
Piedmont	PPMX2				8	8
Northern	NPMX1				4	4

PIEDMONT ELITE POPULATION SELECTIONS

To realize the tremendous genetic and economic potential of breeding highly selected trees, several elite breeding populations have been formed by the Cooperative in recent years. The extra gain possible from breeding only the best trees for specific geographic regions, and possibly for different product goals is the main benefit of including elite populations in the Cooperative's third-cycle breeding strategy. The active elite populations for breeding in the Cooperative are the Piedmont Elite Population (PEP), the Lower Gulf Elite Population (LGEPop), and the three "Conventional" Elite populations.

For the Piedmont Elite Population, results from Cooperative studies and other seed source trials indicate that across many sites in the Piedmont, loblolly pine from the Atlantic Coastal Plain grows 5-10% faster than trees indigenous to the Piedmont region. Unfortunately, the Coastal trees tend to be more susceptible to cold and have worse stem form than the Piedmont trees. The PEP breeding population is based on the production of hybrids between Coastal and Piedmont trees to incorporate the advantages of each population. Both industry and state organizations are willing to take the calculated risk that this approach will pay big dividends.

The 6-year measurements of the PEP Population tests have now been completed and analyzed. This includes both pollen mix (PMX) tests as well as factorial and diallel tests. To date, two refereed publications have resulted from the PEP studies. A seedling study assessing cold tolerance among PEP hybrid crosses was conducted by Kegley et al. (South. J. Appl. For. 2004). An early evaluation of the growth performance of PEP hybrids was published by Alizoti et al. 2006 (For. Sci. 2006). See list of publications at the end of the report.

In March 2007, superior individuals were selected from full-sib crosses of these elite populations in 8- & 9-year-old field trials. From the two breeding groups of the PEP, a total of 21 superior individual trees from 19 different full-sib crosses were selected and grafted into breeding orchards. Estimated gains over the unimproved checklot (CC7) are excellent for the superior full-sib crosses and individuals from the PEP. Volume gains averaged 30% for the PEP Population I select parents (2nd-gen hybrid parents), and volume gains averaged 33% for the PEP Population II select parents (interprovenance elite crosses). These elite selections will be bred into the 3rd- and 4th-cycle programs for future deployment.

SEED AND CONE YIELDS

Approximately 26 tons of loblolly pine seed were harvested in the Cooperative in 2006. Overall the total amount of seed harvested was slightly less than the 2005 harvest of 28 tons. In both the coastal and piedmont regions there was an increase in 3rd-generation seed and a decrease in 1st-generation seed. Average seed yields dropped slightly from 1.55 to 1.51 pounds per bushel. Second-generation orchards contributed about 77% of total seed, and Coastal orchards accounted for 88% of total seed production.

Table 1. Comparison of 2006 seed and cone yields with previous year.

Provenance	Bushels Of Cones		Pounds Of Seed		Pounds per Bushel	
	2006	2005	2006	2005	2006	2005
Coastal 1.0	4024	5389	5795	8156	1.44	1.51
Coastal 2.0	21149	23765	34758	39242	1.64	1.65
Coastal 3.0	4450	3231	5300	3638	1.19	1.13
Piedmont 1.0	129	305	190	375	1.47	1.23
Piedmont 2.0	3912	3375	5214	4863	1.33	1.44
Piedmont 3.0	670	330	693	253	1.03	0.77
Northern 2.0	183	150	178	225	0.97	1.50
Totals	34,516	36,545	52,127	56,752	1.51	1.55

Annual seed yields have varied over the years (Figure 1) due to regeneration needs, changes in membership within the Cooperative, environmental factors, and growth and technology within the industry. Since the mid 1980's cooperators have produced sufficient quantities of improved seed, and therefore have been making selective harvests of 20 to 40 tons of seed per year.

From 1968 to 2006, over 2 million pounds of improved seed have been produced by Cooperative members (Figure 2). At 15,000 seedlings per pound, this is enough seed to grow over 32 billion improved seedlings. We look forward to greater production from advanced generation seed orchards in the near future!

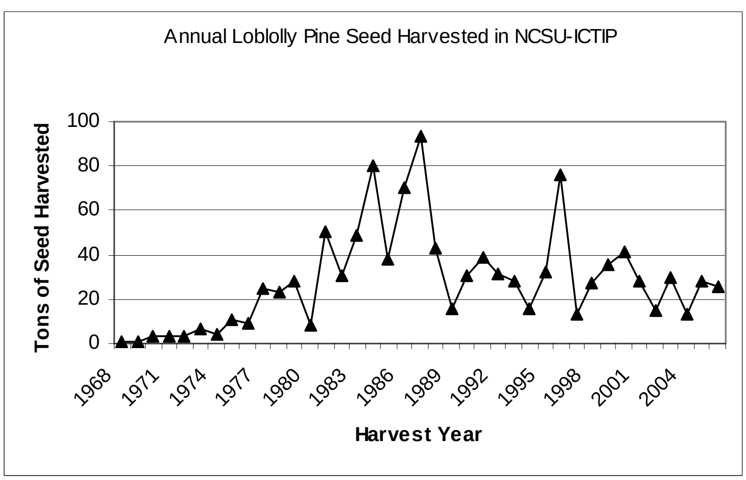


Figure 1. Annual seed yields from 1968 to 2005.

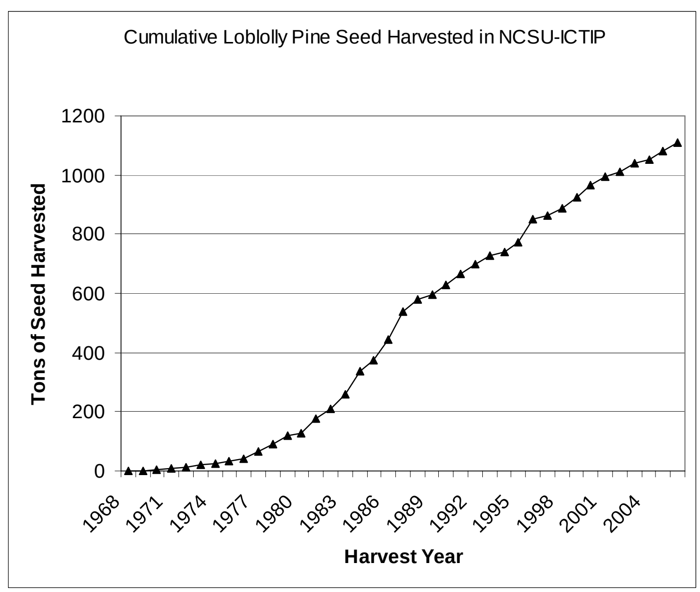


Figure 2. Cumulative seed yields for the NCSU-ICTIP starting from recorded amounts in 1968. Approximately 1,108 tons of improved seed harvested over the past 38 years.

The Loblolly Pine Performance Rating System (*LP-PRS*)

In 2006, the NC State Tree Improvement Cooperative released the Loblolly Pine Performance Rating System (***LP-PRS***) as a service to forest landowners, nursery managers, and the tree improvement community. We hope that the ***PRS*** will simplify interpretation of breeding values and make decisions about the value of different seedlings more understandable.

Loblolly pine is among the most genetically variable tree species on earth. A landowner should always plant adapted genotypes that are fast growing, straight, disease resistant, with desirable wood quality. But not all genotypes available from forest tree nurseries are "the best" for all traits. Some parental families may be very fast growing but are susceptible to fusiform rust disease. Some may have excellent stem quality and rust resistance but are only fair for growth. There will be a select few families that have many or all the desirable characteristics that a landowner desires, and there are many families that are only average or slightly above average for these traits.

The ***PRS*** was developed because of the inherent variation in loblolly pine for so many different traits. ***PRS*** also stands for Productivity, Rust, and Straightness that are the three traits that are evaluated in ***all*** our loblolly pine progeny trials. The ***PRS*** expresses the **genetic potential** of a tree genotype for stem volume production, resistance to fusiform rust disease, and stem straightness. This potential will be modified by the actual environmental and cultural conditions in which a tree genotype grows. We use the following scores for each trait:

P**roductivity** – This number represents the percentage increase in stem volume at age six years that would be expected from planting a specific family or mix of families or full-sib family or clone, compared to the local unimproved loblolly pine seedlings.

The main benefit to landowners from the ***P*****roductivity** rating is the relative values for different families; a ***P***38 is better than a ***P***29 that is better than a ***P***15; the higher the number, the more valuable the family. The actual growth and volume of the different families will depend on the site where it is planted and the silvicultural system used to manage the timber (see McKeand et al. 2006 Journal of Forestry article for a more comprehensive discussion of financial value of genetics under different management regimes).

R**ust** – Resistance to fusiform rust disease is measured by what southern pine tree breeders call R50. If an unimproved loblolly pine seedlot would be expected to have 50% rust on a site, then its R50 = 50. A very resistant family would have an R50 value of 20% or so. A susceptible family would have a R50 value above 50%. We have converted these rust scores to relative ***R*** grades of A, B, C, D and E. The most rust-resistant would have ***R*** grades of A, and the most susceptible would have ***R*** grades of E. An ***R*** grade of C means that it is average for rust resistance.

S**traightness** – Unimproved loblolly pine is crooked. Tree breeders have had a major impact on improving the straightness of most families. The ***S*** rating is our estimate of the percentage improvement in stem straightness above unimproved loblolly pine. An ***S*** grade of A would be for a family with excellent form. If the ***S*** grade is C, then the straightness would be slightly better than unimproved loblolly pine.

LP-PRS ratings are developed for each geographic region where a family is adapted. Ratings are based on deviations from the local unimproved check seedlots (see example of families in Table 1). For each of the traits, gain estimates are based on open-pollinated (OP) progeny test data, or OP-level values derived from half-sib (controlled cross) test data, or a combination of test data.

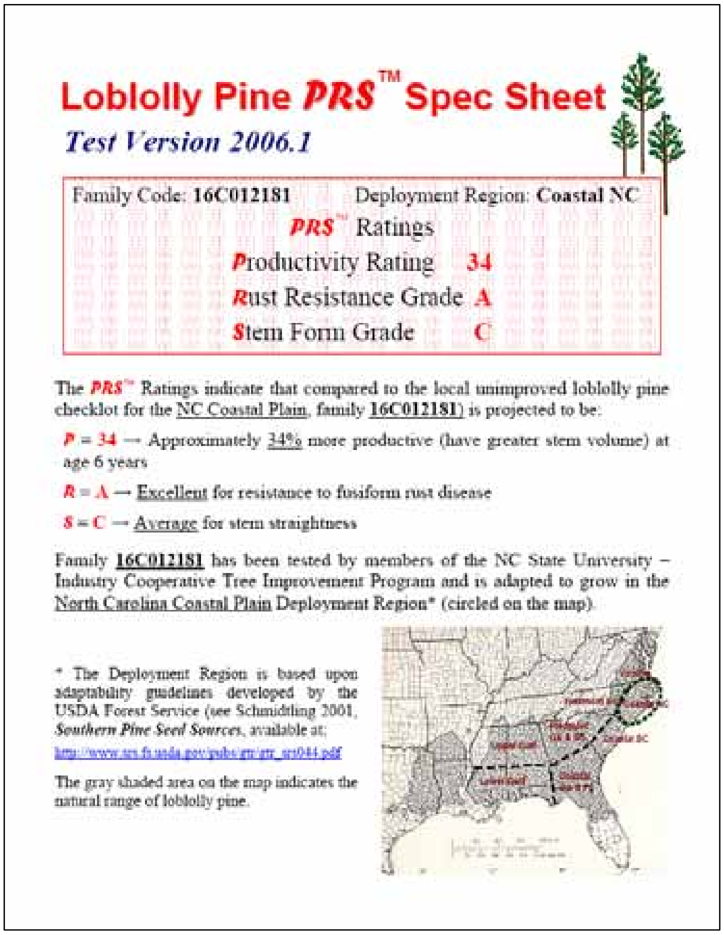
Landowners should request seedlings from forest nurseries with the highest ***LP-PRS*** Ratings they can obtain. Over the past 10 to 20 years, most nurseries have not only sold mixtures of seedlings from various families, but also individual OP families. These families could range from the very best genotypes to average genotypes, but many industry nurseries have no extra seedlings for sale or want to keep the best seedlings for their own use on company lands. Industry foresters recognize the tremendous financial advantage that comes from planting the most highest-yielding families with good quality traits.

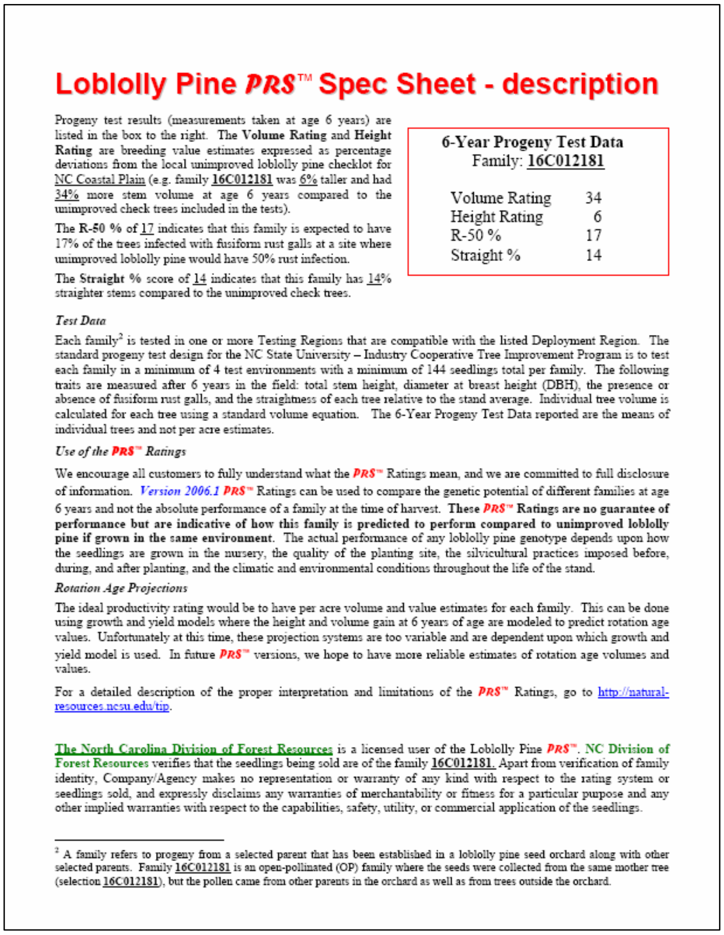
Unfortunately, other landowners are often not as knowledgeable and are not always able to purchase the best genetic quality seedlings except in mixture with other families. If landowners were better informed of the benefits of using specific families for forest regeneration, then they should be willing to pay more for the best genetic quality seedlings to recognize the increase in the net present value of their plantation investment. Likewise, if nursery managers received a better price for the best seedlings, then they might be willing to sell them on the open market and not use them exclusively on company lands.

The ***LP-PRS*** Rating System is a step in this direction. The rating system will continue to evolve and be updated as more progeny test data is incorporated in coming years.

Table 1. Example of hypothetical ***LP-PRS*** ratings for Coastal Plain Georgia and Florida.

Parent ID	Reference Region	Test Area	Vol% / CC4	R-50 %	Straight %	P	R	S
001001	C-GA&FL	3	36.87	47.89	14.4	37	D	C
001002	C-GA&FL	4	20.72	33.20	18.3	21	B	C
001003	C-GA&FL	4	22.55			23	X	X
001004	C-GA&FL	3	39.30	21.10	24.4	39	A	B
001005	C-GA&FL	4	33.11	55.65	19.1	33	E	C
001009	C-GA&FL	4	10.13	46.37		10	D	X
001013	C-GA&FL	3	34.41	57.42	28.5	34	E	B
001014	C-GA&FL	3	41.48	39.00	22.5	41	C	B





RESEARCH

FrCad Project – Use of Molecular Markers to Enhance Selection of Superior Clones of Loblolly Pine

Marker-linked major gene discovery is providing opportunities to integrate biotechnology with clonal forestry to increase forest productivity. The Forest Biotechnology Group at NC State University has identified two major impact genes in loblolly pine. The *Fr1* gene, found in selection 10-5, confers fusiform rust disease resistance to certain strains of the fungus. The *cad-n1* gene, found in selection 7-56, affects wood quality and growth. These two genes are the most important and highest effect genes ever identified in loblolly pine. To incorporate favorable genes in the same clone, we crossed parents 10-5 and 7-56. The question we would like to answer from this research is clear: when selecting superior genotypes within cross 10-5 x 7-56, does the presence or absence of the gene markers have important impacts on the phenotypic values of genotypes?

Over 300 progeny of the cross were cloned via rooted cutting. Prior to cuttings being taken, each hedge was given a unique identifier and needle tissue was harvested. DNA has been extracted from the needle tissue, and is in process of being genotyped for the two genes of interest. We expect to have the genotyping assays completed by the end of this summer. Mendelian ratios will be assessed and, depending on the number of ramets available and the configuration of the two genes, clonal field and greenhouse tests will be designed to test the impact of these genetic markers on the phenotypes of the cloned genotypes.

With clonal testing, we can unambiguously distinguish the major gene effects (*Fr1* and *cad-n1*) from environmental noise and determine the economic value of these genes. We expect this project will result in the development of an effective model and methodology to use marker aided selection and breeding to improve gene pyramiding and clonal testing. These improvements will help increased productivity and efficiency in breeding and deployment of superior genotypes.

Above: FrCad seedlings, June 2005, first hedging.

Above: FrCad hedges in early spring 2007 before the cuttings were taken.

Left: FrCad cuttings in the mist house that are being carefully looked after by Maria Wilkes.

The Value of DNA Markers in Selecting Genetically Superior Individuals in Advanced-Generation Loblolly Pine Breeding Populations

Major genes that affect economically important traits are likely to be present in the Cooperative's advanced-generation breeding populations. The cad-n1 allele mutation, arguably the largest-effect major gene known for volume growth in loblolly pine, is an interesting target to focus on the value of major genes (see previous work published by Yu and others in the list of publications at the end of this report). Due to the simple Mendelian inheritance of the mutation itself, and the quantitative impact it has in loblolly pine, the cad-n1 allele lends itself well to study the impact and value marker aided selection (MAS) may have for selection of genetically superior individuals.

The low heritabilities of growth traits (typically about 0.1 to 0.2) mean that the effectiveness of within-family selection is limited. MAS may provide enough additional information about individual selections to increase selection efficiency for a trait. But the question remains whether MAS a cost-effective method to capture the effects of the desired trait, in this case the volume gain from the presence of the cad-n1 allele?

In early January 2007, we selected the top 10+/- individuals from 25 crosses of MeadWestvaco elite diallels. Each of these crosses had half the progeny carrying the cad-n1 allele and half without it. The selections were based on individual-tree breeding values for 6-year volume and height. Foliage was collected from these 10 individuals from each of the 25 crosses (Figure 1). DNA was extracted and each tree was genotyped for the presence/absence of the cad-n1 allele. Based on the phenotypic scores for growth, stem form, rust, and cad-n1 genotyping, we selected the 4 best individuals within each cross; 2 trees with the cad-n1 allele and 2 trees without it. The intent of this selection structure is to compare the additional contribution, if any, of the MAS for cad-n1 to the breeding value of the selections in contrast to the traditional selection criteria. Are progeny from selected trees that carry the cad-n1 allele any different from progeny that do not carry the allele?

To compare progeny, scions were collected from each tree in early March 2007, and top-grafted into the NC Forest Service 2nd-Generation Coastal Seed Orchard (Figure 2). Assuming good graft survival, open-pollinated seeds from grafts should be available for progeny testing in October 2010. A target year to plant progeny tests will be winter 2011-2012, and reliable assessments of growth and wood density could be made by age 4 to 6 years.

Figure 1 (left). Foliage from the biggest individuals within each family were collected from the MeadWestvaco diallel tests in January 2007. Ross Whetten is applying the latest molecular genetic tools to this project while Fikret Isik and Patrick Cumbie watch in amazement.

Figure 2 (above). Patrick topgrafts one of the selections in the top of one of the NC Forest Service trees at the Goldsboro Seed Orchard.

Prediction of Whole-Stem Wood Properties in Loblolly Pine[1]

The use of fast-growing genotypes and intensive silviculture has dramatically decreased pine plantation rotations, and as a consequence, the proportion of juvenile wood has increased. Since there are tremendous differences in juvenile wood properties between and within trees, and since many wood properties are economically valuable and under a high degree of genetic control, the improvement of wood quality has become a highly emphasized operation. Improvement of most wood properties has been focused on taking a single sample at breast height. However, this single sample may not be representative of the overall whole-stem wood properties. Therefore, selecting genotypes based on their overall whole-stem wood properties is a critical step towards improving the quantity and quality of wood produced in southern pine plantations. The objectives of this study were: 1) The development of practical models for accurately predicting whole-stem wood density, α-cellulose, and lignin in 14 and 20-year-old loblolly pine; 2) The examination of the relationship between juvenile-, transition- and mature-wood density, α-cellulose, and lignin content at breast-height and overall whole-stem weighted averages; and 3) The examination of the relationship between breast-height and whole-stem wood property values while assessing genetic and environmental effects.

Prediction models for whole-stem wood density, α-cellulose and lignin content were developed based on a sample of 23 trees harvested from a 14-year-old clonal trial located in Florida and Alabama. These methods of sampling, data collection, and model development were also applied to 20 unrelated 20-year-old trees harvested in Jones County, North Carolina. Wood density measurements were taken using x-ray densitometry and α-cellulose and lignin content were measured using reflectance NIR spectroscopy. The α-cellulose and lignin content data were fitted to chemical wood property prediction models for loblolly pine. A weighted average for the whole-stem wood properties of each tree was then calculated based on samples taken from breast-height and at 8-foot increments.

For the juvenile clones growing in Florida and Alabama, correlations between breast-height wood properties and whole-stem wood properties were high and ranged from 0.71 to 0.90 (Figure 1). Over both sites, no clonal differences in breast-height and whole-stem wood properties were found except for breast-height juvenile wood α-cellulose content. There were significant differences between clones for height and no significant genotype by environment interaction was present for any growth measurement.

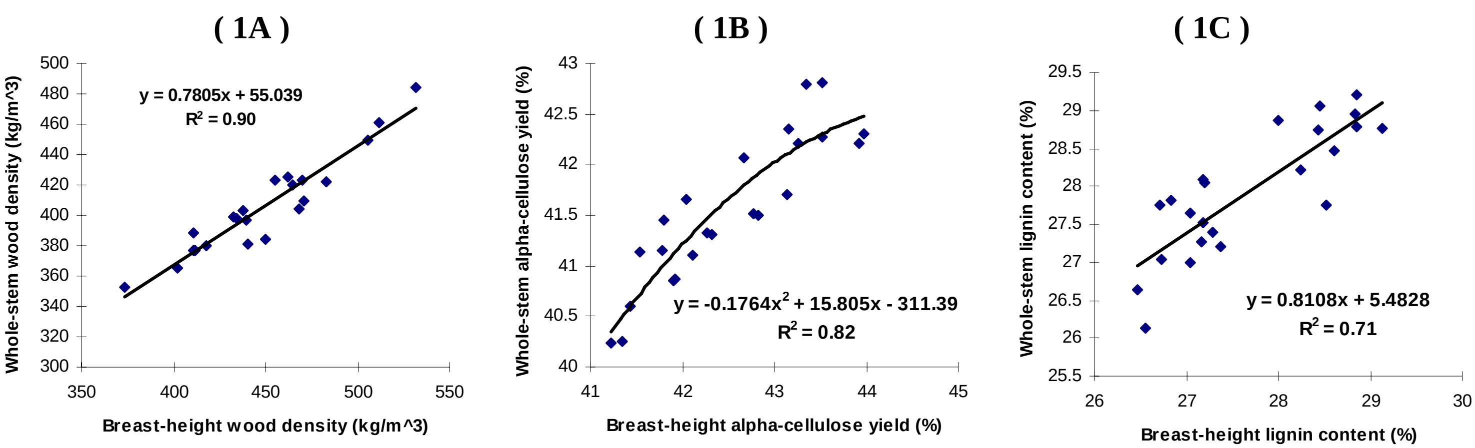


Figure 1. Whole-stem regression models for juvenile clonal samples across Florida and Alabama. (A) Breast-height wood density as a predictor of whole-stem wood density. (B) Breast-height α-cellulose yield as a predictor of whole-stem α-cellulose yield. (C) Breast-height lignin content as a predictor of whole-stem lignin content.

[1] This is a brief summary of Mike Aspinwall's Masters of Science thesis completed in 2007.

For the 20-year-old trees growing in North Carolina, both linear and polynomial regression models were significant and coefficients of determination for wood density, α-cellulose and lignin content were all very high (Figure 2). Other prediction models for the juvenile section of the breast height core or the mature wood section of the core were not as good as models using the entire core.

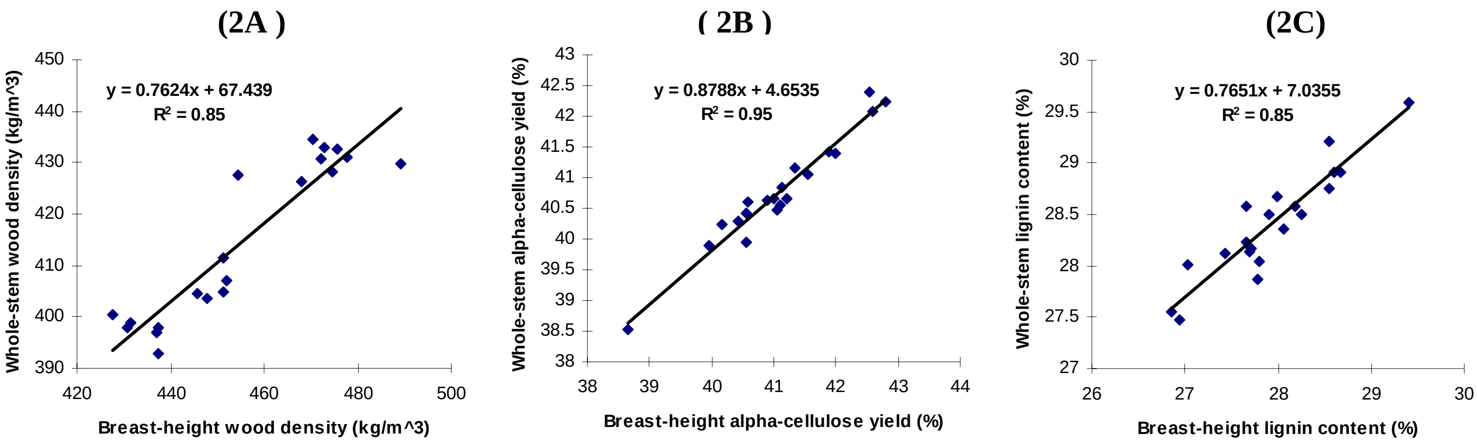


Figure 2. *Whole-stem regression models for 20-year-old trees in North Carolina. (A) Breast-height wood density as a predictor of whole-stem wood density. (B) Breast-height α-cellulose yield as a predictor of whole-stem α-cellulose yield. (C) Breast-height lignin content as a predictor of whole-stem lignin content.*

Both linear and polynomial models were developed for predicting whole-stem wood properties in juvenile and harvest-age loblolly pine. Linear models were the most effective and were the easiest to interpret biologically. This finding has implications for selection of wood properties at a young age when a high percentage of wood is juvenile. The overall breast height sample proved to account for more variation in the wood properties at breast-height and the overall whole-stem wood properties. Although no clonal differences were found for whole-stem wood properties, it is likely that sampling more genotypes would detect genetic differences useful for selection of genotypes with superior whole-stem wood properties. Similar relationships were found between breast-height wood properties and whole-stem wood properties, and prediction models for whole-stem wood properties in 20-year-old loblolly pine were also fairly robust. The prediction models developed in this study may improve the knowledge of how wood properties at breast-height compare to overall whole-stem wood properties in juvenile and harvest-age loblolly pine. These models may also aid further research related to improvement of wood properties. Selection of genotypes displaying superior wood quality traits could increase the quality and quantity of wood produced in southern pine plantations.



Rapid Screening Techniques for Assessing Wood Properties for Genetic Improvement and Deployment of Loblolly Pine[1]

Wood traits, such as density and microfibril angle are important in tree improvement programs due to their effects on wood products. Yet, with the exception of some research, wide scale measurement of wood traits for selection of genotypes has yet to be employed. One of the major obstacles has been the lack of rapid, cost-efficient, and reliable methods for screening a large sample of trees for wood traits.

Two new methods have recently shown potential for wood quality screening on a large number of standing trees. The Resistograph is a drilling instrument that measures power consumption (amplitude) as it drills through wood material. Our previous research has shown that amplitude measurements are highly correlated with wood density. The TreeSonic has been tested for screening of mechanical wood properties of several pine species and is based on the premise that acoustic waves travel faster through stiffer wood.

Figure 1. Measuring acoustic velocity for trees from a diallel test series with the TreeSonic

In 2005, two grants from the USDA Forest Service Agenda 2020 program were secured to develop rapid wood quality screening methods for live trees. One project is being jointly conducted with the University of Georgia to assess the ability of the TreeSonic for mechanical wood properties. The second project is about testing the efficiency of the Resistograph and TreeSonic for clonal selection and deployment.

Project 1: Wood Quality Screening in Diallel Tests

During 2006, two test sites of diallel series from each of the following breeding populations were sampled: Northern series in NC; Atlantic Coastal in SC; and Piedmont in GA. The progeny of 30 full-sib families were drilled for increment cores and measured for acoustic velocity using the TreeSonic (Figure 1). A subset of trees was felled to obtain samples for static bending tests. Wood strength and stiffness were measured in the USDA Forest Service Southern Research Station laboratories in Athens, GA. The data are currently being analyzed to assess the efficiency of the acoustic measurements by comparison with traditional bending test results.

Figure 2. Tyler Eckard, a graduate student, measuring relative wood density of trees using the Resistograph in a clonal trial

Project 2: Wood Quality Screening in Clonal Tests

An 8-year-old clonal test established by MeadWestvaco in Berkley County, SC was sampled in 2006. The clonal test contained three superior full-sib families. From each family, 30 clones were selected for wood quality assessment. Six ramets of each clone were drilled for direct assessment of wood density. The same trees were drilled with the Resistograph. TreeSonic measurements (acoustic velocity) were also obtained (Figure 2). A subset of 36 clones (3 ramets per clone) was felled, and whole tree density was determined by obtaining

[1] This is a brief summary of Tyler Eckard's Masters of Science research.

increment cores along the stem at fixed heights. Bolts were also obtained from felled trees to provide samples for direct measurement of mechanical wood properties using static bending tests.

We found a linear relationships between clone means for wood density and amplitude (regression $R^2 = 0.48$). Adjusting amplitude measurements for friction along the drilling needle slightly improved the relationship ($R^2 = 0.52$). Similar to our previous research, strong genetic correlations were found between amplitude and density ranging from 0.83 to 0.97. The repeatability of clone means was high for breast-height (0.83), but it was considerably lower for amplitude (0.59) due to greater intra-clone variance for this trait.

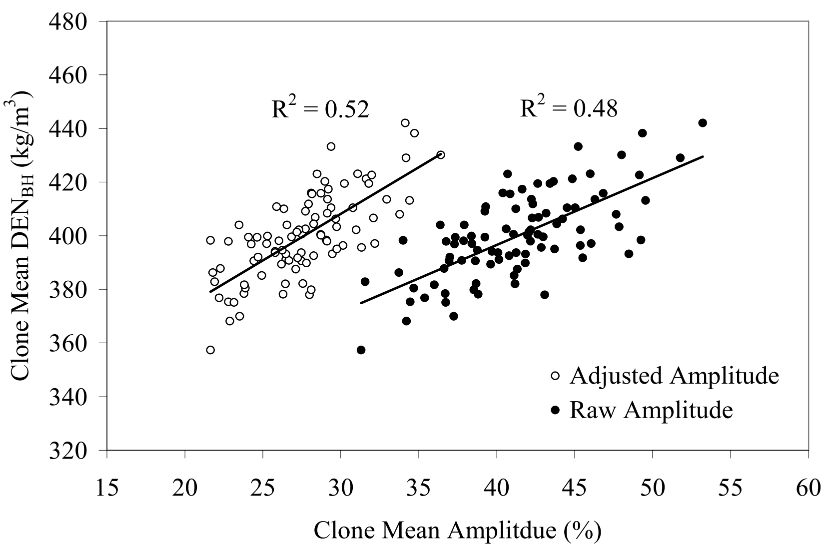


Figure 3. Clone mean phenotypic correlations between Resistograph amplitude values and breast height wood density. Raw amplitude measurements were output directly from the Resistograph. Adjusted amplitude values were calculated as the mean of the amplitude profiles after correcting for friction

How efficient is the Resistograph system for selecting clones for wood density? If wood density is measured directly to select clones, the selection efficiency would be 100%. We found relative efficiency of 78% for using the Resistograph. Considering gain per unit cost, this relative efficiency may be sufficient to justify using the Resistograph for selecting clones for wood density since the cost required to screen large numbers of trees would be greatly reduced.

Moderate but significant phenotypic correlations were found between TreeSonic acoustic measurements and both wood stiffness (0.71) and strength (0.50) at the clone mean level. Clone means for acoustic velocity measurements were highly repeatable (0.85). However, for both stiffness and strength measured by bending tests, only 10% of the total variance was explained by clone differences. One possible explanation for low clonal variation is that very few bending samples were obtained from young trees. Sampling bolts from different rings in trees may have caused high within clonal variation. Further analysis is being conducted to assess the relationship between acoustic velocity and mechanical wood properties.

Grants received supporting this research:

Fikret Isik, Bailian Li, Bronson Bullock. USDA Forest Service Agenda 2020. $169,125. Prediction of Whole-Stem Wood Quality of Superior Loblolly Pine Clones for Deployment. 05/05 - 05/07

Lauire Schimlek, Alex Clark III, Bailian Li, Fikret Isik. USDA Forest Service Agenda 2020. $181,000. Rapid techniques for screening wood properties for genetic improvement of loblolly pine. 05/05- 05/07

Genotype by Environment Interaction under Optimal and Deficient Nutrient Regimes in Loblolly Pine at Age 12 [1]

In the winter of 1993-94, the Tree Improvement Cooperative established the SETRES-2 test in the Sandhills of Scotland Co., NC. It is a large yield trial designed to evaluate stand-level performance of different genotypes of loblolly pine in two very different environments. The study is a split-split plot experimental design, with nutrition (annual optimum fertilization and non-fertilized) main plots, provenance (Atlantic Coastal Plain and "Lost Pines" Texas seed sources) sub-plots, and 100-tree family (five open-pollinated families per provenance) sub-sub-plots nested in provenance. Year-12 growth and form data were analyzed for differences due to nutrition, provenance, and family effects, and growth trends over time were studied for interactions.

Growth Traits

Differences in growth traits due to nutrition were highly significant at age 12. Trees in the fertilized plots were 66% taller that trees in the non-fertilized plots, and diameter at breast height was 51% greater in the fertilized plots. Mean individual-tree volume for fertilized plots was increased 183% over non-fertilized, and as a function of the above effects, volume per acre was 157% greater for fertilized plots. Overall uniformity for volume was much greater in the fertilized plots than the non-fertilized plots (CV of 37.0% and 53.1%, respectively). Variation within provenance was much more similar, with a CV of 64.3% in the ACP provenance and 66.7% in the LPT provenance.

Mean diameters for both provenances in the fertilized plots were very similar (Figure 1), but mean height was slightly higher in the ACP provenance fertilized plots (Figure 2). These combinations translate to slightly higher individual tree volumes in the ACP fertilized plots (data not shown); the greater volume observed on a per acre basis in the LPT fertilized plots reflected by the MAI (Figure 3) must be due to the presence of more stems per acre, as evidenced by survival (Figure 4). As survival was beginning to drop more rapidly in the fertilized ACP plots, likely due to competition induced mortality, the increase in individual tree volume growth rates was insufficient to match the volume produced by a greater number of remaining stems in the LPT plots.

Genotype by environment interactions in height and diameter at breast height were limited to differences in magnitude of response to fertilization. Mean annual increment (MAI) for volume per acre, however, showed a cross-over interaction between the provenances in the fertilized plots beginning at age 10 (Figure 3). Prior to age 10, MAI for volume per acre was greater in the Atlantic Coastal Plain provenance than in the 'Lost Pines" Texas plots; after age 10 the volume per acre MAI was larger in the LPT source than the ACP source. This interaction continued through age 12.

Family mean rankings over time were very stable for height and diameter. The greatest rank changes occurred in the MAI for volume, with some families changing rank at least once between ages 5 and 12 in the fertilized treatment (data not shown).

Stem Form

While many families have high growth rates, some of them had high incidence of stem and branch deformities causing serious problems for wood quality. For this reason, straightness, sweep, rust, ramicorn branching / forking, and stem and branch sinuosity were also assessed in 5 reps of this study at age 12. The five reps were chosen based on height and survival uniformity. Rust incidence was significant at the provenance and family (provenance). The ACP provenance mean for rust was 42% infection, while the LPT provenance was 10%. Straightness and sweep showed significant differences at the provenance and family (provenance) levels. The ACP provenance had better straightness and sweep than the LPT provenance. The presence of ramicorns and/or forks was significant for treatment and provenance. The LPT provenance had a higher percent of presence of ramicorns or forks especially in the fertilized plots (data not shown).

[1] Jesus Espinoza and Ben Smith are both using data from the SETRES2 study for portions of their PhD research.

For sinuosity (stem and branch, 1=no sinuosity, 3= high sinuosity), there were significant treatment, family, and treatment x family interactions (Table 1, Figure 5). The overall mean, for stem sinuosity was 22%. Fertilized plots showed 32% stem deformation and in the control plots 13% of the trees showed stem sinuosity.

Summary

Results showed that the growth interactions which began to appear at age 10 continued at age 12. Growth in the fertilized plots continued to far surpass that in the non-fertilized plots (Figure 6), while uniformity remained much greater. Mortality began to have a large impact on per acre volume, and was mainly responsible for the change in rank between provenances in the fertilized plots. Another factor impacting volume was the loss of mean diameter advantage in the ACP provenance. Differences in stem quality were large between provenances and treatments. Rust incidence was much higher in the ACP provenance, while stem form was worse in the LPT provenance. More detailed analyses are underway to look at the relationships among the growth and quality traits.

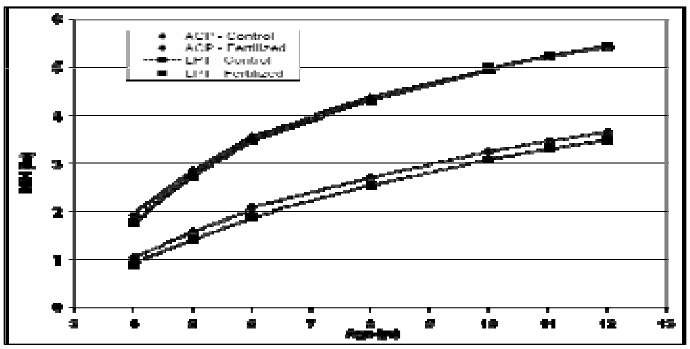


Figure 1. Mean diameters by treatment and provenance

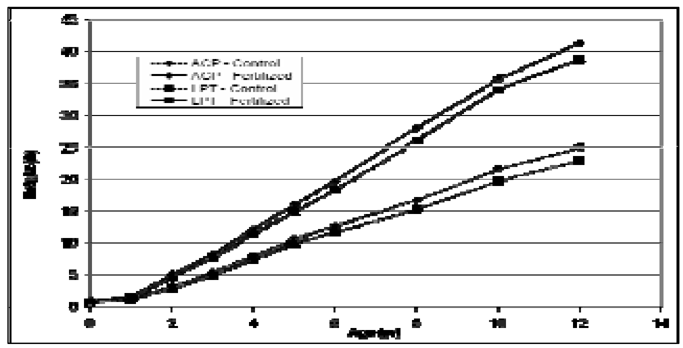


Figure 2. Mean height by treatment and provenance.

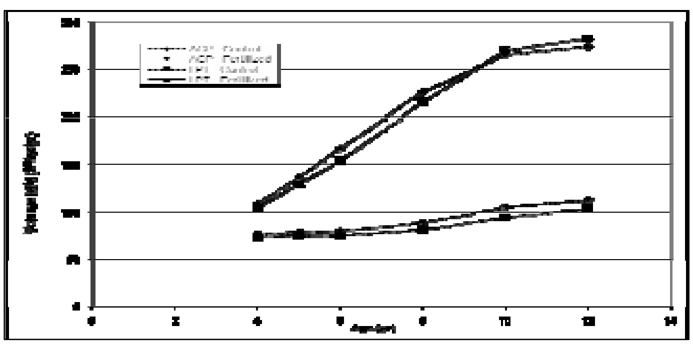


Figure 3. MAI for volume per acre by treatment and provenance.

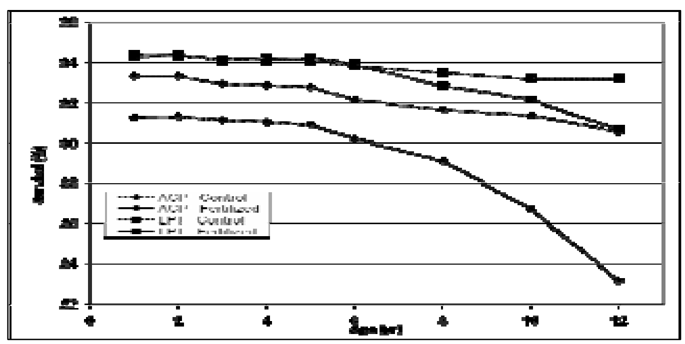


Figure 4. Mean survival by treatment and provenance.

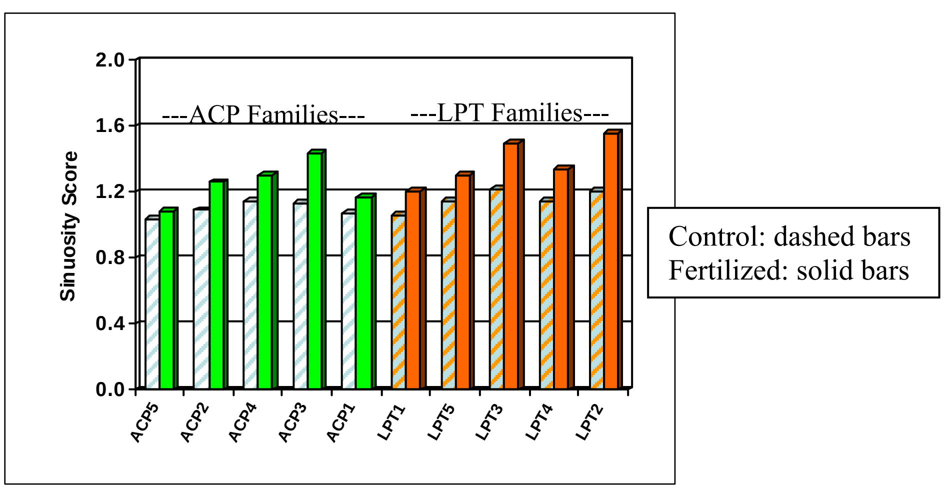
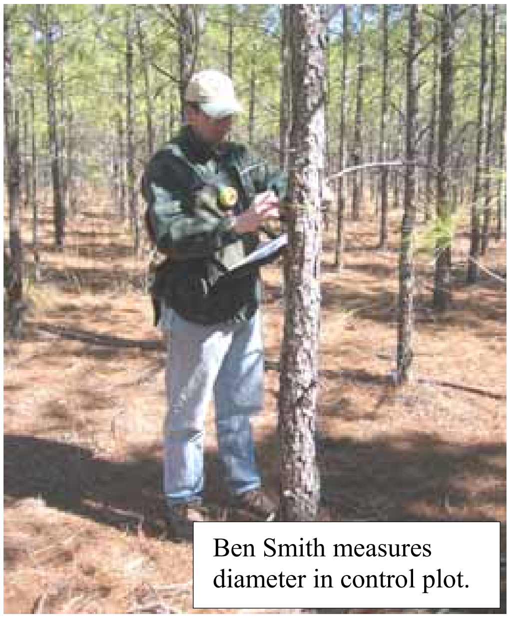


Figure 5. Stem sinuosity means at treatment*family level.

Table 1. Statistical significance for stem form traits at α=0.05

	Trt	Rep	Rep*Trt	Prov	Rep*Prov	Trt*Prov	Rep*trt*prov	Trt*Fam(Prov)	Fam(Prov)
Rust			*	*	*				*
Sweep				*					*
Stem Sinuosity	*							*	*
Branch sinuosity	*							*	*
Straightness				*			*		*
Ramicorn/Fork	*			*		*		*	



Ben Smith measures diameter in control plot.

Matt Lubejko and Tori Brooks measure height and diameter in fertilized plot.

Figure 6. Control (left) and fertilized (right) trees were measured for growth and several stem quality traits at year 12 at the SETRES2 Genetics x Fertilizer Study in Scotland County, NC. Note the competition-induced mortality in the fast-growing fertilized plot above.

ADEPT2 Update

In September 2005, funding from the National Science Foundation began for the Allele Discovery of Economic Pine Traits 2 project (ADEPT 2) under the direction of David Neale and Chuck Langley (UC Davis) and with collaboration with scientists at the University of Florida and Texas A & M University. As described in the 2006 annual report, the overall purpose of this project is to understand the genetics of complex traits and the relationship between natural genetic and phenotypic variation in forest trees. This project is well underway with more than 23,500 cuttings successfully rooted in 2005 and 2006 from a large range-wide association population. Plants have been supplied to collaborators for assessment of three phenotypes including gene expression, pitch canker resistance, and water use efficiency. Genotyping efforts are being coordinated by UC Davis and SNP information should be available in 2007.

Phenotyping for water use efficiency will take place this spring as a component of Patrick Cumbie's PhD research. Approximately 425 clones spanning the natural range of loblolly pine have been grown and will be assessed for water use efficiency using an analysis of carbon isotopes ($^{13}C/^{12}C$). Once the carbon isotope phenotyping is complete, associations with SNPs will be determined. Validation experiments are planned to determine the potential use and application of SNP genotyping for water relations.

Lower Gulf Elite Population Update

This unique population of elite parents for the Lower Coastal Plain of the Gulf Coast was an effort that began in the mid 1990's and involved three cooperative programs in the southeastern United States. The best Coastal material from the NCSU-ICTIP, the Cooperative Forest Genetics Research Program, and the Western Gulf Forest Tree Improvement Program was combined in order to evaluate and develop a superior population of trees for deployment in the Coastal Plain. The original plan involved a complementary breeding design including polymix and diallel mating.

With the increased intensity on economic return in our southern forests, this population affords us the opportunity to not only look at our traditional traits of volume, straightness, and rust resistance but also stem form characteristics that could be improved to add value for solid wood products.

The age-6 Lower Gulf Elite diallel data were collected in the winter of 2007. In addition to the standard suite of traits, we developed a scoring system to evaluate stem sweep in the first log of the tree, branch angle, branch diameter, branch frequency, sawlog potential, stem sinuosity, forking, and ramicorn branching. Also planned for this population is screening of stress wave velocity for assessment of wood stiffness.

In January and February 2007 research assistant Patrick Cumbie and graduate student Jesus Espinoza measured four Lower Gulf Elite diallel tests for stem quality measures (Figure 1). Cooperators measured the age 6 growth and disease traits. This unique data set will allow us to assess the sawlog quality of our best coastal material.

Figure 1. Sweep measurements in the Lower Gulf Elite Population diallel tests. Tree on the left has minimal sweep (<0.5" in the bottom 12' log). Tree on the right has 5.5" sweep.

ASSOCIATED ACTIVITIES

2006 Contact Meeting

Following the 50th Anniversary Celebration in Raleigh, we had our annual Contact Meeting in New Bern, NC. Weyerhaeuser Company hosted the field tour and did a wonderful job displaying the benefits of genetics and intensive silviculture in their forest management system. This was a particularly valuable meeting since we combined efforts with the Forest Nutrition Cooperative. We had 2 days in the field to exchange ideas and look for ways to work more closely with our silviculture colleagues.

The “orange army” at the Contact Meeting with the Forest Nutrition Cooperative was quite impressive. Most of the field tour was hosted by Weyerhaeuser Company, but here the group is looking at the newly planted Genetics – Spacing – Thinning Trial at the Hofmann Forest.

Hofmann Forest Interplanting Study

The Hofmann Forest purchased 50,000 somatic embryogenic (SE) seedlings that were planted operationally in January and February 2007. These varieties are very fast-growing with excellent stem form and rust resistance. SE trees are much more expensive than open-pollinated families or MCP families. Our question is simple. Can the fast-growing SE trees be interplanted with slower-growing, less expensive OP seedlings to produce a stand of crop trees that are predominantly SE trees? If the growth, uniformity, and stem form gains from the SE trees can still be realized when they are interplanted with less expensive seedlings, then the value of these trees can be spread across many acres, and planting costs can be significantly reduced.

We will compare clonal blocks of Q3802 and Q7766 with blocks of these same clones that have been interplanted with OP seedlings of 7-56 and with an elite family mix on two very different sites (one dry and uniform, the other wet and variable). These treatment combinations were chosen, given that the success and growth of any tree is as much, if not more, a function of the microsite rather than the genetics of the tree only. If the site is extremely uniform, then the genetics will have a better opportunity to be expressed. On variable sites, typical of most forested areas, the environmental variation will often mask the genetic potential.

Our testable hypotheses are: if a genetically superior tree (e.g. clone Q3802 or Q7766) happens to go on a poor spot, and a genetically poorer tree is planted on a better spot next to it, the poorer genetics will likely win out. If blocks of clones are planted, the final crop trees will be better because more good trees will be there to compensate for the trees planted on the poor microsites.

The objective of the Hofmann Forest Interplanting Study is to compare the composition of stands planted as clonal blocks to stands interplanted with a mixture of clonal seedlings and open-pollinated seedlings in loblolly pine. We will compare both individual-stem and stand-level traits. This study establishes a set of growth and yield block plots that will be used to research any differences in the two planting regimes.

Six blocks (replications) of the study design were established at the Hofmann Forest February 3 and 10, 2007. Three replications were planted on a very good "dry" site, and 3 reps were planted on the poorer and more variable wet site. Each replication consists of three planting treatments for each clone:

1) pure clonal block
2) interplanted clonal and seed orchard mix (SOM)
3) interplanted clonal and 7-56 OP seedlings

All plots (100-tree block plots) were planted on an initial spacing of 5×20 ft (436 TPA). In the interplanted treatment, the clones were planted on a 20×20 ft spacing while the SOM and 7-56 seedlings were planted in between the clones. A total of 3600 trees over all plots, replications, and locations were planted (Figure 1).

The Cooperative continues to enjoy excellent support from the North Carolina Forestry Foundation and the Hofmann Forest. The Interplanting Study will be a valuable resource to help guide the use and management of clonal stands at the Hofmann in the coming years.

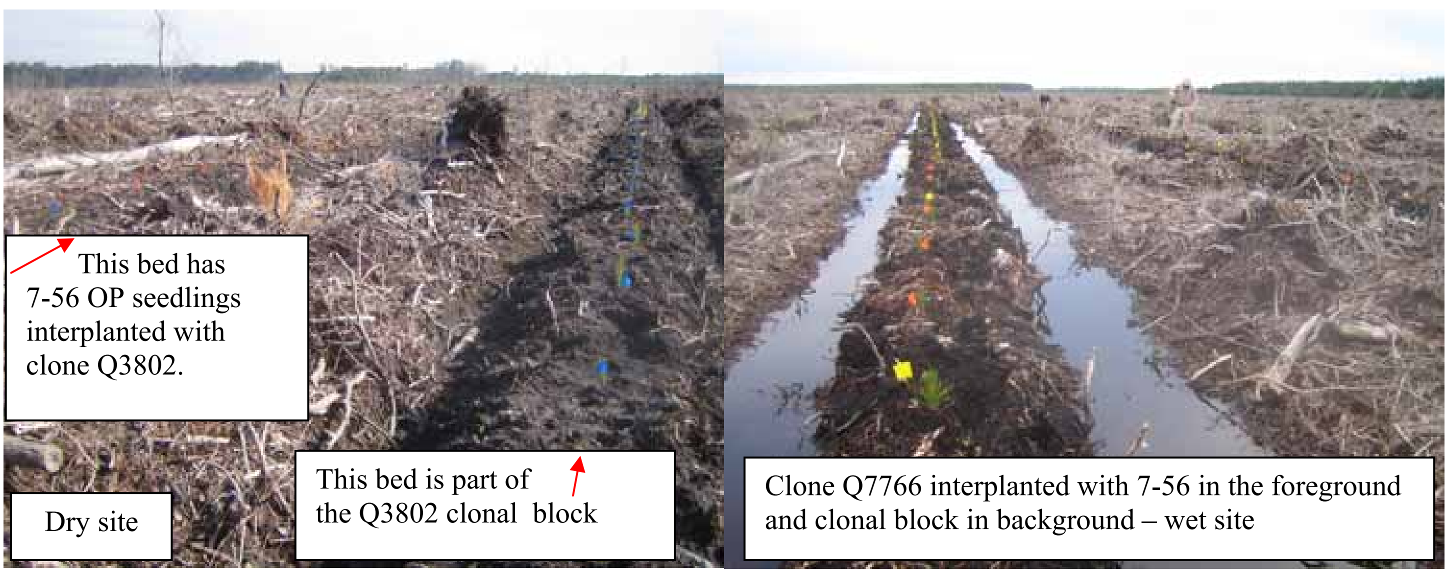


Figure 1. The Interplanting study was established in February 2007 on two separate sites at the Hofmann Forest in eastern NC. The "dry" site on the left had very uniform beds and is a higher site index than the wet site on the right. The "wet" site is more typical of the poorly drained, more variable soils in the lower coastal plain of North Carolina.

GRADUATE STUDENTS

The Cooperative continues to be dedicated to graduate education. Graduate students bring fresh ideas and facilitate collaboration with other faculty at NC State and in other institutions. Through the Tree Improvement Program, students are educated and trained to be the tree improvement leaders of tomorrow.

Mike Aspinwall joined us in January 2005 as a masters student. His project dealt with wood properties and the inherent variation present up the boles of different genotypes. Mike has completed his project, passed his exam, and is in the final stages of finishing his thesis. Mike is staying on for his PhD and will work on a physiology / genetics project with John King and Steve McKeand.

Jonathan (Tyler) Eckard started his MS in August 2005 and is funded by a research grant from the USDA Forest Service, Agenda 2020 Sustainable Forestry Research Program. He is working with Fikret Isik and Bronson Bullock looking at development of prediction models for whole-stem wood Quality of superior loblolly pine clones for deployment. He has collected all his data and is currently in writing mode, expecting to finish this summer.

Jesus Espinoza is working on a project jointly funded by the Forest Nutrition and the Tree Improvement Cooperatives. Jesus received his MS with CAMCORE in 2003 then worked with Carton de Venezuela before returning for his PhD. Jesus has begun collecting data for his project on genetics and cultural effects on stem quality with emphasis on stem sinuosity in loblolly pine.

Daniel Gräns's PhD research is looking at solid wood properties in loblolly pine and Norway spruce. Daniel's Nicholson Fellowship is supporting his work both in Sweden and with the Cooperative. His loblolly pine trial is a Genetics x Culture trial established by International Paper Company in Bainbridge, GA. His samples have been collected, and he is currently analyzing and interpreting data. Daniel hopes to finish by the end of the year.

Ben Smith is a PhD student on a Hofmann Forest Graduate Fellowship. His project is focusing on incorporating realized gain from genetic improvement into loblolly pine growth and yield models using trials established by MeadWestvaco in Walterboro, SC. Ben has collected a majority of the measurements this past winter for his project and is working on analyses.

Sherry Xiong joined us this past fall from China for her PhD work.. She was introduced to fieldwork shortly after her arrival when she joined Daniel on his trip to Bainbridge, GA. Sherry will be working on a project looking at the genetic factors of forking in loblolly pine.

Student, Degree, Research Project

Mike Aspinwall, MS, Whole stem wood properties in loblolly pine

Patrick Cumbie, PhD (part time), Association genetics in loblolly pine

Tyler Eckard, MS, Prediction of whole-stem wood quality of superior loblolly pine clones for deployment

Jesus Espinoza, PhD, Genetics and silvicultural effects on stem quality in loblolly pine.

Daniel Gräns, PhD, Variation in solid wood properties in Norway spruce and loblolly pine.

Ben Smith, PhD, Incorporating realized gain from genetic improvement in loblolly pine growth & yield models

Sherry Xiong, PhD, Genetic factors in forking of loblolly pine.

COOPERATIVE STAFF

A year ago, we reported that Bailian Li took over as Interim Vice Provost for International Affairs. We now have to report that he has accepted the Vice Provost position as a permanent one with the university. Here is a description of what Bailian will be up to (http://www.ncsu.edu/oia/oiaadmin.html):

Dr. Bailian Li is the leader of University International Programs, reports to the Provost, and collaborates with College Deans and their International Coordinators in the internationalization of the University. His mandate is to lead and promote a global perspective into all functions of teaching, research, and extension/ engagement and to strengthen NC State's international presence in an ever-changing global society. Before joining OIA, Dr. Li was a professor in the Department of Forestry and Environmental Resources and Co-Director of the North Carolina State University-Industry Tree Improvement Program. Previously, he worked at the University of Minnesota for six years and has been at NC State since 1996. Dr. Li has extensive international experience in research and teaching collaboration with many foreign universities, research institutes and governmental agencies, including Australia, Canada, China, Chile, Finland, Malaysia, New Zealand, Sweden, and Turkey. He has been active leader in several international professional organizations and served as adjunct professor at several foreign universities.

Bailian joined the Cooperative staff in 1996 and was an integral part of the success of the program. His scholarship and practical problem-solving contributions will be sorely missed. We struggle seeing Bailian in a suit and tie all the time, but we wish him the best of luck. Once again, the problem with having such talented people on our staff is that they get stolen to work in other units on campus. Gosh, we sure do like having friends in high places!

Steve McKeand now begins his tenure as Director of the Cooperative. A long-standing staff member of the Cooperative, he has taken the helm during a time of great change.

Along with the loss of Bailian, we also lost our Administrative Secretary, Kathie Zink. As changes come about lately in the Cooperative, there is always that one person who applies for the new job. Tori Batista-Brooks came into the new joint position of Assistant Director of Administration with the Tree Improvement and Forest Nutrition Cooperatives. Tori is the *go-to* gal for all of those unanswerable questions that arise on a daily basis.

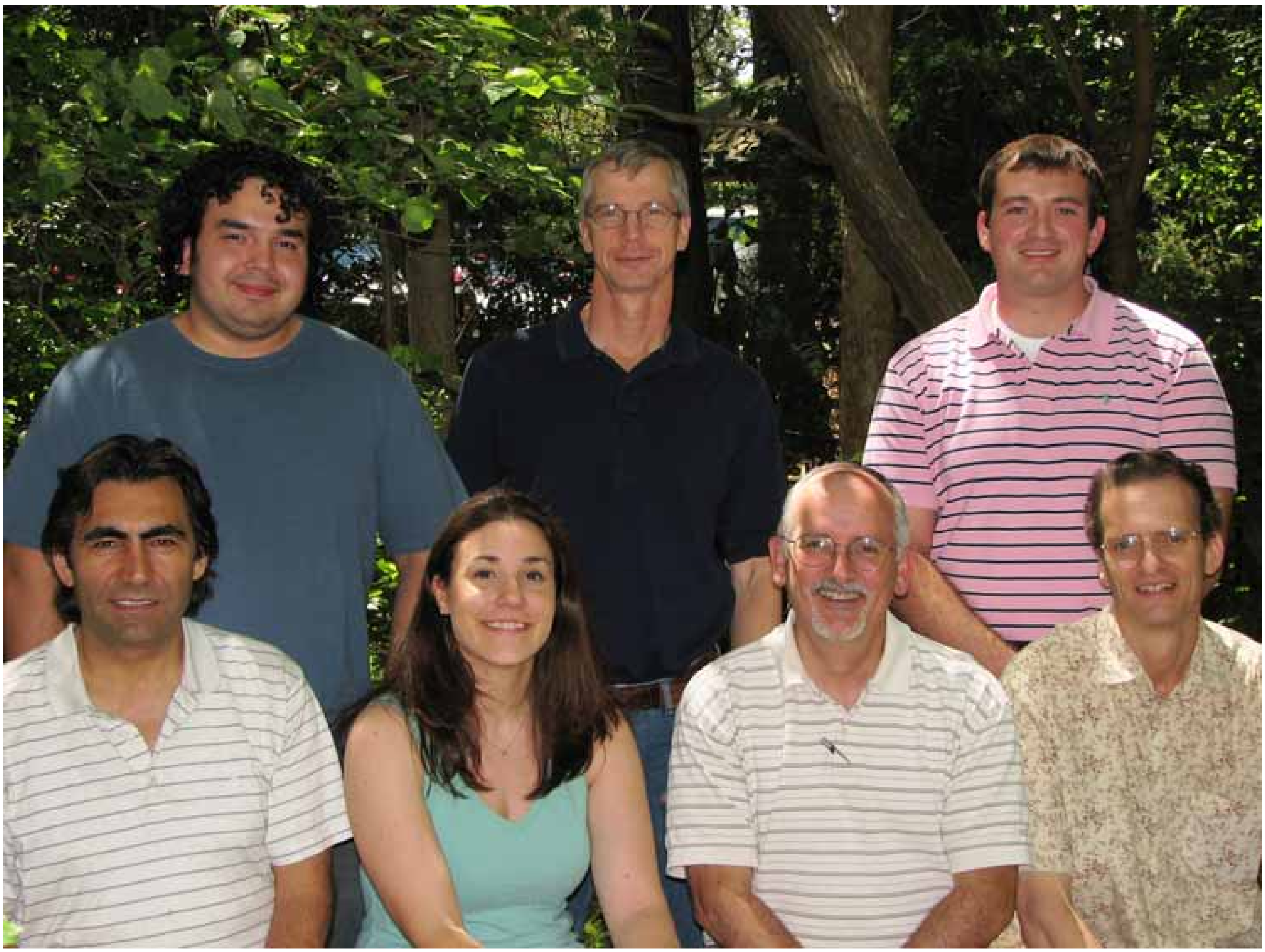
Like any good experiment there always needs to be a control, and our constant is Dr. Jim Grissom. He continues as Tree Improvement Analyst with primary duties of managing and developing the Cooperative's database. He has also been the lead in getting the Performance Rating System (PRS) up and running for Cooperative members. Jim also had big news recently. Having recently returned from a honeymoon vacation with his new bride, he looks forward to continuing to help develop the programs of the Tree Improvement Co-op.

For the last year Patrick Cumbie and Dr. Fikret Isik have helped fill the hole that Bailian had left. Fikret has worked with Jim on statistical details for the PRS and taken the lead on several of the grants that Bailian had acquired before his departure. It has been beneficial to all of us having another statistical guru on staff, and we look forward to Fikret's continued contribution to the program in a full-time position.

Patrick has been working on several special projects such as the Lower Gulf Elite Population measurements and has taken over the management duties of the breeding and testing from Tori, all while pursuing his PhD "on the side". He also added a future tree breeder to the family this spring, Baby Will … and he thought he was busy before! Patrick will continue in his role as breeding coordinator and field manager for the foreseeable future.

Saul Garcia continues as the molecular master, but has gotten a crash course in Tree Improvement over the last year! He has taken over the lab manager position as well as jumping in to help teach the lab portion of the tree improvement course (FOR 727) that was taught this spring semester. He has also been a leader in some departmental changes in lab space and has ensured that Tree Improvement will not only maintain but improve its current lab facilities. Saul and Patrick have been working closely to develop QA/QC protocols for incoming seed and pollen to provide more precise and streamlined breeding and testing outputs from the lab.

Last but not least, we have a new addition to the research team of the Cooperative staff, Dr. Ross Whetten. Ross has been a leader in forest genetics research at NCSU for many years, and this leadership will fill some of the void that Bailian left behind. Ross has taken on a more active role in the Cooperative, and we look forward to benefiting from his strong molecular genetics background.



Tree Improvement Staff*: Back Row L→R: Saul Garcia, Ross Whetten, and Patrick Cumbie*
Front Row L→R: Fikret Isik, Tori Batista-Brooks, Steve McKeand, and Jim Grissom

Membership of the NCSU-Industry Cooperative Tree Improvement Program

And I thought I had seen everything last year when I said in the Annual Report "*The Cooperative is in the midst of the greatest period of change in membership in its 50-year history. This change is a reflection of the unprecedented shift in forest land ownership during the past 20 years, as well as budget limitations by many of the state forestry agencies. Since 1985, mergers and acquisitions within the industry have resulted in a significant decline in Cooperative membership*". Little did we know that even more significant membership changes were on the way. In the fall 2006, International Paper Company's land sales were finalized. We are all still waiting to hear what will become of the Nurseries and Orchard business. As of the time of this writing (mid May 2007), no buyer has been announced.

Before the dust has even settled with the IPCo changes, in January 2007, MeadWestvaco announced the sale of much of their timberlands and that they were exiting the business of nurseries and orchards. We are optimistic that the MeadWestvaco tree improvement program will survive in some fashion, but it will not be owned by the same company – stay tuned. In February, Temple Inland announced the sale of their timberlands. This will mean the end of Temple's membership in the Cooperative, but stranger things have happened.

We wish all of our long-term supporters, colleagues, and friends with IPCo, MeadWestvaco, and Temple the best of luck. To paraphrase the old Irish blessing♣ *May the pollen be always blowing at your back.*

Membership of the
NCSU-Industry Cooperative Tree Improvement Program

CellFor, Inc.
Georgia Forestry Commission
Hancock Timber Resources Group
International Paper Company
Joshua Land Management, L.L.C.
MeadWestvaco Corporation
North Carolina Division of Forest Resources
Plum Creek Timber Company
Rayonier, Incorporated
Smurfit - Stone Container Corporation
Temple-Inland Inc.
Tennessee Department of Agriculture
Virginia Department of Forestry
Westervelt Company
Weyerhaeuser Company

Research Associate Member
ArborGen

♣ May the road rise to meet you. May the wind be always at your back. May the sun shine warm upon your face. And rains fall soft upon your fields. And until we meet again, may God hold you in the hollow of his hand.

PUBLICATIONS OF SPECIAL INTEREST TO MEMBERS (2004-2007)

From our inception in 1956, there have been over 800 publications written by Cooperative Scientists, Students, and Associates. Below is a list of publications from the last 3 years. The entire list is available at our web site: http://www.cnr.ncsu.edu/for/research/tip/tip.html

2007

Sherrill, J.R., T.J. Mullin, B.P. Bullock, S.E. McKeand, R.C. Purnell, M.L. Gumpertz, and F. Isik. 2007. An evaluation of selection for volume growth in loblolly pine. Silvae Genetica (in press).

McKeand, S.E., B. Li, J.E. Grissom, F. Isik, and K.J.S. Jayawickrama**.** 2007**.** Genetic parameter estimates for growth traits from diallel tests of loblolly pine throughout the southeastern United States. Silvae Genetica (in press).

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Education has always been a mainstay of the Cooperative. Students from around the world have come to NC State and taken courses such as FOR 725 (Forest Genetics) and FOR 727 (Tree Improvement Research Techniques). Students, staff, and faculty enjoyed the trip to the NC Forest Service nursery and orchards at Goldsboro, NC: L→R: Haley Hibbert, Saul Garcia, Nhora Isaza, J.B. Jett (instructor FOR 727), Sherry Xiong, Steve McKeand (instructor FOR 725), Tyler Eckard, Ben Smith, Juan Lopez, and Lizzie Wood.

Department of Forestry & Environmental Resources
College of Natural Resources
North Carolina State University May 2007

Mass Controlled Pollination at MeadWestvaco

Over 94 million control-pollinated full-sib seedlings have been planted operationally in the southeastern US since 2000.