FORTY-EIGHTH

PROGRESS REPORT

OF THE

COOPERATIVE

FOREST TREE IMPROVEMENT

PROGRAM

By

**T. D. Byram, F. E. Bridgwater, G. D. Gooding,
D. P. Gwaze, W. J. Lowe, and J. H. Myszewski**

Circular 401

December 2000

**TEXAS FOREST SERVICE
a Member of
The Texas A&M University System**

An Equal Opportunity Employer

TABLE OF CONTENTS

INTRODUCTION

The long-term stability of cooperatively supported silvicultural research was a major concern for many organizations in 2000. This anxiety stemmed from a number of factors, including continued consolidation in the forest industry, changes in land ownership patterns, uncertainty regarding the future of support for long-term forestry studies, and increased emphasis on proprietary research. The Western Gulf Forest Tree Improvement Program was not immune to these pressures with the loss of Champion International Corporation as a distinct entity and with other impending mergers likely to further reduce the number of cooperative members. In addition, the ownership of large acreages continued to be transferred to investment firms that have traditionally not supported silvicultural research. Furthermore, the rapidly developing field of biotechnology has increased pressure on both government funding agencies and industry to support short-term proprietary research at the expense of more traditional long-term research programs.

The impact of industry consolidation and shifting ownership patterns on tree improvement programs is two-fold. The most immediate effect is to reduce the number of organizations financially supporting the cooperative's operating budget. However, a much more serious impact is the reduction in the number of members participating in the breeding and testing program. Historically, when a member has withdrawn from the program, responsibility for their portion of the breeding population has either been assumed by the acquiring organization or redistributed among existing members within the same breeding zone. This has resulted in a breeding population that has been remarkably stable in size and organization despite the changing makeup of the cooperative's membership.

Maintaining the integrity of the breeding and testing program with fewer members will be one of the major challenges facing the cooperative within the context of industry consolidation. However, the Western Gulf Forest Tree Improvement Program is well positioned to accomplish this task. First, the cooperative has a solid core of very active state organizations with progressive breeding and progeny testing programs. Each of the state organizations maintains a significant portion of the breeding population in their respective breeding zones, working with all species and provenances represented in the program. They have aggressively pursued their breeding and progeny testing efforts and were among the first organizations to complete first-generation progeny test establishment. Secondly, the major investment in the first cycle of tree improvement is complete with most first-generation parents now established in progeny tests. As a result, the cooperative is currently experiencing an influx of new data that will enable the advanced-generation breeding program to concentrate on a smaller, more highly selected population. Finally, changes in the breeding program such as the use of polymix tests for parental evaluation and the adoption of new technology like top-grafting have made the program more effective and efficient.

A second major challenge facing the cooperative is to maintain the collaborative atmosphere that has characterized applied tree improvement programs under increasing pressures for proprietary research. Tree improvement programs have been a model for such collective efforts since their inception nearly 50 years ago. From the beginning, common standards have been maintained for managing the breeding and testing programs and the resulting information and plant material has been freely shared among members. However, the composition of the production populations and the business plans based upon those populations have been determined by the individual members. While biotechnology has complicated these considerations, it has not changed their fundamental nature. All production programs benefit from access to an improved base population regardless of the strategy for further enhancement and deployment. The cooperative has addressed these issues through a clear definition of germplasm ownership.

The benefits of a collaborative breeding program are at least as great for advanced-generation breeding programs as they were for the initial stages of selection and testing. Regional cooperation in test establishment distributes the workload, shortens the testing cycle, and improves the accuracy of the comparisons among parents. More importantly, as tree improvement populations are only one or two generations removed from the wild, collaboration is still necessary to screen the large number of parents needed to identify individuals with combinations of the most desirable traits.

During 2000, the Western Gulf Forest Tree Improvement Program – Pine made substantial progress in both seed orchard establishment and the breeding and progeny testing programs. Orchard acreage within the cooperative has gradually increased over the last 10 years. Sixty-three acres of advancing-front orchard were established in 2000, while only 28 acres of first-generation seed orchard were removed from production. In addition, a record number of progeny tests were measured in 2000 resulting in the identification of the most second-generation selections found in a single year. Accelerated flowering resulting from the widespread adoption of top-grafting also continued to benefit the breeding program. Using this technique, it may be possible to polymix cross one-half or more of the new selections in the year after they are selected. Twelve of the cooperative's fifteen members are currently conducting polymix breeding of second-generation selections for ranking performance. Pedigreed breeding for third-generation selection also continued with four members making controlled crosses for this population in 2000.

Progress was made in both first-generation and advanced-generation progeny test establishment during 2000. Fifteen progeny tests representing 351 first-generation loblolly and slash pine parents were planted by the cooperative. Eight members have now completed the establishment of all of their first-generation loblolly pine progeny tests. Polymix tests of second-generation selections were also established in two regions. The first tests in the South Louisiana/South Mississippi breeding region were grown during the summer of 2000 and field planted in the fall by the Mississippi Forestry Commission, The Timber Company, and Weyerhaeuser Company. Second-generation polymix tests were also established in East Texas by Champion International Corporation and Temple Inland Forest.

The cooperative continued to examine its breeding objectives and strategies with the overall goal of improving profitability. Most members desire a multipurpose tree, and this objective can be met with the traditional emphases on improving growth, disease resistance, bole straightness, and wood specific gravity. As the program matures, there will be opportunities to add additional traits or to select characteristics for specific end-products. However, it is likely that some of these desirable characteristics will be negatively correlated and incorporation of these traits will require the development of different selection procedures to optimize genetic gain. With these considerations in mind, initial results from several studies are contained in this report. These include the inheritance of microfibril angle, the relationship between growth and wood specific gravity, and estimates of log degrade attributable to fusiform rust infection. Additionally, a recently completed study of the age-age correlations for loblolly pine height and preliminary results from a study examining the suitability of slash pine hybrids for the Western Gulf Region are also summarized.

The members of the Western Gulf Forest Tree Improvement Program – Hardwood continued activities to support the traditional tree improvement program and studies that support natural stand management activities in bottomland hardwoods. Potlatch Corporation collected seven-year data from its hardwood thinning study. To increase the amount of seed available to the nurseries, the Mississippi Forestry Commission, Temple-Inland Forest, and the Louisiana Department of Agriculture and Forestry converted cherrybark and water oak progeny tests to seedling seed orchards.

In 2000, the members maintained 33 progeny tests, mostly Nuttall oak. The members obtained first-year survival data from the last series of tests for this species. In total, 22 progeny tests that contain 216 selections from Arkansas, Louisiana, Mississippi, and Texas were established. Ninety percent of these selections have been grafted and preserved in scion banks. The best selections, based on progeny test data, will be used to establish future seed orchards.

To help meet the expanded need for hardwood seed, a portion of the cherrybark oak and water oak progeny tests was converted to seedling seed orchards. Even though the tests were between 15 and 20 years old, acorn production was observed. These seed orchards will produce an interim supply of seed for the nurseries until the grafted second-generation seed orchards begin seed production. The members decided to establish another series of open-pollinated progeny tests to evaluate the clones in the second-generation seed orchards. The data from these tests will determine which clones will be used for operational seed collection. These activities will improve the genetic quality of the hardwood seedlings used in the expanded bottomland reforestation program.

After seven-years, data collected for the hardwood thinning study maintained by Potlatch Corporation indicated the thinning could increase diameter growth without causing a decrease in log quality. The more intensive thinning treatments resulted in a greater stimulation of diameter growth than light thinning treatments.

WESTERN GULF FOREST TREE IMPROVEMENT PROGRAM

Highlights

- Seven members of the cooperative grafted 63 acres of advancing-front seed orchards in 2000. The cooperative now manages 2,193 acres of seed orchards including 966 acres of advanced-generation orchard.
- The annual increase in genetic gain for newly established loblolly pine seed orchards has averaged 1.7 percent improvement for volume growth over the last seven years. This exceeds the 0.5 percent annual improvement projected when advancing-front seed orchards were initiated.
- The cooperative's continued emphasis on profitability as the ultimate breeding objective is highlighted in sections addressing log degrade caused by fusiform rust and the inheritance of specific gravity and microfibril angle.
- Age-age genetic correlations for height growth appear to be larger than phenotypic correlations for loblolly pine. The current selection age appears to be conservative if selection is made on height alone.
- In four studies of slash pine hybrids, no hybrid taxa outperformed the parental species for growth. Several of the hybrid taxa suffered severe freeze damage and appeared to be extremely susceptible to fusiform rust.
- A record number of progeny tests were measured in 1999/00, resulting in the identification of a record number of second-generation selections. Fifty-four progeny tests were screened with 11 cooperators, which resulted in 152 second-generation selections.
- Two regional advanced-generation polymix tests were established in East Texas during the 1999/00 and 2000/01 planting seasons and three tests in South Louisiana/South Mississippi during the 2000/01 planting season. The tests established in the South Louisiana/South Mississippi region represented the first plantings for this breeding region and included 107 parents.
- The cooperative participated with other organizations managing conifer seed orchards to compile a list of commonly used pesticides and to document the methods and rates of application. This survey is being used to support industry's use of insecticides for cone and seed insect control

Seed Orchards

The seed orchard acreage managed by the cooperative has remained remarkably stable over the last several years, despite the members' changing needs and the realignments within the forest industry. In fact, the orchard acreage under management has consistently exceeded the acreage needed to support the projected regeneration program by almost 25 percent. This excess capacity should have resulted in record harvests and the opportunity for members to divest themselves of surplus orchard acres. However, members continued to add acres at a slightly faster rate than they were removed from management.

The factors behind this apparent contradiction relate to both short-term seed needs and perceived long-term seed demands. The weather has been capricious with unseasonable spring freezes resulting in unpredictable flower crops. The region-wide drought that began in Texas in 1995 has further increased the need for seed because of increased planting due to fire and drought-related mortality. This has reduced seed inventories and resulted in temporary shortages for specific seed lots. Furthermore, many organizations have recognized that the regulatory environment under which seed orchards and tree nurseries operate is uncertain. Increasingly restrictive pesticide regulation threatens to make seed production more unreliable and optimal seed-to-seedling ratios more difficult to obtain. Because of this, many organizations are maintaining older orchards in an attempt to increase the amount of seed in inventory. Controlled mass pollination programs have also provided an incentive to continue active management of older orchards.

Long-term seed needs are based on projected harvest and regeneration schedules. As planning horizons for seed orchard production programs must anticipate seed needs ten or more years in the future, these projections are unavoidably imprecise. Current predictions have been further complicated by the ongoing series of mergers, mill closures, and changing patterns of land and mill ownership. However, it appears certain that the continued use of smaller logs will increase the rate of harvest on both industry and small private landholdings. This will increase the absolute amount of seed needed. A direct result of shorter rotations is to place a premium on seed with the highest possible genetic gain. Industry, which emphasizes intensive land management, needs the fastest growing sources to maximize its return on investments in site preparation, fertilization, and competition control. Non-industrial private landowners have also increasingly shown a willingness to pay a premium for the best seedlings, making genetic improvement an important element in seedling sales.

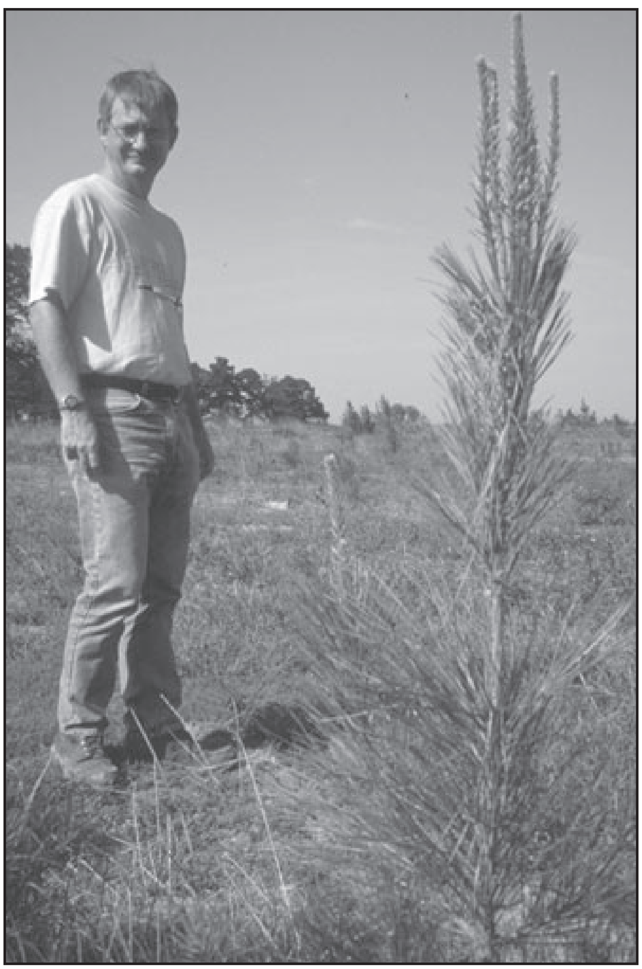

Figure 1. French Wynne reviewing the grafting success in Potlatch Corporation's new seed orchard complex.

Increased demands for the best genetic material makes the rapid transfer of genetic gain from the breeding population to the production population essential. The recognition that advancing-front orchards are one of the most effective means of making this transfer is reflected in the cooperative's aggressive seed orchard establishment and replacement program. Seed orchard establishment within the cooperative appears to be accelerating. In addition to the recent induction of Louisiana Pacific Corporation into the cooperative with its aggressive seed orchard establishment program, several members are responding to projected increases in long-term seed needs with accelerated orchard establishment programs of their own (Figure 1).

Orchard Establishment and Roguing

During 2000, seven of the cooperative's fifteen members grafted 63 acres of loblolly pine advancing-front seed orchards. This included five members that postponed grafting from the previous year due to poor rootstock development caused by the hot-dry weather during the 1998 growing season. Orchard blocks were established by Boise Cascade Company, Arkansas Forestry Commission, Deltic Timber Company, Louisiana Department of Agriculture and Forestry, Louisiana-Pacific Corporation, and Potlatch Corporation. In addition, Arkansas Forestry Commission grafted a progeny-tested shortleaf pine seed orchard, and Weyerhaeuser Company converted seven acres of longleaf pine progeny tests into a seedling seed orchard. The Timber Company was the only organization removing orchard acreage from production. They removed 28 acres of genetically obsolete first-generation orchard to make room for their next block of advancing-front orchard. As a result of these additions and deletions, the cooperative now manages 2,193 acres of loblolly and slash pine seed orchards (Figure 2). Of this total, 966 acres (44 percent) are advanced-generation orchards

Irrigation and fertigation are routinely used by most members of the cooperative during orchard establishment. These cultural practices have improved rootstock quality for field grafting and have contributed greatly to the overall grafting success. This was certainly true this year in Boise Cascade Company and Louisiana-Pacific Corporation's new orchards. Boise Cascade Company established 15 acres of advancing-

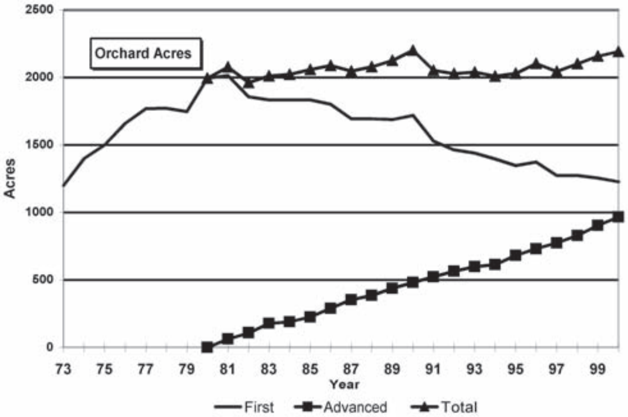

Figure 2. Seed orchard acres managed by the cooperative.

front orchard that was 100 percent completed after only minor transplanting. Louisiana-Pacific Corporation established its second 24-acre block of seed orchard in as many years (Figure 3). After minor amounts of transplanting, the first 24-acre orchard block was 98 percent complete. The second 24-acre orchard block was 96 percent established before transplanting.

Figure 3. Arthur Nichols, Louisiana Pacific Corporation, with a two-year-old graft in their first block of seed orchard.

Genetic gain for the most recently established orchard blocks averaged 33.1 percent above the unimproved local checklots (Figure 4). Over the seven-year period from 1993 to 2000, the cooperative's new orchards have averaged an annual improvement of 1.7 percent gain in breeding value for volume production. This rate of improvement has exceeded the 0.5 percent annual improvement projected when the replacement of first-generation orchards began due to the quantity and quality of progeny testing conducted by the members. The projected 0.5 percent annual improvement was based on a 16-year breeding cycle, which can be substantially shortened in the next cycle with the adoption of accelerated flowering methods such as top-grafting. The cooperative anticipates obtaining substantially more genetic gain in future cycles.

The Bosch Nursery and Temple-Inland Forest rogued loblolly pine seed orchards in 2000. This resulted in improving the genetic quality of these orchards by 1.8 percent. The Louisiana Department of Agriculture and Forestry also rogued its 30-acre longleaf pine seedling seed orchard (Figure 5). This

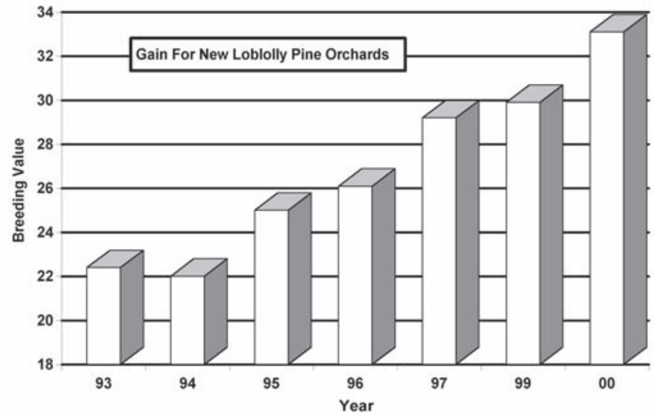

Figure 4. Gain in breeding value for volume growth averaged over new loblolly pine seed orchards by year of establishment.

orchard was established with families selected on the basis of their performance for survival, brown spot resistance, and grass stage emergence in the cooperative's short-term progeny tests. Families are now being eliminated based on ten-year data from long-term growth and form progeny tests. Individuals within family plots are also being removed with the ultimate objective of leaving approximately 50 families in the orchard at an average density of 50 trees per acre.

Orchard Yields

The 1999 seed crop totaled 25,250 pounds of loblolly pine and 1,742 pounds of slash pine seed. This was well below the amounts collected in the record years of 1996 and 1998, and was also substantially below the average production of 38,850 pounds achieved over the last 10 years (Figure 6). It has been impossible to estimate the impact of the hot dry weather on the seed crop. Wet springs and dry summers are generally considered conducive to abundant flower production during the following spring. However, anecdotal evidence from East Texas indicates that the severe drought experienced in this region has had a negative impact on flower production. Furthermore, both cones and seed were observed to be smaller than average. There were also many cones that failed to complete normal development. The exact cause for this problem is un-

Figure 5. Roguing in the Louisiana Department of Agriculture and Forestry longleaf pine seedling seed orchard.

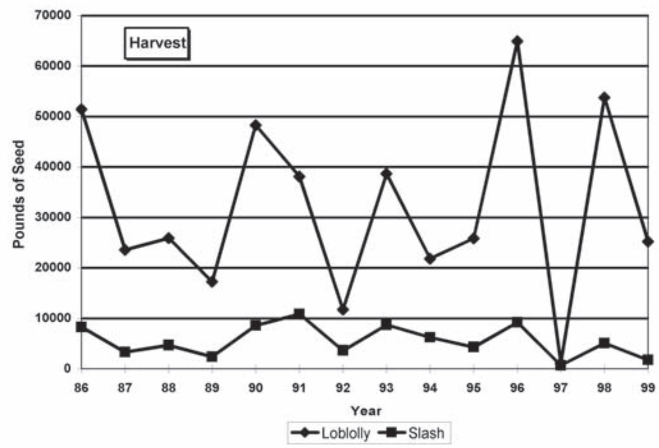

Figure 6. Pounds of seed harvested by the cooperative from 1986 to 1999.

known, but possible factors are late season outbreaks of coneworms, fungal problems, or drought-related developmental problems.

Loblolly pine seed yields were definitely below expectations in 1999, averaging only 0.96 pounds of seed per bushel of cones. Only three members managed to exceed the 1.1 pounds per bushel average that the cooperative uses to plan orchard expansions. These were Champion International Corporation with 1.19 pounds per bushel, The Timber Company with 1.18 pounds per bushel, and Weyerhaeuser Company with 1.14 pounds per bushel. One cause of the lower seed yields was reflected in the x-ray data collected as part of the annual cone harvest monitoring program. In 1999, the percentage of seed classified as good seed was 68.9 percent, compared to the historical average of 77.5 percent. Most of this loss was in seed classified as insect damaged. The seed per pound was not determined, but it is likely that there were also larger than average fractions of small and medium seed. More small seed would weigh less per bushel, but not necessarily result in fewer seed per bushel.

The 2000 cone harvest totaled 35,255 bushels. This included 28,211 bushels of loblolly pine and 6,930 bushels of slash pine. This should be sufficient to meet the cooperative's annual needs, but does not provide any surplus to increase seed inventories. A highlight of the 2000 cone harvest was the first commercial collection from the Mississippi Forestry Commission's longleaf pine seedling seed orchard. Ninety bushels of cones were collected from 12 acres of 12-year-old trees. This orchard received a summer application of nitrogen to stimulate flower production, but at rates lower than those typically used in loblolly and slash pine seed orchards (Figure 7).

The 2000 cone crop completed development under unprecedented August and September temperatures with daily highs exceeding 110° F on several occasions. As a result, cones opened earlier and over a shorter period of time than normal, compressing the available time period to complete the harvest. The impact on seed yield and quality has not yet been determined, but the daily high temperatures were greater than the kiln temperature typically used for cone drying and seed extraction.

Figure 7. Precocious flowering in the Mississippi Forestry Commission's longleaf pine seedling seed orchard at age 12.

Breeding Objective: Increased Profitability

All commercial tree improvement programs are predicated on increased profitability as the primary breeding objective. At the initiation of the selection and breeding programs in southern pines, improved volume production per acre was recognized as the single most important factor contributing to economic return. In fact, early work showed that as little as two percent improvement in growth rate would justify the entire breeding and testing effort[1]. Improved volume production still remains the most important trait among the Western Gulf Forest Tree Improvement Program's breeding objectives. However, as the program matures, other traits are being evaluated that may contribute to overall profitability.

Two of these traits are wood quality and disease resistance. Wood quality is an important trait that influences major strength properties of sawn timber as well as pulp and paper properties. At this time, there is no market premium paid for stumpage with improved wood quality if bole straightness and diameters meet minimum standards. However, there is evidence that wood specific gravity and microfibril angle may have unfavorable genetic correlations with volume growth. Therefore, continued selection for volume growth alone could result in a deleterious effect on wood quality. This could reduce the ability to produce an all-purpose tree for the diversified southern pine timber market. Disease resistance has a direct effect on volume production. In addition, the resulting product degrade has a direct impact on value. The next two sections address ongoing research into the genetic relationships between wood quality and growth. The third section attempts to quantify the relationship between fusiform rust resistance and log value.

Microfibril Angle

Microfibrils are bundles of cellulose chains found in the secondary cell wall and contribute to many properties of pine

[1] Porterfield, R. L. 1973. Predicted and potential gains from tree improvement programs – A goal programming analysis of program efficiency. Ph.D. Dissertation. Yale Univ. New Haven, CT. 240 p.

lumber. In the most prominent layer, the microfibrils run nearly parallel to each other and to the bole of the tree. The more closely the microfibrils align with the bole of the tree (low microfibril angle or MFA), the higher the tensile strength and stiffness of the fibers and solid wood products experience less longitudinal shrinkage. The objectives of the WGFTIP microfibril angle study were to determine 1) if microfibril angle was inherited in loblolly pine, 2) if the variation was sufficiently large to warrant a breeding program, and 3) the genetic relationships among MFA, height and diameter growth, and wood specific gravity.

In 1994, increment cores were collected from the progeny of 12 and 17 crosses, respectively, in two of The Timber Company's South Arkansas loblolly pine progeny tests (GP065 and GP258). The cores were dissected in the fall of 1999 to isolate the earlywood and latewood sections of rings 4, 5, 19, and 20 for MFA analysis. Rings 4 and 5 were considered to be juvenile wood, and rings 19 and 20 were considered to be mature wood. MFA was measured in all samples by Dr. Robert Megraw of Weyerhaeuser Company using X-ray diffraction techniques.

A wide range of MFA values was observed among trees in both progeny tests (Figure 8). Differences between earlywood and latewood MFA and between juvenile and mature wood MFA were highly significant. Differences in MFA between crosses at both tests were also significant.

Family heritability estimates were moderate and variable. At GP065, estimates were 0.46 for juvenile earlywood, 0.45 for juvenile latewood, 0.27 for year 19 earlywood and 0.44 for year 20 latewood MFA. At GP258, heritabilities were estimated as 0.35 for juvenile earlywood, 0.45 for juvenile latewood, 0.46 for mature earlywood and 0.44 for mature latewood MFA.

MFA had a favorable genetic relationship with specific gravity and a moderate but generally unfavorable genetic relationship with height and diameter growth. These preliminary results indicate that MFA is heritable and has variation of sufficient magnitude to be incorporated into a tree improvement program, especially one focusing on specific gravity. Additional research is still necessary to understand the implications of including this trait in a breeding program.

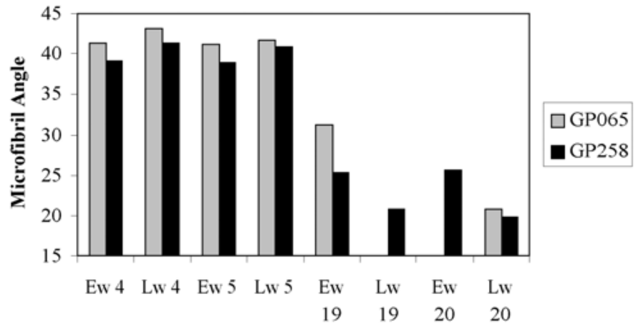

Figure 8. Mean microfibril angle by test for earlywood (Ew) and latewood (Lw) by ring number. Samples for Lw19 and Ew20 from GP065 were dropped due to sample contamination.

Genetic Parameter Estimates for Growth and Wood Density in Mature Loblolly Pine

Understanding the relationship between traits is important for improving selection efficiency, predicting genetic response to selection, and developing efficient breeding plans. This is particularly true for wood quality and growth, which may have a negative genetic correlation. Most information about the relationship among these characteristics has been phenotypic primarily because of the lack of older controlled pollinated progeny tests in which genetic parameters could be estimated. This study was undertaken to estimate individual-tree heritabilities for wood density, height and diameter growth, and genetic correlations among these traits.

The data were from a mixture of half- and full-sib families involving a total of 33 first-generation parents selected for superior growth. The tests were established in four different years between 1967 and 1974 by the Georgia Pacific Corporation (now The Timber Company) in Ashley County, Arkansas. Trees were planted at 8 x 8 feet (2.4 x 2.4 meters) spacing and each plot was composed of 9 to 64 trees. The progeny tests contained 3 to 10 replications in a randomized-complete-block design. The trees were assessed for height and diameter at 5-year intervals from 5 to 25 years. Wood density was determined for each tree from a core sample taken bark-to-bark with a 7mm increment borer at breast height. Specific gravity was determined for cores from rings 0 to 5, 6 to 20, and the total core.

Estimates of individual tree heritabilities suggested that mature wood density and height were strongly inherited (h^2 = 0.48-0.78 and 0.15-0.63, respectively) and that diameter was less strongly inherited (h^2 = 0.04-0.61) (Table 1). Heritability estimates for juvenile wood density were less than those for mature wood density and total density. Heritability estimates for mature and total wood densities were highest in the test with the slowest growth rate and highest mean wood densities (GP103).

Genetic correlations between juvenile and mature wood density were generally lower (0.52-0.95) than those between total wood density and either juvenile or mature wood density

Table 1. Heritability estimates for growth and wood density at four tests and five ages.

Trait[1]	Test			
	GP065	GP102	GP103	GP258
H05	0.15	-	-	-
H10	0.16	0.63	-	0.41
H15	0.21	0.52	0.23	0.39
H20	0.24	0.33	0.19	0.51
H25	-	0.35	-	0.43
D05	0.11	-	-	-
D10	0.17	0.07	-	0.61
D15	0.24	0.07	0.04	0.28
D20	0.34	0.12	0.07	0.39
D25	-	0.30	-	0.48
DenJ	0.43	0.38	0.18	0.39
DenM	0.48	0.54	0.78	0.62
DenT	0.48	0.55	0.69	0.63

[1] H=height, D=dbh, 05-25=age, DenJ=juvenile wood density, DenM= mature wood density; DenT = total wood density

(>0.8) (Table 2). The high genetic correlations between juvenile or mature wood densities and total wood density were expected given that the juvenile and mature cores are parts of the total core. Genetic correlations between height growth and wood density ranged from strongly negative (–0.94) to near zero at all ages with only one exception (Table 3). The age 10 data for test GP258 had moderately positive genetic correlations between height growth and both juvenile and total core specific gravity (0.18 and 0.29, respectively). Genetic correlations between height growth and specific gravity at other measurement ages were all negative or near zero.

Juvenile wood density was a good predictor of total wood density, indicating that early selections at 5 years for wood density – the age at which selections are made for growth – will produce a correlated increase in total wood density at rotation age. However, the weak association between growth and wood density traits indicated that selection on growth traits alone would result in little or slightly negative genetic change in wood density. To achieve optimum improvement in both quantity and quality of wood produced, both growth and wood density traits must be properly weighted and included in the selection scheme.

It is important to note that genetic parameters reflect the population structure, and even with negative correlations there will be individuals that possess combinations of desirable traits. Identifying individuals that combine good growth with high wood specific gravity will be extremely important for both the deployment population and the breeding program.

Estimated Decline in Slash Pine Stand Values from Product Degrade due to Fusiform Rust Infection[2]

The primary breeding objective of the slash pine tree improvement program is increased resistance to fusiform rust, *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *Fusiforme*. Therefore, the value of the program is greatly dependent on the economic loss attributable to this disease and the ability to offset this damage using rust-resistant planting stock. Losses result from three factors: rust related mortality, slower growth, and product degrade. The cooperative's predictive equations for slash pine are based on progeny tests measured through age 15. These equations reflect the substantial improvement in volume production due to greatly improved survival of rust resistant planting material and better growth rates. The following study documents additional economic gains that result from the reduction in the amount of product degrade associated with rust infected trees.

Table 2. Genetic correlations among wood density traits.

Traits	Test			
	GP065	GP102	GP103	GP258
DenJ – DenM	0.60	0.52	0.95	0.76
DenJ – DenT	0.84	0.85	0.99	0.92
DenM – DenT	0.96	0.90	0.99	0.94

[2] Submitted by F.E. Bridgwater and W.D. Smith

Table 3. Genetic correlations between height and wood density traits.

Traits	Test			
	GP065	GP102	GP103	GP258
H05 – DenJ	-0.24	-	-	-
H05 – DenM	-0.43	-	-	-
H05 – DenT	-0.33	-	-	-
H10 – DenJ	-0.27	0.08	-	0.18
H10 – DenM	-0.33	-0.05	-	0.06
H10 – DenT	-0.29	0.01	-	0.29
H15 – DenJ	-0.37	-0.25	-0.55	-0.31
H15 – DenM	-0.49	-0.32	0.07	-0.08
H15 – DenT	-0.41	-0.31	0.07	-0.13
H20 – DenJ	-0.48	-0.07	-0.94	-0.39
H20 – DenM	-0.55	-0.14	-0.21	-0.16
H20 – DenT	-0.50	-0.07	-0.22	-0.29
H25 – DenJ	-	-0.02	-	-0.30
H25 – DenM	-	-0.05	-	-0.11
H25 – DenT	-	0.02	-	-0.22

This study was based on four plantations located in Jackson County, Mississippi within 30 miles (50 kilometers) of the Gulf of Mexico. A group of nine plantations was established in 1974 to sample a wide range of site hazard potentials for fusiform rust, but only four survived through the 1998 growing season (25 years of age). The four surviving plantations were determined to represent high hazard (plantation 2), intermediate hazard (plantation 1), and low hazard (plantations 3 and 4) based on cumulative infection levels at age five.

Initially, 750 trees were planted at each planting site, but mortality was quite high during the first planting year at all four locations (Table 4). Percent survival after one year in the field was 58, 33, 53, and 44 percent for the four plantations, respectively. Mortality from fusiform rust after age 1 for Plantations 1 and 2 was more than double that for Plantations 3 and 4 (Table 4). Rust mortality combined with mortality from other causes (essentially the same for all four plantations) resulted in 128 to 280 trees per acre remaining at age 25 (Table 4).

A computer algorithm was developed to merchandise trees into logs of variable lengths from 8 feet to 20 feet by 2-feet increments beginning at a stump height of 0.3 feet. The merchandiser checked each 2-feet segment beginning at the stump height for the presence of a gall. If any portion of a gall occurred within a 2-feet segment, that segment was assigned to rust volume. If there were one or more 8- to 20-feet logs that were canker free, the merchandiser assigned those logs to pulpwood, chip-n-saw, or log volume, depending on the estimated small-end diameter of the log (pulpwood – less than 4 inches, chip-n-saw - grater than 4 inches but less than 6 inches, saw logs - greater than 6 inches).

The free-on-board (f.o.b.) price of lumber was determined from a sample of 47 logs from trees in an earlier study that were similar in size to those in the present study. The value of each board was taken from Random Lengths © 1999 annual averages. Lumber from the original study was not graded.

Table 4. Cumulative mortality for four plantations with different rust hazards and the number of surviving trees at age 25.

Plantation	# Trees alive at age 1	Cumulative % Mortality [1] Due To: Rust %	Other	# Trees alive at age 25	# Trees/acre at age 25
1	435	24	19	250	242
2	245	26	19	132	128
3	401	11	17	289	280
4	331	9	18	239	231

[1] Mortality and tree counts included border row trees. Values are the percentages at age 25 for the trees surviving after one year.

Therefore the grade proportions for number 1, 2, and 3 lumber from butt, second, and top logs determined by Biblis[3] in a study of slash pine at age 27 were used. The lumber value in each log was calculated for butt, second, and top log proportions and regression equations were developed for each log type. These equations were then used to estimate the log values in the current study.

To estimate the stumpage value of the lumber in each log, logging and manufacturing costs were estimated as in Bridgwater and Smith[4] and adjusted to 1999 dollars for the change in the average annual Consumer Price Index for lumber. The delivered pulpwood value was calculated for each log, and the greater of the two values (saw log stumpage or delivered pulpwood at $ 61.38/cord) was assigned to the log. This was consistent with the assumption that integrated producers will use a log for its highest value product, though this objective is not likely to be achieved in actual practice. In general, butt and second logs with small end diameters greater than seven inches were more valuable as saw logs. Logs with small end diameters of 6 inches were worth more as saw logs only if they were at least 16 feet in length.

The value of bark, sawdust, and chips from residuals was included. Volumes for bark and sawdust were estimated as a percentage of total log volume (8% and 11%, respectively). The volume of chips from residuals was estimated to be 81% of residual volume from logs. Residual volume was estimated for the sample of 47 logs described earlier by subtracting the volume of lumber produced from each log from the total log volume. A prediction equation was developed from this data for use in the present study. The value of bark, sawdust, and chips from residual volume were assumed to be $15/ton for both bark and sawdust and $28/ton for chips.

Site hazard assignments were accurately reflected in the percentages of trees that survived to age 25 with stem galls. Plantation 2 had significantly greater percentages of trees with at least one stem gall (62 percent) than the other three plantations. Plantation 1 had a significantly greater percentage of galled trees (40 percent) than Plantations 3 and 4 (28 and 25 percent, respectively), which were not significantly different from one another (Table 5).

The potential for growth varied significantly among the four sites (Table 5). Plantations 1 and 4 had higher site indexes at base age 25 (71.7 feet and 77.9 feet respectively) than the other two sites. These potentials were reflected in the average tree height at each site. Mean dbh of the surviving trees was greater at plantation 2, which had a lower site index than plantations 1 and 4. This occurred because mortality was higher at plantation 2 (Table 4), leaving more growing space for survivors. Mean height of the 10 tallest trees was significantly greater for non-galled trees than for galled trees at plantations 1,3, and 4. Mean dbh for the 10 tallest trees was significantly greater for non-galled trees than for trees with galls at plantations 2 and 4.

Gross yields varied widely among the four plantations

Table 5. Stand parameters for four plantations measured at age 25[1].

Plantation	% Trees with stem galls	Dbh (in)	Height (ft)	10 Tallest Trees: Height (ft): No Stem Galls	With Stem Galls	Dbh (in): No Stem Galls	With Stem Galls
1	40 % b	8.3 b	59.8 ab	71.7*	69.4	10.0	10.0
2	62 % a	9.2 a	58.8 b	67.2	67.2	11.1*	10.2
3	28 % c	7.2 c	53.8 c	65.5*	61.6	9.4	8.7
4	25 % c	8.3 b	60.9 a	77.9*	70.0	11.0*	9.6

[1] Border trees were included in the calculations for percentages of trees with stem galls.
Values followed by the same letters indicate plantations that were not significantly different at P<0.05. Values followed by * indicate that values were different for galled and non-galled trees at P<0.05.

[3] Biblis, E.J. 1990. Properties and grade yield of lumber from a 27-year-old slash pine plantation. For. Prod. Jour. 40(3):21-24.

[4] Bridgwater, F.E. and W.D. Smith. 1997. Economic impact of fusiform rust on the value of loblolly pine plantations. South. Jour. of Appl. For. 21(4):187-192.

Table 6. Merchantable yields (per acre) from four plantations with and without rust.

Plantation	# Merchantable Stems		Mbf (Scribner)		Saw log Volume (ft^3)		Galled Volume (ft^3)	Pulpwood Volume (ft^3)	
	No Stem Galls	With Stem Galls	No Stem Galls	With Stem Galls	No Stem Galls	With Stem Galls		No Stem Galls	With Stem Galls
1	149	142	5.4	4.3	1434	1137	73	1004	1020
2	89	70	3.5	2.3	966	652	60	425	504
3	98	88	2.4	2.0	661	550	43	1003	949
4	118	116	5.4	4.7	1453	1278	38	799	771

(Table 6). The impact of rust, both from rust-induced mortality and losses from merchandising out rust galls, are confounded with differences in site index and numbers of merchantable stems at age 25. For example, the number of merchantable stems was highest at Plantation 1, which had the second-highest incidence of galled stems. This occurred largely because survival at age 1 was greater for Plantation 1 than for the other three plantations (Table 4). Plantation 4 had the second greatest number of merchantable stems, although the number of surviving trees at age 1 was intermediate. This occurred, in part, because Plantation 4 had the greatest growth potential (Table 5). However, fusiform rust galls clearly reduce saw log volume (Table 6), following the same trend as the percentage of trees with stem galls at harvest (Table 5). Saw log volume was reduced by 21, 32, 17 and 12 percent for plantations 1-4, respectively. The reduction in saw log volume was due to a decrease in the number of logs produced, not a decrease in the average log size. The average log dimensions showed only minor and statistically non-significant differences among plantations (Table 7).

Higher frequencies of galled stems also resulted in a reduction in log grade. Since most galls occurred lower on the stems, the frequency of butt logs was reduced in stands with more rust (Table 8) and second and third logs had lower value. Log grade value decreased dramatically with increasing percentages of galled stems. For the plantation with the greatest frequency of stem galls (Plantation 2), the number of butt logs was nearly halved (Table 8).

Total estimated stumpage values were substantially reduced by the presence of galled stems in all four plantations (Table 9). The percentage reduction was strongly linearly related to increasing proportions of galled stems. The slopes

Table 7. Average log parameters with and without rust for four plantations.

Plantation	# Logs		Board ft.		Vol (ft^3)		Small end Diameter		Log length	
	No Rust	Rust	No Rust	Rust	No Rust	Rust	No Rust	Rust	No Rust	Rust
1	170	148	23.7	23.5	6.3	6.2	6.2	6.2	16.7	16.8
2	108	81	24.4	23.4	6.7	6.5	6.3	6.3	16.5[1]	15.9
3	91	82	19.7	19.6	5.4	5.4	6.1	6.1	15.2	15.2
4	154	149	26.5	25.6	7.1	6.9	6.4	6.4	17.0	16.7
Overall	-	-	23.6	23.0	6.4	6.3	6.2	6.2	16.4	16.2

[1] Means for No Rust and Rust were statistically different at $P<0.05$. No other means were different at $P<0.05$.

Table 8. Frequencies of log grades by plantation for logs with and without rust.

Log Grade[1]	Plantation 1			Plantation 2			Plantation 3			Plantation 4		
	1	2	3	1	2	3	1	2	3	1	2	3
No Rust	121	49	0	72	36	0	79	12	0	96	54	4
% Frequency	71.2	28.8	0	66.7	33.3	0	86.8	13.2	0	62.3	35.1	2.6
With Rust	92	55	1	37	43	1	67	15	0	86	57	6
% Frequency	62.2	37.2	0.7	45.7	53.1	1.2	81.7	18.3	0	57.7	38.3	4.0

[1] Log Grade 1 - butt log, grade 2 – second log, grade 3 - third log.

of regressions through the origin were 0.26 for the percentage of galled stems both at age 5 and age 25. Thus, stand value declined 0.26 percent for each 1 percent increase in the number of stems infected at either age 5 or 25.

Reductions in stand values were strongly dependent on the proportion of galled stems because the reduced values reflect only the losses due to merchandising rust galls out of infected stems. These reductions do not reflect losses due to differences in rust-associated mortality or growth losses on infected stems. Reductions in stand values from rust-associated mortality and growth losses have been shown to be substantial in other studies and can be estimated from other models (e.g. Busby and Haines 1988[5]). These predicted values were functions of site index, the number of trees planted, the percentage of infected stems, and harvest age. However, these predictions did not take into account degrade from processing infected stems. These results are simple to use in conjunction with this or other models to estimate losses due to product degrade because these losses are strongly dependent on the percentage of infected stems at age 5.

Table 9. Total estimated stand values (per acre) of four plantations with different percentages of galled stems.

Plantation	No Rust	With Rust	Reduction in value (percent)	Galled Stems (percent) Age 5	Galled Stems (percent) Age 25
1	$2494	$ 2258	9.5	37	40
2	$ 1487	$ 1257	15.5	65	62
3	$ 1625	$ 1502	7.6	21	28
4	$ 2423	$ 2286	5.6	17	25

Slash Pine Hybrid Study

The University of Florida – Cooperative Forest Genetics Research Program (CFGRP) established a series of field plantings in 1994/95 to evaluate the growth potential of slash pine hybrids formed with two varieties of Pinus caribaea. These hybrids have shown outstanding growth in Australia and southern Africa, but the performance of the hybrids created with tested parents had not been evaluated in the southern U.S.

The CFGRP graciously provided seed to the WGFTIP for the establishment of several studies in the Western Gulf Region. Of the 18 study locations planted, the WGFTIP and USDA Forest Service established five in the Western Gulf Region, members of the CFGRP planted 11 in Alabama, Georgia, and Florida, and two were planted in Queensland, Australia.

In the Western Gulf Region, Temple-Inland Forest maintained one test in Hardin County, TX, Boise Cascade Company and the Louisiana Department of Agriculture and Forestry each maintained one test in Beauregard Parish, LA, and the USDA Forest Service maintained one test in Grant Parish, LA and one test in Harrison County, MS. All of the test locations in the Western Gulf Region were comprised of five taxa: the Western Gulf unimproved slash checklot (WG), improved WGFTIP slash (IMP), slash x loblolly (LOB), slash x P. caribaea bahamensis (PCB), and slash x (slash x P. caribaea hondurensis) (F1H). Each test consisted of three replications of 48 or 49 sources planted in five-tree-row plots. Tests were established with a split-plot design with taxa as the main plot and families within taxa as subplots.

In 1997, two-year height and survival data were collected and analyzed for the four tests in Texas and Louisiana, and the results from these measurements were reported in 1997 (45th Progress Report of the Cooperative Forest Tree Improvement Program). The fifth growing season for these tests was completed at the end of 1999, and these four plantings in the Western Gulf Region were re-measured. Boise Cascade Company, Louisiana Department of Agriculture and Forestry and Temple-Inland Forest measured their tests during the dormant season in 1999/00. Data for height, diameter, fusiform rust infection, stem straightness and stem forking were collected. The USDA Forest Service measured their Harrison County, MS, location in June of 2000, about halfway into the sixth growing season. Height, diameter and fusiform rust infection were measured. Data from these four locations are reported here.

Average survival at age 5 of all sources in individual tests ranged from 68 to 89 percent with an average survival across all four locations of 81 percent. Fusiform rust infection in individual tests ranged from 31 to 55 percent with an across-location average of 40 percent. Average volume growth in individual tests was extremely variable, ranging from 2.8 dm^3/planted tree at the Boise Cascade Company location to 10.3 dm^3/planted tree at the Louisiana Department of Agriculture and Forestry location. The average over all four locations was 5.8 dm^3/planted tree.

When each test was analyzed separately, significant differences among taxa were found for volume growth, height, diameter, and fusiform rust infection at all four locations. Significant differences among taxa were also found for survival at all locations except at the Harrison County, MS, location. When all tests were analyzed together, significant differences among taxa were found for survival, height, diameter, and fusiform rust infection, but not volume growth (Figure 9). There was a statistically significant interaction between location and taxon for all traits, but this was due to changes in rank based on relatively small differences and did not appear to be biologically important.

In general, the hybrid taxa PCB, F1H, and LOB performed poorly compared to the pure species taxa, IMP and WG. The PCB hybrid had the highest level of rust infection and the smallest diameter at every location. The IMP source had the lowest level of rust infection and the best survival at every location. These tests will be maintained and remeasured at age ten. As the tests age, the differences among sources are expected to become more pronounced as the hybrid taxa succumb to fusiform rust-related mortality. However, based on the five-year results, there is no advantage to planting these Caribbean slash pine hybrids in the Western

[5] Busby, R.L. and T.K. Haines. 1988. Determining the value of a fusiform rust-infected stand. USDA-Forest Service Southern For. Exp. Stat. Res. Pap. SO-245 5pp.

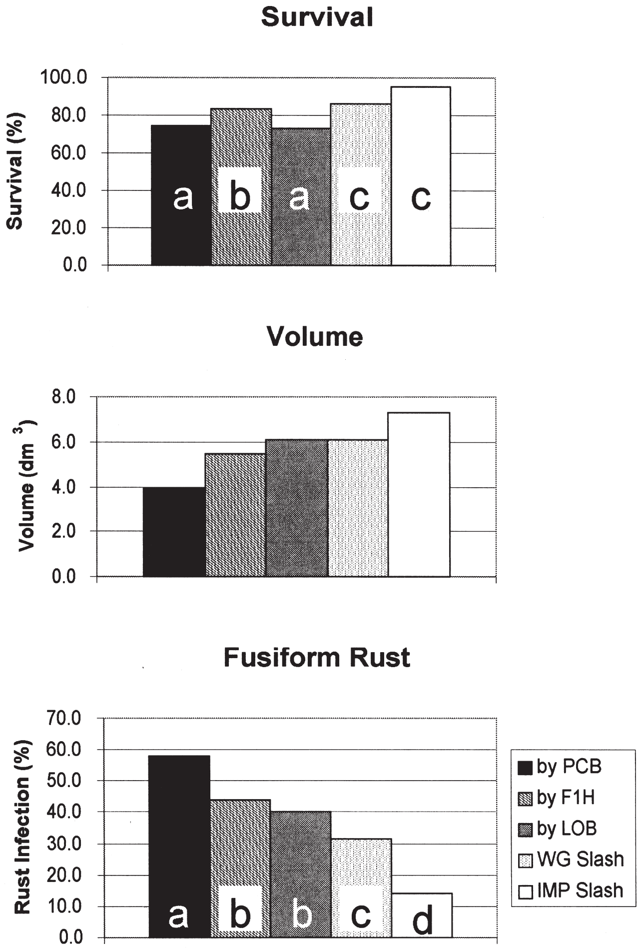

Figure 9. Five-year data from the slash pine hybrid tests for taxa averaged over four locations. Bars with different letters are significantly different at the 10 percent level according to a Duncan's Multiple Range test.

Gulf Region. They are highly susceptible to both fusiform rust and frost damage (Figure 10). Most importantly, they grow more slowly than the pure improved slash pine sources currently available.

Modeling Age-Age Genetic Correlations in Loblolly Pine

Loblolly pine has a nearly continuous range throughout the southeastern United States. The species extends from Delaware to Texas, with a natural gap of 30-120 miles (50-200 km) formed by the Mississippi River Valley, which separates the species into divergent eastern and western populations. Data from many large genetic tests planted throughout the southern U.S. combined with data from Zimbabwe, where it is planted as an exotic, were used to do a meta-analysis for the prediction of age-age correlations.

Predicting age-age genetic correlations is critical for determining the best age for measurement and advanced-generation selection efforts. Previous prediction equations have been based on data from older tests (established early in the program) and used phenotypic correlations rather than genetic correlations. Both factors tend to favor older selection ages. Older tests may produce lower age-age genetic correlations

Figure 10. Deformed top in a two-year-old slash pine hybrid caused by extensive frost damage.

than newer tests, presumably because when these tests were planted, early maintenance was generally less intensive than that currently practiced in newer tests (Figure 11). Phenotypic correlations are also generally lower than the corresponding genetic correlations.

Figure 11. David Gwaze (WGFTIP and USDA Forest Service) and Becky Maxwell (The Timber Company) reviewing a one-year-old seedling in an intensively prepared progeny test located in Ashley Co. AR. The test was bedded, fertilized, and received intensive weed control.

The objectives of this study were to develop a generalized prediction equation for loblolly pine age-age genetic correlations for height, to validate the generalized predictive equation with younger tests, and to compare the goodness-of-fit for growth-dependent and age-dependent predictive equations.

This study was based on a total of 51,439 trees from 520 loblolly pine parents located in 31 randomized-complete block tests. Height was measured at different intervals ranging from 2 to 25 years. Two generalized predictive equations were developed using 233 parents originating from east of the Mississippi River and 190 parents originating from west of the Mississippi River. These equations were compared to a validation population consisting of two intensively managed populations from the East Coast of the United States (W1 and W2) and one population from Zimbabwe (ZIM).

Genetic parameters were estimated using the individual tree model ASREML[6]. Two prediction equations were

[6] Gilmour, A.R. 1969. ASREML, A spatial REML program. NSW Agriculture, Orange, NSW, Australia. 54pp

developed for age-age correlations. In the first equation, the predictor was the ratio of younger age to older age. In the second equation, the predictor was the ratio of height at the younger age to the height at the older age.

A single generalized prediction equation for age-age genetic correlations for loblolly pine could not be determined. Equations based on tests east of the Mississippi River were similar, and those based on tests west of the Mississippi River were similar; however, the equations for eastern and western populations were statistically different (P<0.05) (Table 10). Both predictive equations differed statistically from Lambeth's generalized age-age phenotypic predictive equation for conifers[7].

Validation equations derived from younger tests were similar to each other even though one test was from Zimbabwe. However, the equation derived from the combined younger tests differed from both the prediction equations derived from older tests east and west of the Mississippi River. The validation tests had higher age-age genetic correlations at earlier ages than predicted by the two genetic prediction models (Figure 12).

Height-dependent prediction equations were as good as or superior to the age-dependent predictive equations. However, they are difficult to implement because height-dependent equations require an estimate of height at rotation age.

The results indicated that loblolly pine populations east and west of the Mississippi River were different, and there was justification for making selections on height earlier in the western populations than in the eastern populations. Furthermore, if selection is based only on height growth, current selection ages are conservative. Reducing the selection age could increase genetic gain per year.

Breeding and Progeny Testing

The last few years have been difficult for progeny test establishment because of the extremely hot, dry conditions. Several members have established their 'last' first-generation loblolly pine test more than once because of unacceptable first year mortality. Despite these set backs, eight of the cooperative's fifteen members have now established all of their required loblolly pine first-generation progeny tests. Breeding for the remaining crosses is also nearly finished. As field test establishment of first-generation loblolly pine parents nears completion, the six members of the slash pine breeding program have accelerated first-generation test establishment. First-generation breeding for slash pine should be completed quickly as this population was reduced by half on the basis of early greenhouse screening for rust resistance and because all selections in the program are already flowering in scion banks.

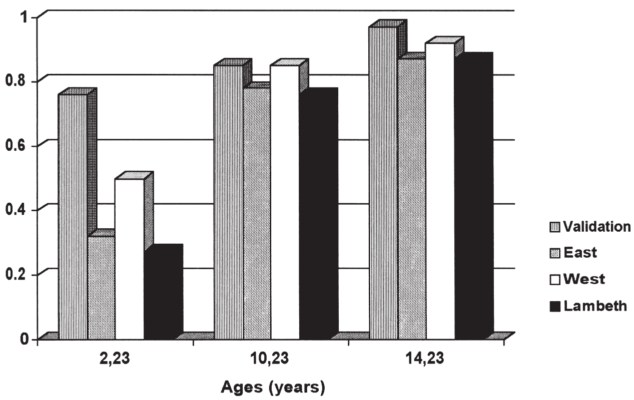

Figure 12. Comparison age-age genetic correlations predicted using four different prediction equations.

Slash Pine

In 1999/00, 73 slash pine parents were established in first-generation control-pollinated field tests by Boise Cascade Company and Weyerhaeuser Company. The four tests established by these two members represented a total of 16 diallel by location combinations (Table 11). Progeny test establishment planned for 2000/01 should evaluate an additional 15 diallel by location combinations. If this effort

Table 10. Parameter estimates for age-dependent equations.

Data Set	β_0	(se)	β_1[1]	(se)	Df	R^2
CZ	0.97	0.05	0.25 a	0.05	8	0.74
IP	1.03	0.02	0.29 a	0.01	13	0.97
GP	1.04	0.02	0.22 b	0.04	4	0.89
TFS	1.02	0.04	0.20 b	0.05	4	0.80
W1	1.02	0.02	0.13 c	0.03	8	0.77
W2	1.01	0.03	0.16 c	0.04	4	0.78
ZIM	0.98	0.04	0.08 c	0.03	4	0.64
EAST (CZ & IP)	1.01	0.02	0.28 a	0.02	23	0.91
WEST (GP&TFS)	1.03	0.02	0.22 b	0.03	11	0.85
Validation (W1,2 & ZIM)	0.99	0.02	0.09 c	0.02	20	0.63

[1] Slopes followed by the same letter are not statistically different at the 95% confidence level.

[7] Lambeth, C.C. 1980. Juvenile-mature correlations in *Pinaceae* and implications for early selection. Forest Science 26:571-580.

is successful, approximately 80 percent of the first generation tests needed for the slash pine program will be established. Only 39 more diallel by location combinations will need to be planted. Four of the six members have completed all control-pollination breeding needed to support this effort. The two remaining members need to complete 66 crosses, most of which have been done once already and are being repeated for insurance purposes.

While only two of the six members in the slash pine breeding program currently have large internal demands for the seed, the slash pine selections in the program represent a unique resource. All have been tested for increased rust resistance with greenhouse screening at the USDA Forest Service Resistance Screening Center. The effort to complete first-generation field evaluations is very nearly completed and will allow the establishment of intensively selected seed orchards. The cooperative intends to screen these tests for second-generation selections. Once these selections have been evaluated with polymix tests, the cooperative will have the option to develop a third-generation breeding population if the demand for this species increases in the future.

Loblolly Pine

Eleven first-generation progeny tests were established by five cooperative members during the 1999/00 planting season (Table 11). These tests evaluated a total of 278 parents, 106 for the first time (Figure 13). A sufficient number of tests have been established to evaluate 3,088 loblolly pine parents; 2,395 in balanced control-pollinated progeny tests and an additional 693 in open-pollinated tests. With the progeny tests established in the fall of 2000, eight members have completed establishment of all first-generation loblolly pine progeny tests. This total does not include Champion International Corporation who planted their last first-generation loblolly pine progeny test as part of International Paper Company. The seven members with tests left to establish have a total of 25 partial-diallels remaining (approximately 19 field tests). These 25 partial-diallels represent approximately 200 parents. Breeding has been completed in 18 of these partial diallels and is essentially done in the remaining seven.

Table 11. Progeny tests established during the 1999/2000 planting season.

Cooperator	Number of Tests	Number of Diallels
First-Generation Loblolly Pine Tests		
Boise Cascade Company	3	13
Louisiana Dept. of Ag. and Forestry	4	10
Louisiana-Pacific Corporation	2	8
Oklahoma Forestry Services	1	2
The Timber Company	1	5
First Generation Loblolly Pine Total:	**11**	**38**
First-Generation Slash Pine Tests		
Boise Cascade Company	3	12
Weyerhaeuser Company	1	4
First Generation Slash Pine Total:	**4**	**16**
Advanced-Generation Loblolly Pine Polymix Tests	Number of Tests	Number of Families
Champion International Corporation	1	80
Temple-Inland Forest	1	80

The Louisiana Pacific Corporation, the cooperative's newest member, planted their first two progeny tests in 1999/00 and will plant two more tests in 2000/01. They joined the cooperative just as the first-generation breeding program in East Texas was nearing completion and have benefited from the work of others in the region. Because they inherited breeding groups for which breeding was essentially complete, they have been able to establish half of the 36 diallel by location combinations for their first-generation testing in just two years and are scheduled to establish the remainder in another two years. They are making a meaningful contribution by assuming responsibility for four breeding groups and by establishing regional tests that include selections belonging to other members in addition to their own.

Test Measurement and Second-Generation Selection Activity

For the second year in a row, the cooperative measured a record number of progeny tests. During the 1999/00 measurement season, the cooperative evaluated 90 loblolly and 12 slash pine progeny tests established to support the cooperative's mainline breeding program (Figure 14). An additional 10 tests established for other reasons were also measured.

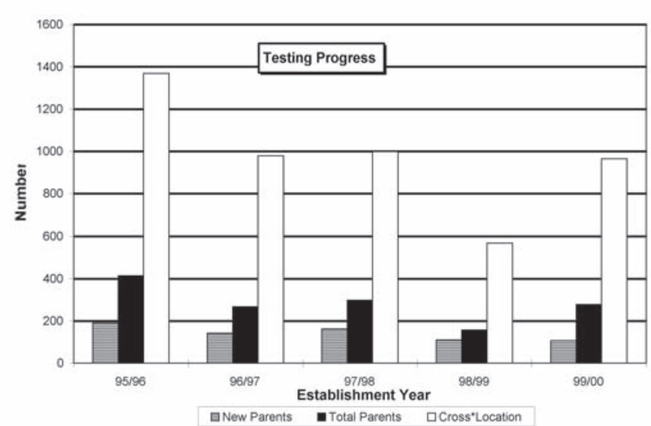

Figure 13. The number of loblolly pine crosses (total number of cross by location combinations), the total number of parents, and the number of parents established in tests for the first time in each of the last five years.

Figure 14. Jerry Watkins in a five-year-old test evaluated in the 1999/00 measurement season by The Timber Company.

Of the 90 loblolly pine tests evaluated in 1999/00, 56 were five years old. These progeny tests provided information on 468 parents, 272 for the first time. The total number of parents represented in five-year old tests was down from the 515 evaluated in the previous year; however, the number of new parents represented increased by 47 from the 225 evaluated in 1998/99. This was the greatest number of new first-generation parents evaluated in a single year and represents the peak of first-generation progeny testing for the cooperative. A total of 710 new parents established in progeny tests have not yet reached measurement age (Figure 15), and approximately 200 more parents are currently in the breeding program.

The unprecedented number of tests measured in 1999/00 contributed a record number of second-generation selections. In 1999/00, eleven members of the cooperative screened 54 progeny tests identifying 149 loblolly pine and 3 slash pine second-generation selections. The loblolly pine selections were made in 32 breeding groups and contributed to the breeding population in all of the cooperative's breeding zones (Figure 16). The four members contributing the majority of the loblolly pine selections were International Paper Company with 49, The Timber Company with 27, Champion International Corporation with 22, and the Arkansas Forestry Commission with 15. Three members now have five-year data on all of their first-generation

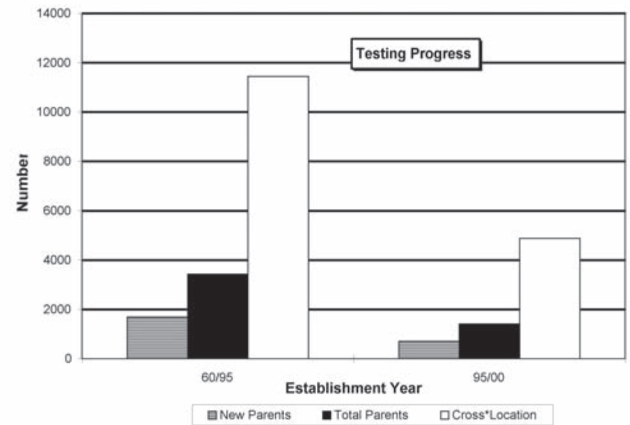

Figure 15. The number of loblolly pine crosses (total number of cross by location combinations), the total number of parents, and the number of parents established in tests for the first time from 1960/1995 and from 1996/2000.

loblolly pine progeny tests and anticipate completing their second-generation selection activities in the near future. In the slash pine program, The Texas Forest Service identified three new second-generation selections. The cooperative now has identified a total of 1,153 loblolly pine selections and 162 slash pine selections (Figure 17). Most of these selections were top-grafted in the same season in which the tests were measured.

Second-Generation Breeding and Testing

The second-generation breeding cycle will be very different from the first-generation cycle. It promises to be much shorter in duration, require fewer, but larger field tests, and be completed through regional cooperation. This is possible for a number of reasons. Second-generation breeding is not dependent on completing the first-generation breeding and testing program. Fourteen of the cooperative's fifteen members have now identified second-generation selections, and twelve of the members are producing polymix crosses for parental evaluation. Top-grafting for the stimulation of early flowering has eliminated much of the delay between selection

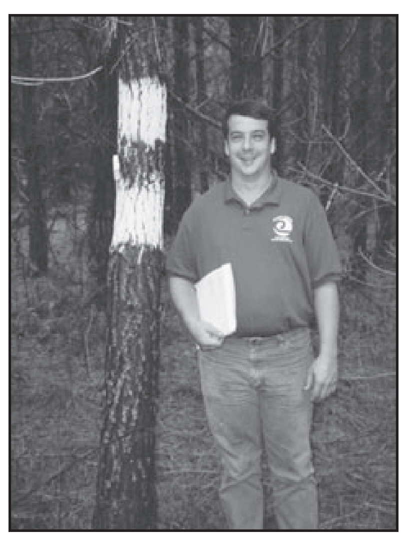

Figure 16. Stephen Williams, Mississippi Forestry Commission, and one of the many second-generation selections identified in 1999/00.

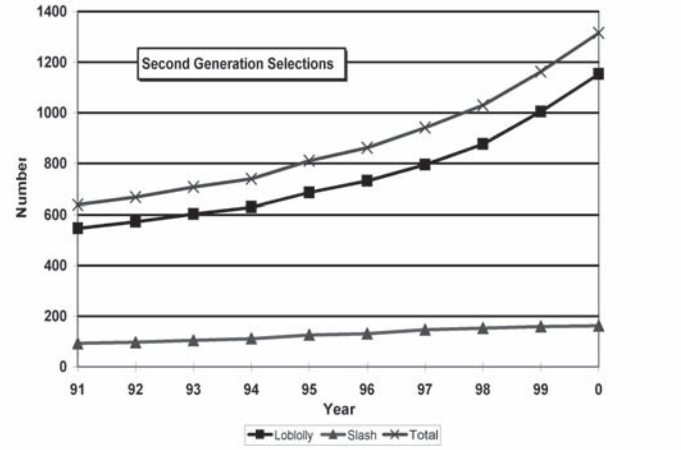

Figure 17. The cumulative numbers of second-generation selections in the cooperative.

Figure 18. Seedlings grown by The Timber Company for the first South Mississippi-Southeast Louisiana second-generation polymix progeny tests.

and breeding. Therefore, members with newly identified second-generation selections have the opportunity to close the gap between their breeding programs and those belonging to older programs that started making second-generation selections earlier, but had to rely on breeding in traditional scion banks. Complementary breeding and single-tree plot field designs will also change the second-generation breeding cycle. These tests require fewer seedlings for parental evaluations; as a result, establishing regional tests with selections from multiple cooperators is now practical.

Four polymix advanced-generation progeny tests were originally scheduled for establishment during 1999/00 in Southeast Texas. Champion International Corporation and Temple Inland Forest planted two tests evaluating 80 parents (Table 11). Establishment of the two remaining tests, one a companion to the two tests already planted and the other an additional test of another 60 parents, was delayed because of the drought. These seedlings were held over the summer by the Texas Forest Service and will be planted in 2000/01. The first second-generation progeny tests for the South Mississippi and Southeast Louisiana breeding region were grown during the summer of 2000 for fall planting (Figure 18). These tests were grown jointly by the Mississippi Forestry Commission and the Timber Company and included 105 parents contributed by the Mississippi Forestry Commission, The Timber Company, and Weyerhaeuser Company. One location will be established by each member contributing seed. Both the effort in Southeast Texas and the effort in South Mississippi/Southeast Louisiana exemplified regional cooperation at its best.

Additional Activities

The cooperative's additional activities included a range of endeavors in which the members directly participated or supported other studies in forest genetics. A primary goal of the cooperative has always been to provide training. This effort includes the annual Contact Representative's Meeting, with its dual emphasis on the future of tree improvement and new techniques to make daily operations safer and more productive (Figure 19). Additional training is made available as the need arises. In 1999, the cooperative sponsored a Tree Improvement Short Course (described in the 47th Progress Report of the Cooperative Forest Tree Improvement Program). In 2000, employees from many members of the cooperative were able to take advantage of additional training in cone, seed, and regeneration insects provided at a workshop sponsored by the Seed Orchard Pest Management Subcommittee.

The members of the cooperative directly and indirectly supported many additional activities. This year the members participated in a pesticide use survey sponsored by the Seed Orchard Pest Management Subcommittee. This database has already proven useful in assisting regulatory agencies to make more informed decisions. The cooperative also plays an integral role in supporting forest genetics research. Members did this by supplying plant material and data for various research projects. The results from these studies provide insight into a range of topics beyond the scope of the cooperative's limited research objectives. Some of these activities are described in the last segment of this section.

Figure 19. Stress load testing of bucket trucks demonstrated at the 2000 Contact Representative's Meeting.

Contact Representative's Meeting

The Timber Company hosted the 2000 Contact Representative's Meeting in Hattiesburg, MS. This year's meeting was one of the best attended in the history of the cooperative with nearly 70 people in the audience. Presentations at the two-day meeting addressed three themes: clonal forestry, greenhouse production, and seed orchards. Two speakers from the Pacific Northwest discussed clonal forestry. Ben Sutton (Cellfor, Inc., Vancouver, Canada) reviewed his company's work with somatic embryogenesis and the potential for clonal forestry with southern pines. Brian Stanton (James River Corp., Camas, WA) described the current use of clones in short rotation hybrid poplar production. Two speakers addressed the theme of greenhouse production. Steve Ross (Stuppy Greenhouse Manufacture) discussed greenhouse design and control systems. A video presentation prepared by Arne Aiking of American Tree Seedling, Inc. illustrated an automated production line for containerized seedlings. While clonal forestry in southern pines has not yet proven economical, it is rapidly improving in efficiency. Recent improvements in vegetative propagation and greenhouse automation, combined with more practical experience with clonal forestry, are all likely to be important to those members of the cooperative who are seriously considering this emerging technology.

The discussion of seed orchards centered on cone and seed insect control. After an update on the activities of the Seed Orchard Pest Management Subcommittee (SOPM), John Taylor (USDA Forest Service-Forest Health and Protection) discussed the Food Quality Protection Act and recent pesticide label changes. Alex Mangini (USDA Forest Service-Forest Health Protection) presented results from trials with a new synthetic pyrethroid, Warrior T®, which may prove to be an effective tool for cone and seed insect control. Geoff Gooding presented the early results from the pesticide use survey sponsored by the SOPM Subcommittee. This survey was distributed nationally to develop information on the actual use patterns of pesticides in seed orchards.

Several other topics were also discussed. David Gwaze, working with the USDA Forest Service and the WGFTIP on a two-year post doctoral appointment, discussed the use of pine hybrids around the world. Jennifer Myszewski, Ph.D. student, gave an update on the microfibril angle study. The initial results of this study were described earlier in this report. Ron Schmidtling (USDA Forest Service-Southern Research Station) discussed some of the seed movement guidelines currently under development by a subcommittee of the Southern Forest Tree Improvement Committee. All southern pine species suffer from reduced growth or higher mortality if moved to an area with more than a ten degree Fahrenheit difference in the average minimum annual temperature than experienced at their origin. Loblolly pine also shows important population differences from east to west across its range.

Floyd Bridgwater (USDA Forest Service-Southern Research Station) discussed his research with controlled mass-pollination techniques and the impact of timing on isolation bag installation on pollination efficiency. He found that isolation bags installed before flowers reach stage two and left on the branches at least 48 hours after pollination significantly decreased pollen contamination. Finally, Tom Byram discussed some ongoing research on the genetics of fusiform rust resistance in slash pine. Slash pine families were exposed to different genetic isolates of fusiform rust spores and infection levels were tabulated. Initial results appear to be consistent with the gene-for-gene theory of disease resistance, which postulates that disease resistance is partially controlled by the interacting genetics of the host organism and the pathogen. This could have a large impact upon screening procedures and the breeding program for fusiform rust resistance in both loblolly and slash pine. Several of the cooperators will be making crosses with slash pine to evaluate the implications of this preliminary study.

The field tour was hosted by The Timber Company at their Moselle Seed Orchard. Tommy Sims (The Timber Company) gave an overview of the orchard complex, including a history of the site, a description of the orchard types maintained by the company, and a discussion of orchard management strategies (Figure 20). Steve Ross (Stuppy Greenhouse Manufacture) continued his morning discussion of greenhouse construction and control systems, using the Timber Company's new greenhouse as an example. Two presentations were dedicated to lift equipment maintenance and safety. Bucket truck inspection and safety related issues were discussed by Drey Edwards from Petal, MS, and load testing procedures for bucket trucks were demonstrated by Randy Skinner and his staff from Independent Testing Laboratories in Gardendale, AL.

Seed Orchard Pest Management Subcommittee

The Seed Orchard Pest Management Subcommittee is a working group of the Southern Forest Tree Improvement Committee with representatives from the three southern pine tree improvement committees, state agencies, the USDA Forest Service, and the forest products industry. Membership includes representatives from the Pacific Northwest as well as

Figure 20. Tommy Sims (far left) of the Timber Company describes the Mosselle Seed Orchard Complex during the 2000 Contact Representative's Meeting.

the South. The subcommittee members, both as a group and as individuals, continued to be active in research and policy issues surrounding the control of cone and seed insects.

Several members of the subcommittee joined in an effort led by the American Forest and Paper Association to brief staff members of the Biological and Economic Analysis Division of the Environmental Protection Agency (EPA). One of the topics covered in depth was the importance of controlling cone and seed insects in order to meet forestry's regeneration needs. Other topics included the need for pesticides in general forest management and for nursery production. Approximately 50 EPA staff members attended the briefing.

John Taylor (USDA Forest Service-Forest Health Protection) was temporarily assigned to the USDA Office of Pest Management Policy. This organization is charged with representing agriculture's interests in the recertification process and in the continuing review required by the Food Quality Protection Act. Having a representative in this office familiar with forestry, seed orchards, and nurseries was extremely valuable.

The SOPM Subcommittee was also involved with an effort to include conifer seed orchards on the labels of two additional pesticides, Imidan® and Warrior T®. Imidan® is an organophosphate similar in efficacy and mode of action to Guthion®. Warrior T® is a third-generation pyrethroid that appears to be very effective at controlling a number of different insect pests. Labels with seed orchard uses have been submitted to the EPA and approval is pending.

The SOPM Subcommittee was instrumental in conducting a Cone, Seed, and Regeneration Insect Workshop. The workshop, organized by Alex Mangini (USDA Forest Service-Forest Health Protection) and John Taylor (USDA Forest Service-Forest Health Protection), included a wide variety of topics and speakers. The training session emphasized the biology of these insects, recognizing their damage, appropriate control methods, regulatory issues, and equipment characterization and calibration. This type of training has not been offered in several years, and the workshop was well attended.

An additional activity organized through the SOPM Subcommittee was the Pesticide Use Survey which is described in the next section. Providing this information to the regulatory agencies charged with estimating pesticide risk is critically important. In the absence of actual use data, the regulatory agencies assume that the maximum allowable rates are used for all applications; thus the total amount of chemical used is greatly overestimated.

Pesticide Use Survey

The Seed Orchard Pest Management Subcommittee surveyed pesticide use in seed orchards nationwide. The bulk of the chemicals are used in the South, and most of the responses originated from members of the three southern tree improvement cooperatives. The survey documented information on chemicals used in the seed and cone insect control program, chemicals used in the establishment phase management, and chemicals applied for miscellaneous purposes. Survey responses detailed actual usage patterns for the last three years, including the chemicals used, the amounts and rates applied, the number of acres treated, and the number and timing of applications.

As of July 2000, replies had been received from 17 private companies and 11 state agencies across the southern U.S.. They detailed pesticide use at 51 different orchard complexes from 1997 to 1999. The three major pesticides used for seed and cone insect control were Asasna XL® (Esfenvalerate), Capture® (Bifenthrin) and Guthion® (Azinphos-methyl). Table 12 shows the number of applications, number of orchards and acres treated, average application rate, and the total pounds applied per year for each of the three major chemicals in each year. Asana XL® is the most commonly used chemical in total number of applications, number of orchards and number of acres treated. Guthion®, which is applied at much heavier rates, was the most used chemical in terms of total pounds of active ingredients applied. Capture® is used by several organizations but to a lesser extent than either Asasna XL® or Guthion®. Other chemicals mentioned in responses to the pesticide use survey included Cygon® (Dimethoate), Ambush® and Pounce® (permethrin), Foray®, Dipel® and Condor® (*Bacillus thurigensis*), and Orthene®(Acephate). These chemicals were not used as widely or in the same quantities as the three main chemicals: Asana XL®, Guthion® and Capture®. However, they were still important in many orchards across the south.

The most common use pattern of a pesticide for control of cone and seed insects in orchards started with an application of Asana XL® in the early spring, timed to fit the emergence of *Dioryctria disclusa* (webbing cone worm). This initial spray was followed by two or three applications of Guthion® four to six weeks apart, and finished with another application of Asana XL® in the late summer. This is an example of an integrated pest management system because it incorporates biological factors in timing applications and relies on multiple chemical products with different modes of action.

This information has been summarized and provided to the USDA Office of Pest Management Policy and the American Forest and Paper Association to aid them in their efforts to respond to questions from the regulatory agencies.

Formal Reviews

Formal Reviews are scheduled on a three-year cycle with each member of the cooperative. They are intended to be a comprehensive analysis of all aspects of the basic tree improvement program including a review of breeding, field tests, and production orchards. Because of the long planning horizon required for seed orchard establishment, one of the most important items discussed is always the long-range objective of the individual programs. This was certainly true in 2000. All three members participating in Formal Review this year were undergoing major realignments in their orchard programs. In one case, the cooperative staff became aware of the need to alter the composition of future orchards in order to expand the possible deployment zones. In the other two cases, the Formal Review finalized plans to

Table 12. Summary of results from the pesticide use survey for the three major chemicals used for cone and seed insect control.

Survey Year	Number of Applications	Number of Orchards	Number of Acres	Average Rate (lbs. ai/acre)	Total lbs. applied
Asana XL (Esfenvalerate)					
1997	158	65	2443	0.178	1223
1998	170	72	2842	0.170	1284
1999	172	71	3204	0.170	1387
Capture (Bifenthrin)					
1997	35	15	558	0.150	162
1998	47	18	860	0.146	240
1999	58	16	1067	0.146	382
Guthion (Azinphos-methyl)					
1997	121	47	1948	1.675	9085
1998	136	51	2098	1.524	9546
1999	129	42	2120	1.456	9856

double existing seed orchard acres in response to dramatically increased seed demands. The Formal Reviews have proven invaluable in helping both the staff and the members to keep abreast of the rapidly changing goals of the cooperative members.

Forest Genetics Research at Texas A&M University[8]

A total of 237 microsatellite markers have been developed from the low copy and undermethylated portion of the loblolly pine genome. This part of the genome is expected to have high concentrations of genes, and therefore markers in these areas are likely to be very useful. All markers have been tested for Mendelian inheritance and for polymorphism in the base pedigree (11-1060 x 20-1010). The marker development project exceeded its objective to identify 235 microsatellite markers by December 1, 2000.

The development of microsatellite markers is only an intermediate step in the study of pine genetics. Emphasis is now shifting from the development of tools to their use to answer questions about pine evolution and population dynamics. One important first step will be to locate these 237 microsatellite markers on a genetic map. This is being done by placing the markers on a new map of a selfed loblolly pine family and also by adding the markers to a public loblolly pine pedigree for which a RFLP map has previously been generated. A secondary objective of this project is to use high throughput data collection via automated sequencing to create these maps. Two related studies are examining the conservation of microsatellite markers across species and the allelic variation within species. Low copy microsatellites are more highly conserved among pine species than similar types of sequences in other plants. This has implications for consensus mapping across pine species and the study of speciation. Within the loblolly pine population, microsatellite markers exhibit considerable allelic diversity. This diversity has confirmed that the population east of the Mississippi River is significantly different than the population west of the Mississippi River. This variation will be used to study the migration and diversification of loblolly pine.

An important activity has been the training of students and fostering interactions among scientists working in the fields of genomics and molecular genetics. Lisa Reimer Auckland and Dr. Zhou Yi have worked to develop the undermethylated microsatellite markers and the high-throughput automated marker system. Doctoral student Mohammad Al-Rabbah has been studying the allelic variation within the loblolly pine species. Professor Humberto Reyes-Valdes, a visiting scientist form the Agricultural University in Saltillo, Mexico, spent the summer in College Station extending and developing a theory for QTL detection inoutbred pedigrees and writing a suite of computer programs for QTL analysis. He and Dr. David Gwaze are constructing linkage maps and undertaking QTL analyses. Dr. Christine Elsik, who received her Ph.D. degree in May, has contributed significantly to the understanding of retroelements and other repetitive DNA in the organization of the pine genome.

[8] Submitted by Dr. C. G. Williams

HARDWOOD TREE IMPROVEMENT PROGRAM

Highlights

* The Arkansas Forestry Commission and Temple-Inland Forest established second-generation sweetgum progeny tests in cooperation with the North Carolina Hardwood Research Cooperative.

* To increase the amount of seed available for the nurseries, the Louisiana Department of Agriculture and Forestry, the Mississippi Forestry Commission, and Temple-Inland Forest converted cherrybark oak and water oak progeny tests to seedling seed orchards.

* Two-hundred and sixteen selections of Nuttall oak have been established in 22 progeny tests. Over 90 percent of the selections were preserved by grafting and have been established in scion banks.

* After seven years, thinning continued to stimulate diameter growth in Potlatch Corporation's hardwood thinning study. Thinning has not resulted in an increase in the number of epicormic branches present on the butt log.

Tree Improvement

Progeny Testing

During the past year, the members of the Hardwood Tree Improvement Program maintained a total of 33 progeny tests (Table 13). The number of active tests decreased in 1999 because some of the tests were abandoned after the 20-year data were collected and a portion of the younger cherrybark oak and water oak progeny tests were converted to seedling seed orchards. These seedling seed orchards will produce an interim supply of hardwood seed for the nurseries until seed production begins in the second-generation clonal seed orchards.

Nuttall oak comprised the majority of the active progeny tests (65 percent). Combined, the 22 tests contain a total of 216 selections from Arkansas, Louisiana, Mississippi, and Texas. The best performing parents identified by these tests will be grafted into production seed orchards.

First-year survival was collected on the last series of Nuttall oak tests during the 1999/00-measurement season.

Table 13. Active progeny tests in the Hardwood Tree Improvement Program.

Species	Number of Tests
Cherrybark oak	3
Green ash	1
Nuttall oak	22
Sweetgum	2
Sycamore	4
Water/willow oak	1

Figure 21. A Nuttall oak progeny test maintained by the Mississippi Forestry Commission in the second growing season.

This series completed the initial test establishment process for the species. Five tests were planted, each containing 50 families selected primarily from Arkansas. All of the tests had good survival, averaging 88 percent. Survival varied among families within each test and ranged from a low of 52 percent to a high of 100 percent (Figure 21).

During the 1999/00-measurement season, the members also measured five 20-year-old and two 15-year-old cherrybark oak progeny tests. Table 14 shows the average plantation performance for each of these tests. Survival and growth were acceptable in all of the tests. The best growth was obtained in the Warren County, MS, test maintained by the Mississippi Forestry Commission. The average height in this test was 21.2 meters at age 20. No new second-generation selections were made in any of the tests. Families from which second-generation selections were made at earlier ages continued to perform well, producing between 24 and 41 percent more volume than the plantation average. The 20-year-old tests were released to the cooperators, and some of these tests were converted to seedling seed orchards.

Fifteen-year-old water oak progeny tests were measured by the Mississippi Forestry Commission and by Temple-Inland Forest (Table 15). Second-generation selections had previously been made from the best families in both tests. These families averaged 47 percent more volume than the test mean. Both of these tests were converted to seedling seed orchards. Acorn production was observed in the Temple-Inland Forest test when the trees were being selected for the seed orchard.

The Arkansas Forestry Commission and Temple-Inland Forest established the first second-generation sweetgum progeny tests in the program (Figure 22). These tests were established in cooperation with the North Carolina Hardwood Research Cooperative and contained approximately 130 families. Thirty-seven of the families were from the Western Gulf program. The members of the North Carolina program established additional tests with this material east of the Mississippi River. Data from all of the tests will be shared between both programs, and plant material will be exchanged to support future seed orchards.

Table 14. Cherrybark oak progeny test data summary.

Location (Co./Par., State)	PlantationAverage				Pct.[1] Vol. Imp.
	Survival (%)	Height (m)	Diameter (cm)	Volume (dm^3)	
Age 20					
Bradley Co., AR	77	17.1	18	136	28
Cass Co., TX	76	17.1	18	121	24
St. Landry Par., LA	66	14.2	16	71	27
Tyler Co., TX	82	18.3	17	136	25
Warren Co., MS	71	21.2	20	175	32
Age 15					
Tyler Co., TX	81	15.8	16	98	36
Yazoo Co., MS	83	15.1	16	92	41

[1] Percent volume improvement is the mean of the selected open-pollinated families compared to the plantation average.

Table 15. Fifteen-year data summary for water oak progeny tests.

Location (Co., State)	PlantationAverage				Pct.[1] Vol. Imp.
	Survival (%)	Height (m)	Diameter (cm)	Volume (dm^3)	
Tyler Co., TX	60	10.9	13	43	36
Yazoo Co., MS	63	11.4	14	53	58

[1] Percent volume improvement is the mean of the selected open-pollinated families compared to the plantation average.

Figure 23. Joe Hernandez, Texas Forest Service, with open-pollinated green ash seed maintained by family for future testing.

At the 2000 Executive Committee Meeting, the members decided to establish additional open-pollinated progeny tests for each of the selected species. The data from these tests will be used to rogue the seed orchards and determine which clones should be used for operational seed collection. This will improve the genetic quality of the seedlings used in the expanded bottomland hardwood reforestation programs. To support this effort, the Texas Forest Service began collecting and maintaining seed by open-pollinated family from their green ash, sweetgum, and sycamore seed orchards (Figure 23).

Figure 22. A second-generation sweetgum progeny test being planted by the Arkansas Forestry Commission.

Table 16 shows the number of second-generation selections and the status of seed collection and testing for each of the hardwood species in the program. It is anticipated that sufficient seed can be collected to begin sowing these tests in two years.

Seedling Seed Orchards

Expanded bottomland hardwood reforestation programs have greatly increased the demand for seed from certain hardwood species. The older grafted seed orchards are producing sufficient sycamore and sweetgum seed for the expanded planting programs. However, the amount of green ash seed being produced in these seed orchards is not sufficient to meet the increased seed demand.

Table 16. Status of seed collection and testing of hardwood second-generation selections.

Species	Number of Selections		
	Total Selections	Established In Tests	With Seed Collected
Green Ash	61	0	20
Sweetgum	84	37	28
Sycamore	70	12	19
Cherrybark oak	62	0	0
Water/willow oak	44	0	0
Yellow-Poplar	12	0	0

Significant seed production has not started in any of the grafted second-generation oak seed orchards. Therefore, to obtain a supply of seed with some genetic improvement before these seed orchards begin seed production, a portion of the cherrybark oak and water oak progeny tests were converted to seedling seed orchards. The Louisiana Department of Agriculture and Forestry converted two cherrybark oak progeny tests, the Mississippi Forestry Commission converted two cherrybark oak progeny tests and one water oak progeny test, and Temple-Inland Forest converted one cherrybark and two water oak progeny tests to seedling seed orchards (Figure 24). These progeny tests were planted with either six or ten replications of four-tree-row plots. Initially, the stocking was 435 trees per acre in all of the tests.

When the tests were converted to seedling seed orchards, the target was to leave the best tree in each row-plot from all of the families with above average volume production based on 15 or 20-year data. The five-cherrybark oak progeny tests were thinned to an average of 40.7 trees per acre (Figure 25). It was not possible to leave one tree in every row plot for the all of the above average families. In some cases, poor form prevented tree selection from a desirable family. A few trees with outstanding growth and form were also kept from families that had slightly below average performance. The final stocking varied from 32.3 to 46.5 trees per acre. Family volume superiority of the remaining trees in the seed orchards averaged 26.4 percent and ranged from 21.4 percent to 31.3 percent. Fewer trees per acre were left in the three water oak progeny tests (average 34.3). However, the average volume superiority of the remaining families was greater (52.0 percent). Additional genetic improvement for volume growth was obtained by leaving only the best tree in each row- plot. Selection pressure was also applied to improve stem straightness and reduce forking.

Figure 25. A Temple-Inland Forest cherrybark oak progeny test that was converted to a seedling seed orchard.

Selections and Seed Orchards

The Texas Forest Service continued grafting the first-generation Nuttall oak selections at College Station in 2000. Both the Mississippi Forestry Commission and the Texas Forest Service are planting these grafts in scion banks for preservation (Figure 26). Out of a total of 216 Nuttall oak selections, grafting has preserved 185. Based on progeny test data, the best selections will be grafted into future seed orchards. A portion of the selections has been lost and can not be preserved. If families from these selections have good field performance, second-generation selections will be made and included in future seed orchards.

Prior to the Nuttall oak selection program, no effort was made to preserve the original selections for any of the other species. Second-generation selections were made from the best 15 percent of the families in each of the open-pollinated progeny tests and grafted into scion banks and seed orchards for seed production.

No new second-generation selections were made in 2000. In previous years, the members have made a total of 333 hardwood second-generation selections (Table 16). These selections have been established in scion banks and seed orchards and have started producing seed that is being used in the nurseries (Figure 27). Because of the increased seed demand for selected species, the state forestry agencies of Louisiana and Mississippi have decided to expand their grafted seed orchards. The Mississippi Forestry Commission planted rootstock to expand their cherrybark oak seed orchard, and The Louisiana Department of Agriculture and Forestry planted

Figure 24. A Mississippi Forestry Commission cherrybark oak progeny test that will be converted to a seedling seed orchard.

Figure 26. Nuttall oak grafts maintained by the Mississippi Forestry Commission to be moved to their scion bank for the preservation of the first-generation selections.

rootstock for a new green ash seed orchard at their hardwood nursery near Monroe, LA.

Hardwood Thinning Study

In 2000, Potlatch Corporation collected seven-year data from their hardwood thinning study. The study was established in 1992 in a 24-year-old even-aged hardwood stand in Arkansas. The study contains five thinning treatments in a completely-randomized design with four replications. The initial basal area was approximately 95 square feet of basal area per acre in trees greater than 5 inches dbh (Figure 28). Two levels of thinning intensity were applied using both chemical and mechanical techniques. Each treatment-replication combination was one acre in size. The light thinning treatments left about 60 square feet of basal area per acre, while the heavy thinning treatments left approximately 39 square feet of basal area. Diameter at breast height and the number of epicormic branches on the butt log were determined prior to thinning.

Tree diameter and the number of epicormic limbs on the butt log were determined on a 0.5-acre plot in each treatment-replication combination in 2000. Seven years after thinning, mortality averaged 15.4 trees per acre. There were no meaningful differences in mortality among thinning treatments or species. During this seven-year period, ingrowth averaged 33.1 trees per acre. The four thinning treatments averaged an ingrowth of 35.9 trees per acre as compared to the control treatment that averaged 22.0 trees per acre. The heavy thinning treatments had more oak ingrowth (average 16.2 trees per acre) than the other treatments (average 7.5 trees per acre).

All thinning treatments significantly increased diameter growth and resulted in a similar response of growth stimulation for the oaks present in the stand (Table 17). When all species were considered, the heavy thinning treatments had greater diameter growth than the light thinning treatments. Basal area growth per acre did not vary significantly among treatments (Table 18). As the thinning intensity increased, the same level of basal area growth was obtained with fewer trees per acre. Because the number of trees per acre reflected the thinning intensity, the increased growth was concentrated on fewer, more valuable stems.

The average number of epicormic branches on the butt log ranged from 0.4 in the control treatments to 4.8 in the

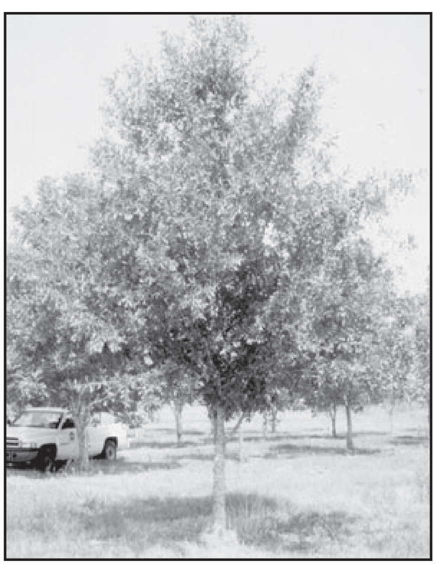

Figure 27. The Texas Forest Service water oak second-generation seed orchard in Angelina Co., TX.

Figure 28. Potlatch Corporation's hardwood thinning study: a) control treatment, and b) a chemical, heavy thinning treatment.

Table 17. Diameter growth at age seven for the hardwood thinning study maintained by Potlatch Corporation.

Treatment	Diameter Growth (in.) [1] All Species	Diameter Growth (in.) [1] All Oaks
Control	1.0 a	2.0 a
Mechanical Light	1.4 b	3.0 b
Mechanical Heavy	2.4 c	3.1 b
Chemical Light	1.5 b	2.4 a b
Chemical Heavy	2.2 c	3.0 b

[1]Means followed by the same letter are not significantly different at the 10 percent level of confidence by Duncan's New Multiple Range Test.

Table 18. Stocking and basal area growth at age seven for the hardwood thinning study maintained by Potlatch Corporation [1].

Treatment	No. of Trees/ Acre	Basal Area Growth (sq. ft./acre)
Control	271 a	25.8 a
Mechanical Light	209 b	26.7 a
Mechanical Heavy	158 c	33.0 a
Chemical Light	212 b	30.4 a
Chemical Heavy	165 c	29.2 a

[1] Means followed by the same letter are not significantly different at the 10 percent level of confidence by Duncan's New Multiple Range Test

mechanical, heavy thinning treatment. There were no significant differences among the thinning treatments for the number of epicormic branches present on the butt log. The seven-year results of this study suggest that diameter growth can be stimulated by thinning in young bottomland hardwood stands with no decrease in log quality.

PERSONNEL

There were two significant additions to the cooperative staff in 2000. Phoebe Castro assumed the responsibilities of Staff Assistant. Ms. Castro has several years experience within the TAMU system where she worked for the Office of International Admissions. Her knowledge of the system procedures and her general office skills make her well qualified to help deliver the cooperative's program to the members. Dr. David P. Gwaze joined the Forest Genetics Group in February as a Postdoctoral Research Associate working with Dr. Floyd Bridgwater. Dr. Gwaze received his Ph.D. in Forest Genetics from the Edinburgh University in Scotland. During his two-year appointment, he will be working on the use of individual tree models for the calculation of quantitative genetic parameters. Dr. Gwaze's position is financially supported by both the WGFTIP and the USDA-FS.

The staff now includes the following:

W. J. Lowe ....WGFTIP Geneticist
T. D. Byram ....Assistant WGFTIP Geneticist
G. D. Gooding ....Assistant WGFTIP Geneticist
P. D. Castro ....Staff Assistant
J. G. Hernandez ....Research Specialist
J. H. McLemore ....Aide to Specialist
D. P. Gwaze ....Postdoctoral Research Associate
J. H. Myszewski ....Graduate Student
G. R. Lively ....Research Specialist
I. N. Brown ....Research Specialist
D. M. Travis, Jr. ....Aide to Specialist
G. F. Fountain ....Aide to Specialist

PUBLICATIONS

Bridgwater, F.E., D.L. Bramlett, and V.D. Hipkins. 1999. Timing of bag application and removal in controlled mass pollination. Proc. 25th Southern Forest Tree Improvement Conference, New Orleans, LA. July 12-14. pp. 40-42.

Byram, T.D. and F.E. Bridgwater. 1999. Risk analysis of loblolly pine controlled mass pollination programs. Proc. 25th Southern Forest Tree Improvement Conference, New Orleans, LA. July 12-14. pp 44-51.

Byram, T.D., W. J. Lowe, and G.D. Gooding. 2000. Western Gulf Forest Tree Improvement Program gene conservation plan for loblolly pine. Forest Genetic Resources 27:55-59.

Elsik, C.G., V.T. Minihan, A.M. Scarpa, S.E. Hall, and C.G. Williams. 2000. Low-copy microsatellite markers for *Pinus taeda* L. Genome 43:550-555.

Elsik, C.G. and C.G. Williams. 2000. Retroelements contribute to the excess low-copy DNA in pine. Molecular and General Genetics 264(1-2): 47-55.

Elsik, C.G. and C.G. Williams. Low-copy microsatellite recovery from a conifer genome. Theoretical and Applied Genetics (In press).

Elsik, C.G. and C.G. Williams. Families of clustered microsatellites in a conifer genome. Molecular and General Genetics (In press).

Gooding, G.D., F.E. Bridgwater, D.L. Bramlett and W.J. Lowe. 1999. Top grafting loblolly pine in the Western Gulf Region. Proc. 25th Southern Forest Tree Improvement Conference, New Orleans, LA. July 12-14. pp.60-66.

Gwaze, D.P., F.E. Bridgwater, T.D. Byram, J.A. Woolliams and C.G. Williams. 2000. Predicting age-age genetic correlations: a case study with *Pinus taeda* L. Theoreticaland Applied Genetics 100(2):199-206.

Gwaze, D.P., F.E. Bridgwater, and W.J. Lowe. Performance of interspecific F_1 Eucalypt hybrids in Zimbabwe. Forest Genetics. (In press).

Gwaze, D.P., F.E. Bridgwater, T.D. Byram and W.J. Lowe. Genetic parameter estimates for growth and wood density in loblolly pine (*Pinus taeda* L.). Forest Genetics (In press).

Gwaze, D.P. and J.A. Woolliams. Making decisions about optimal selection environement using Gibbs sampling. Theoretcal and Applied Genetics (In press).

Hall, S.E. W.S. Dvorak, J.S. Johnston, H.J. Price and C.G. Williams. 2000 Flow cytometric analyses of DNA content in tropical and temperate New World pines. Annals of Botany. 86 1081-1086.

Joyner, K.L., K.-R. Wang, J.S. Johnston, H.J. Price and C.G. Williams. DNA content for Asian pines parallels New World Relatives. Canadian Journal of Botany (In press).

La Farge, T., F.E. Bridgwater and M. N. Baez. 1999. Performance of loblolly pine seed sources in Argentina. Proc. 25th Southern Forest Tree Improvement Conference, New Orleans, LA. July 12-14. pp. 114-119.

Myszewski, J.H., L. Fins, J.A. Moore, W.C. Rember, M. Rust, and P. Mika. 1999. Variation in root bark chemistry of Douglas-fir. Proc. 25th Southern Forest Tree Improvement Conference, New Orleans, LA. July 12-14. pp.124-125.

Williams, C.G. and T.D. Byram. Forestry's third revolution: integrating biotechnology into *Pinus taeda* L. breeding programs. Southern Journal of Applied Forestry (In press).

Williams, C.G., C.G. Elsik and R.D. Barnes. 2000. Microsatellite analysis of *Pinus taeda* L. in Zimbabwe. Journal of Heredity 84:261-268.

COOPERATIVE TREE IMPROVEMENT PROGRAM

Western Gulf Forest Tree Improvement Program Membership

Pine Program

Full members of the Western Gulf Forest Tree Improvement Pine Program include the Arkansas Forestry Commission, Boise Cascade Company, The Bosch Nursery, Inc., Champion International Corporation, Deltic Timber Company, Inc., International Paper Company, Louisiana Department of Agriculture and Forestry, Louisiana-Pacific Corporation, Mississippi Forestry Commission, Oklahoma Forestry Services, Potlatch Corporation, Temple-Inland Forest, Texas Forest Service, The Timber Company, Inc., Weyerhaeuser Company, and Willamette Industries, Inc.

Associate members include International Forest Seed Company, Louisiana Forest Seed Company, Pacific Millennium Corporation, and Robbins Association.

Hardwood Program

The WGFTIP Hardwood Program includes the Arkansas Forestry Commission, Champion International Corporation, Louisiana Department of Agriculture and Forestry, Mississippi Forestry Commission, Potlatch Corporation, Temple-Inland Forest, and the Texas Forest Service.

Urban Tree Improvement Program

Membership in the Urban Tree Improvement Program includes the following municipalities and nurseries: Aldridge Nurseries (Von Ormy), Altex Nurseries (Alvin), Baytown, Burleson, Carrollton, Dallas, Dallas Nurseries (Lewisvlle), Fort Worth, Garland, Houston, LMS Landscape (Dallas), Plano, Rennerwood (Tennessee Colony), Richardson, Robertson's Tree Farm (Whitehouse), and Superior Tree Foliage (Tomball).

FINANCIAL SUPPORT

Financial support was provided by members of the Western Gulf Forest Tree Improvement Program, the members of the Urban Tree Improvement Program, the Texas Agricultural Experiment Station, the Texas Forest Service, the Texas Christmas Tree Growers Association, and the USDA Forest Service.