FIFTY-FOURTH

PROGRESS REPORT

OF THE

COOPERATIVE

FOREST TREE IMPROVEMENT

PROGRAM

By

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INTRODUCTION

The Western Gulf Forest Tree Improvement Program (WGFTIP) continued to adjust to changing circumstances throughout 2006. The response to 2005 hurricanes Katrina and Rita spilt over into 2006 as one or the other of these two storms damaged nearly every orchard complex in the states of Mississippi, Louisiana, and Texas. In the aftermath of the storms, cooperative members were involved in extensive orchard sanitation efforts, reevaluation of long-term plans for the consolidation and replacement of orchard facilities, and the struggle to make sense of severely damaged progeny tests. The other major factor with which the cooperative continued to deal over the last year was the continuing volatility in timberland ownership. This now seems to be a permanent part of the business environment as the forest industry persists in divesting itself of its landbase. International Paper Company sold its land and began the reorganization of its Nursery and Orchard Group into a regeneration company. Potlatch Corporation completed the conversion to a Real Estate Investment Trust (REIT) and is now Potlatch Forest Holdings, Inc. Furthermore, we are now witnessing the second round of trades as property that was initially spun off by integrated-forest industry is 'flipped' again. ETT, L.P. land formerly owned by Kirby Forest Industries, Inc. was purchased by Hancock Forest Management. Each of these organizations recognized that they have a vested interest in tree improvement and have opted to continue their existing programs. While these changes did not alter the number of organizations supporting the cooperative, some of these realignments will affect the allocation of the workload among members.

Previous annual reports have chronicled the cooperative's struggle to respond to the broader issues raised by the changes in forest land ownership. We have questioned our goals, redefined our clients, and struggled to identify our ultimate customers. The cooperative has made great strides in dealing with the first two of these issues. This has allowed us to effectively broaden our support base within the scope of our mission to include not only the traditional organizations, such as state agencies and integrated forest industries, but also less traditional partners, such as Timber Investment Management Organizations (TIMOs), REITs, regeneration companies, and biotechnology concerns. The cooperative's goals have always been defined as population improvement to provide selections for innovation within individual member's proprietary programs. Clients have been recognized as any organization that has a vested interest in producing genetically improved material regardless of its intended use. Defining the ultimate customer, however, has been more problematic. This is the group to which the benefits of tree improvement primarily accrue and those that should reasonably be expected to pay the costs.

Historically, a case could be made that the ultimate customer of tree improvement was the forest products manufacturer who benefited from having an abundant, low cost, and high quality supply of raw material. The expense of tree improvement was subsidized either by state governments providing seedlings at cost to support their environmental and economic development goals or by an industry that viewed wood production as peripheral to their main manufacturing businesses. With the separation of the forest landbase from the manufacturing sector, the customer for forest genetics is now more appropriately identified as the landowner. This category of investor makes tree improvement pay by converting anticipated improvement in growth into larger immediate harvests (allowable cut effect) and/or by playing the long game for larger final harvests of better quality. Landowners, who are generally paid commodity prices, capture less of the total value available from tree improvement than the integrated-forest industry that can add additional value through manufacturing. A complicating factor is that a higher percentage of the commercial forest land is now owned by individuals and organizations that prefer to outsource tree improvement rather than do it themselves.

The assumption is that these landowners will willingly pay the cost of tree improvement when they purchase seedlings. Indeed, this seems reasonable as the cost:benefit ratio for genetic improvement is outstanding. So with the shift in ownerships, new business opportunities arise. This is reflected by the participation of two pure regeneration companies in the WGFTIP: CellFor, Inc. and International Paper Company's former Nursery and Orchard Group. Neither organization owns any land and intends to recoup their investment in genetics through the sale of planting material.

The one attribute that all members of the cooperative have had in common down through the years is a vested interest in better genetics. This is certainly true for the landowning members, whether they are integrated forest industry or investment companies. Increased productivity makes it possible to increase harvest levels, shorten rotations, and lower production costs. Improved quality translates into a higher value product mix. Integrated-forest industry captured even more of this gain in added value to manufactured end products. State forestry agencies have traditionally invested in tree improvement to support regional economic development and environmental goals. Regeneration companies, whose primary products are seedlings, invest in tree improvement to market improved genetics to the landowner. Individually, each of these entities has an indisputable need for faster growing trees, but they each have their own criteria for evaluating their investments in tree improvement and their own set of challenges in providing economic justifications to their stakeholders.

The collective tree improvement community, made up of tree improvement cooperatives, university researchers, and public and private tree breeders have a fundamentally different set of challenges than those faced by the individual cooperative members. How do we organize, manage, and fund programs that inherently 1) run on a much longer time scale than the planning horizon, or even the likely length of ownership, of individual supporters and 2) whose breeding zones poorly coincide with constantly shifting ownerships?

Timelines for breeding programs are set by the biology of the species and are immutably tied to reproductive and selection cycles. These are, with increasing frequency, much longer than the time frames businesses use to evaluate return on investment. This has led organizations to struggle to define 'pre-commercial value' and to recognize the need, as yet unmet, to develop appraisal systems that reflect the market value of silvicultural research. The second difficulty for the tree improvement community is to maintain an adequate number of mutually supportive programs within regions where ownerships are constantly shifting. This need was first threatened by mergers and consolidations in the 1990s that limited the number of regional participants. Now the opposite problem of fragmentation also threatens the ability to sustain mutually supportive programs. Many ownerships are no longer large enough to justify direct investment in tree improvement. Therefore the difficulty that the tree improvement community now faces, if not a tragedy, is at least a crisis of the commons[1]: the need to reconcile the individual economic short-term demands of an ever divergent group of organizations with the requirement to manage a long-term research and development program for the common good.

All of these competing pressures point to two possible outcomes. The first alternative is to accept the level of genetic gain we currently have in hand and to mothball our tree improvement programs. A less severe variation on this alternative is to accept a slower rate of improvement in genetic gain as the workload is distributed among fewer participants. There is pressure to do this as corporate, state and federal players leave the field. In either case, the US loses competitive position in timber production relative to the rest of the world. The second alternative is to entice public and private breeding programs to continue the long-term capital-intensive investment needed to develop genetically improved trees. To do this, new sources of support must be found. The first option by which this can be accomplished is to find new subsidies to replace the integrated-forest industry/state forest agency model. It is yet unclear whether simply transferring this responsibility for the program to new classes of owners as the cooperatives have so far attempted will be successful. A second option is to charge land owners higher seedling prices with a substantial premium for the best genetic material. Higher prices will require a break with the past, as seedlings have generally been provided on a cost plus basis where the expense of tree improvement was to a large degree hidden in organizational research budgets. Seedling prices historically reflected only nursery and orchard production expenses. Substantially higher prices for seedlings have possible consequences for public policy as they may in turn lead to less planting with ultimately less resource available for forest manufacturers and local economies.

As there are no ecologically viable alternatives to wood and wood fiber, it seems likely that tree improvement is something that society will continue to need. The dilemma then is how to keep a sufficient number of organizations engaged in the difficult tasks of breeding and progeny testing until viable alternatives can be implemented. The solution to this problem may be beyond the scope of the cooperative as the tragedy of the commons by definition has no technical solution, but requires societal and political solutions[1]. Ultimately, we must resolve the question of who our customers are. Who benefits and who pays?

2006 Activities

In 2006, the cooperative was involved in all of the usual activities of planting and measuring progeny tests, collecting seed, grafting and managing orchards. In addition to our normal activities the WGFTIP participated in a number of collaborative projects that may impact future operations. These collaborative projects included further development of the Wood Quality Elite Population, participation in a south-wide worker exposure study to quantify the exposure of harvest crews to pesticide residues, and testing sonic transmission in standing trees as a surrogate for stiffness. Tracking relatedness and population size is also becoming a priority as the cooperative transitions into the next round of breeding.

The Wood Quality Elite Breeding population was expanded to 62 individuals that combined reasonable growth rates and superior specific gravity. These backwards selections are being mated to form a population from which individuals will be identified for use in seed orchards and for further breeding. The unique aspect of this project is the collaboration with CellFor, Inc. to produce varietal lines to evaluate within-family selection for a subset of these crosses. So far, six cooperators have contributed conelets from 10 crosses to support this effort. CellFor has initiated sufficient numbers of cell cultures to make it likely that the cooperative will plant two series of clonal progeny tests, one in Arkansas and one in Texas, beginning in 2008.

The worker exposure study that has been planned for a number of years was finally conducted in 2006. This collaborative study involved a large number of organizations scattered from South Carolina to California. The intent of the study was to quantify the amounts of pesticide residue present in workers blood streams after performing normal cone harvesting activities. Weyerhaeuser Company, Plum Creek Timber Company, MeadWestvaco, Smurfit-Stone Container Corporation, Louisiana and Texas all contributed orchards. The University of California – Riverside is performing the laboratory analysis. After suffering a number of false starts over the last few years caused by crop failures and unpredictable weather, this year was a resounding logistical success. The tree improvement community, represented by organizations from all three southern pine cooperatives, collected far more samples than called for in the original study plan, sampled more job tasks, and were able to evaluate two different classes of pesticides. This

1 Hardin, G. 1968. The tragedy of the commons. Science 162 (3859): 1243-1248.

study also broke new ground in setting acceptable standards for EPA protocols.

A third collaborative project involved the USDA Forest Service Southern Institute of Forest Genetics working in International Paper Company progeny tests. This project evaluated the use of a Fakopp Stress Wave Timer to capture sonic transmission intervals in standing trees. This trait is highly correlated with stiffness and strongly related to differences in microfibril angle. Initial analyses were encouraging, showing sonic transmission times to be moderately heritable. There are still logistical problems to be resolved.

The cooperative is moving into the next cycle of breeding. As the third-cycle breeding population is identified, the need to track relatedness and population size is becoming a burden. This year, the cooperative developed techniques to track coancestry in its entire population. With this parameter, both the Census Number and Status Number can be monitored and the relative reduction in effective population size evaluated as generations advance in our closed population. The most immediate application for coancestry matrices will be to identify relatives considered as candidates for inclusion in seed orchards. Coancestry will be used to plan matings among distantly related individuals so that the rate of inbreeding within the breeding population can be regulated.

Figure 1. Vivian Jimerson's son Michael (right) and grandson Taylor inspect the three-year-old stand that may finance Taylor's college education.

One of the highlights of the year was having the opportunity to host Dr. Dag Lindgren and Finnvid Prescher from Sweden. The WGFTIP was one of several stops in their visit to the southeast to review seed orchard and seedling deployment strategies. This visit was particularly important to the WGFTIP because it was Åke Gustavson, Dag Lindgren's academic predecessor, who provided the impetus for the State of Texas to invest in tree improvement. As the story goes, Gustavson was giving a series of lectures on genetics during a visit to Houston in 1950. Almost as an afterthought, he included a lecture on the potential of tree improvement and forest genetics. This lecture was attended by a number of leaders from the forest industry, the director of the Texas Forest Service and the governor of the state. Because he was so persuasive, the decision was made to undertake the project that eventually grew into the Western Gulf Forest Tree Improvement Program. We were grateful to have the opportunity to repay this debt in even a small way. Temple-Inland Forest and several faculty members from the Forest Science Department at Texas A&M University joined with the Texas Forest Service and WGFTIP staff in hosting Dag and Finnvid for a week in September, 2006.

Last but not least, was the dedication of a sign commemorating the founding of the Texas Forest Service tree improvement program in 1951. The sign is adjacent to Highway 259 south of Henderson, TX on the property of Vivian Jimerson. The tract was planted with seedlings from the Texas Forest Service program in 2003/04 (Figure 1). A partial list of the special guests attending the dedication included the Jimerson family, James Hull, the Director of the Texas Forest Service, J.P. van Buijtenen, former head of the state and cooperative tree improvement programs, Ed Barron, former Associate Director of the TFS, Tom Boggus, Associate Director of the TFS, and Ron Hufford, Executive Director of the Texas Forestry Association (Figure 2).

Figure 2. J.P. van Buijtenen (left) and James Hull were featured speakers at the gathering to commemorate the founding of the program.

Highlights

- In the aftermath of the 2005 hurricanes, only five members were left with producing slash pine seed orchards and only four members were actually collecting seed for this species. New advancing-front slash pine seed orchards are highly improved for rust resistance as disease resistance for most selections have been evaluated both in the greenhouse and the field.

- The 44 acres of advanced-generation orchards grafted in 2005/06 offset the 42 acres of orchard that were abandoned. The cooperative now manages 2,089 acres of orchard, of which 893 acres are intensely rogued first-generation orchards and 1,196 acres are advanced-generation orchards.

- In 2005, 22,293 pounds of loblolly seed and 1,821 pounds of slash pine seed were collected. Seed yields were very good overall, but orchards near the coast were impacted by the hurricanes and had lower yields.

- The cooperative has sufficient seed on hand to grow seedlings for three series of advanced-generation polymix tests in the summer of 2006. Two series were for Arkansas/Oklahoma while the third series was for North Louisiana.

- The loblolly pine second-cycle breeding population totals 1,843 individuals in 93 breeding groups. Fifty-one groups are considered completely reconstituted while selection efforts are on-going in 57 breeding groups.

- Third-cycle selections have been made in five South Arkansas breeding groups.

- The collaboration with CellFor, Inc. to clonally test part of the Wood Quality Elite Population has produced cell lines from eight crosses contributed by six members.

Seed Orchards

The WGFTIP seed orchard program will suffer from the impact of the 2005 hurricane season for years to come. Either Hurricane Katrina or Rita damaged nearly every seed orchard complex in Mississippi, Louisiana, and Texas causing some older orchards to be abandoned while lowering stocking levels and reducing production capacity in others. Members continued to reassess long-range plans throughout 2006 in light of these significant losses (Figure 3). This comes at a time that seedling demands are low as fewer acres are planted across the South and wider planting spacings both reduce the number of trees required. These facts, coupled with opportunities that have arisen because of program mergers and consolidations, resulted in several programs readjusting their orchard replacement plans. The most historically significant of these adjustments was the closing of the Weyerhaeuser Isabel orchard complex. This orchard complex, outside Bogalusa, LA, was originally established by Crown Zellerbach in 1965 and was one of the earliest seed orchards in the region. The older orchards at this location supplied much of the improved Livingston Parish seed planted throughout the southeast and in many other regions of the world.

Figure 3. The Mississippi Forestry Commission's Craig Seed Orchard showing the extensive orchard expansion that will replace production capacity lost to Hurricane Katrina.

Other members adjusted their orchard management by combining roguings with sanitation efforts, advancing rootstock establishment schedules to allow quicker replacement of abandoned orchard blocks, and continued consolidation to more productive orchard sites. Significant production capacity was lost in the slash pine program with two members losing all of their producing slash pine orchards at key orchard complexes. This left only five members with production slash pine seed orchards. As this species has not been in high demand, orchard acres have been declining and some organizations have foregone scheduled replacements. Organizations that have been utilizing the advancing-front orchard replacement scheme, however, have some excellent parents with much improved rust resistance coming on line very soon. This highly improved slash pine seed source may find its niche as it is a suitable alternative to loblolly on many of the acres damaged by the hurricanes. Unusually severe outbreaks of stress related problems were also observed in several orchards (Figure 4). Because of the lead time needed to make significant changes in orchard replacement, the true impact of the storms will continue to be documented

Figure 4. Plum Creek's Moselle Orchard showing the combined impact of wrenching from the hurricane followed by hail and Ips infection resulting in severe die-back in the crowns of older trees.

over the next several annual reports. Previous experience has shown that even orchards with severe crown damage recover full production capacity within two to three years. Recovery from lower stocking levels because of downed trees will require orchard replacement and be much slower.

Orchard Establishment and Acres Managed

Potlatch Forest Holdings, Inc, Deltic Timber Corporation, and the Mississippi Forestry Commission grafted loblolly pine seed orchards in 2006 (Figure 5). These 44 acres of new orchards offset the loss of 42 acres removed from production. New orchards had an average gain of 36.6 percent improvement in breeding value for volume production. All of the removal and replacement activity took place in advanced-generation orchard blocks leaving the number of highly rogued first-generation orchards unchanged. The members of the cooperative now manage 2,089 acres of pine seed orchards (Figure 6). Of this total, 893 acres are rogued first-generation orchards and 1,196 are advanced-generation orchards. The Texas Forest Service also grafted a small Virginia pine seed orchard to supply the Christmas tree growers with a locally tested seed source for this species.

Members establishing rootstock for grafting in 2007 included the Texas Forest Service, the Mississippi Forestry Commission, the Arkansas Forestry Commission, Weyerhaeuser Company, and Temple-Inland Forest.

Orchard Yields

The 2005 seed harvest had promised to be outstanding. Not only was the cone crop one of the best many seed orchard managers had ever seen, it was of excellent genetic quality as many younger orchards were expected to have their first commercial harvest. Then the

Figure 5. Les Welsh and Louis Rainey inspect new grafts in Deltic Timber Corporation's newest orchard expansion. The oldest block of orchard at this location is in the background.

Western Gulf region experienced two major hurricanes, one or the other of which impacted cone collection at nearly every orchard in Mississippi, Louisiana, and Texas. Despite the disruption caused to the 2005 cone harvest by the hurricanes, the cooperative still managed to collect a total of 22,293 pounds of loblolly pine seed and 1,821 pounds of slash pine seed (Figure 7). The 2005 seed harvested exceeded the 2004 collection and came close to meeting the cooperative's annual demands. The genetic quality may have suffered somewhat because the difficult collection conditions made high-grading the cone crop difficult. Older orchards in southeast Louisiana and southern Mississippi were completely destroyed and a number of trees in younger orchards were downed by Hurricane Katrina. This limited the number of trees available for harvest and required lower thresholds for selecting families from which to collect.

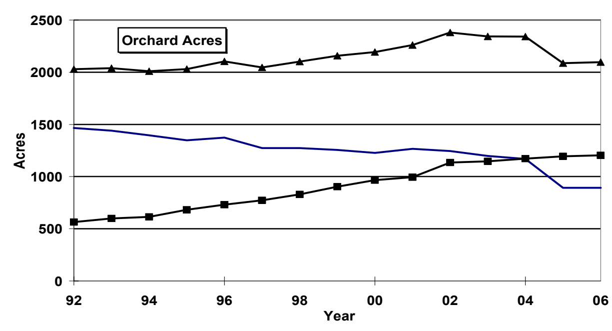

Figure 6. Seed orchard acres managed by the cooperative.

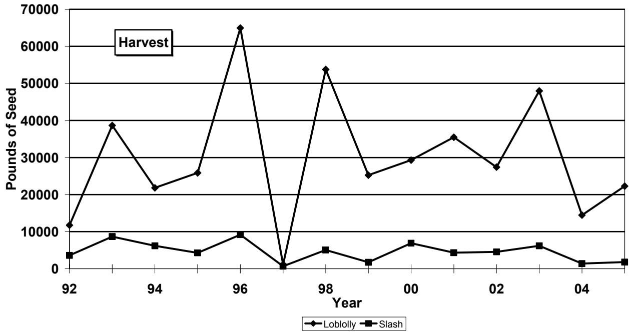

Figure 7. Pounds of seed harvested by the cooperative from 1992 to 2005.

Hurricane Rita occurred close to harvest time, and while it was possible to collect cones from downed orchard trees in Texas and western Louisiana, jumbled tops made family collection difficult. Future slash pine seed production was severely impacted as only five members were left with mature orchards for this species. The 2005 crop was collected from only four of these orchards.

Loblolly pine seed yields by orchard ranged from a low of 0.74 pounds of seed per bushel to an outstanding 1.57 pounds of seed per bushel achieved by the Arkansas Forestry Commission. Orchard complexes managed by Forest Capital Partners, LLC, Plum Creek Timber Company, International Paper Company, Temple-Inland Forest, and Weyerhaeuser Company all exceeded 1.3 pounds of seed per bushel. As a rule, most of the poorer yields were experienced by organizations managing orchards near the coast. Average yields across the cooperative were 1.19 pounds of seed per bushel for loblolly pine and 0.98 pounds of seed per bushel for slash pine seed.

The cooperative collected 23,270 bushels of loblolly pine cones and 2,081 bushels of slash pine cones

Figure 8. An example of the outstanding cone crop many orchards managed to produce in 2006.

Figure 9. Steve Marietta of Hancock Forest Management in their oldest advanced-generation orchard block.

in 2006 (Figure 8). The genetic quality of the seed harvest continues to improve as younger orchards make a significant contribution to the crop and as members continue to collect only the best families (Figure 9). Again this year, only four members collected slash pine. The Mississippi Forestry Commission and the Louisiana Department of Agriculture and Forestry collected a combined total of 1,027 bushels of longleaf. Small quantities of shortleaf and Virginia pine seed were also harvested.

Breeding and Progeny Testing

First-Generation Test Establishment

Seed were sown by Weyerhaeuser Company during the summer of 2006 for the last remaining first-generation diallel by location combination of loblolly pine. Breeding for this diallel, the last for Breeding Group 78, had been completed in 2004. Planting was delayed with the hope of identifying another study with which this material could be combined. As no such opportunity presented itself, seed were sown in the summer of 2006 for the last remaining 15 untested first-generation loblolly families in the program. Survival will be assessed in the fall of 2007. As reported in last year's Annual Report first-generation slash pine breeding and progeny test establishment was completed in 2005 with the planting of the final test series by Temple-Inland Forest. Survival across the three tests in that series averaged nearly 87 percent. The emphasis of the first-generation progeny testing program is now on the measurement of established growth and form plantings and the identification of the additional second-generation selections needed to reconstitute the population for the next cycle of breeding.

Test Measurement and Second-Generation Selection Activity

During the 2005/06 measurement season, the cooperative measured 99 of the 104 progeny tests scheduled for evaluation. Most of the five unmeasured tests were in South Mississippi and southeastern Louisiana and were completely lost to Hurricane Katrina. Many of the other tests along the Gulf Coast were wind damaged. Extraordinary efforts were made by individual members to recover from the storms. Personnel from the Mississippi Forestry Commission, Weyerhaeuser Company, Forest Capital Partners, LLC, Plum Creek Timber Company, Temple-Inland Forest, Louisiana Department of Agriculture and Forestry, Hancock Forest Management and the Texas Forest Service climbed through downed and damaged tests to record diameters (Figure 10). This was done to develop and utilize rankings based on basal area performance in tests where height data were compromised. Basal area, which combines survival and diameter growth, is an approximation for volume per acre. Because it does not include height growth, it is less informative than volume per acre normally used for selection. To compensate for less precise data, selection intensity will be lowered on datasets solely dependent on basal area (Figure 11). Weyerhaeuser Company also evaluated a ten-year-old loblolly pine test off-cycle at age 9 and their installation of block plots at age 4 in South Louisiana to capture data before storm-related mortality affected these tests.

Keeping track of the progeny testing program has become much more complicated as the cooperative uses

Figure 10. Terry Rucker of Forest Capital Partners, LLC with a second-generation selection in a 10-year-old slash pine test. Damaged and leaning trees from Hurricane Rita are evident in the background.

Figure 11. Progeny test trees damaged by Hurricane Rita for which survival, disease incidence, and basal area were assessed.

different crossing schemes and different field designs to accomplish different goals. The testing program now includes plantings established to evaluate growth and form for both first-generation and advanced-generation parents. The first-generation parents are established as control-pollinated families with known pedigrees in replicated plantings at multiple locations. These growth and form plantings serve as both the evaluation population and the selection population. Advanced-generation parents are ranked in growth and form plantings with polymix crosses in replicated plantings at multiple locations. Pedigreed crosses planted in unreplicated blocks form the selection population for both the main-line advanced-generation breeding program and elite populations based on backwards selections such as the super-breeding groups and the Wood Quality Elite Population. For clarity, tests established to rank parents are referred to as growth and form plantings while plantings established to form the population from which the next cycle will originate are referred to as selection plantings.

In 2006, survival was assessed for two series of selection block plots and eight loblolly pine growth and form progeny tests, most of which were advanced-generation polymix tests. Age three height was evaluated in one polymix test series with three locations in South Mississippi/South Louisiana and the rankings used to select parents for the initial pedigree breeding effort. This assessment is preliminary and is only intended to provide cooperators with guidance on which parents will most likely be chosen for the selection population at older ages. Growth and form were evaluated on 19 five-year-old tests, including one shortleaf pine polymix test, as well as loblolly pine polymix test series in each of three breeding regions: Arkansas/Oklahoma/North Mississippi, East Texas, and South Mississippi/South Louisiana. Fifth-year measurements of six first-generation diallel tests resulted in first-time evaluations of 57 loblolly pine parents in East Texas and 43 slash pine parents. Fifth-year measurement of eight advanced-generation polymix tests resulted in first-time evaluations of 46 first-generation and 274 advanced-generation parents.

In 2005/06 only 32 ten-year-old tests were measured, 60 percent of the number of age-10 tests measured the previous year. Twenty tests were measured at age 15, including five long-term longleaf tests. Four tests received their final measurement at age 20. All of these older tests were first-generation growth and form plantings. The cooperative is measuring fewer progeny tests each year as first-generation plantings are mothballed and because the advanced-generation testing scheme requires fewer field installations.

Cooperators screened 71 control-pollinated families over multiple locations in first-generation growth and form plantings and identified 45 new second-generation selections in 2006 (Figure 12). Of these, 30 were loblolly pine and 15 were slash pine. International Paper Company and Hancock Forest Management added the most new loblolly pine selections, each adding eleven to their Texas programs. Forest Capital Partners, LLC led the effort in slash pine by adding eight of the 15 new slash pine second-generation selections to the program. The cooperative now has a total of 1,663 loblolly pine and 260 slash pine second-generation selections (Figure 13).

Figure 12. Tommy Sims of Plum Creek Timber Company with a newly identified second-generation selection in his program.

The cooperative is beginning to move into the next cycle of selection and breeding. In 2005/06, five sets of pedigree block plots were measured at age five by International Paper Company, Plum Creek Timber Company and Potlatch Forest Holdings, Inc. The data from these plots was used to make 28 new third-cycle selections and add 4 new super-breeding group selections to the South Arkansas population. Two of the cooperative's oldest breeding groups, belonging to International Paper Company and Plum Creek Timber Company (originally a Georgia-Pacific breeding group), have been reconstituted for the third-cycle. To date, third-cycle selections have been made in five breeding groups, all in South Arkansas. Groups are reconstituted strictly on the basis of parental breeding values. While most members of the next cycle will be true third-cycle selections, they will also include a few outstanding parents from both the first and second generations and some individuals that were created by crossing first-generation with second-generation parents.

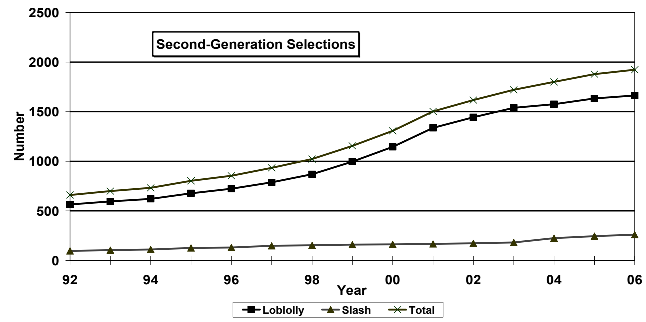

Figure 13. Cumulative number of WGFTIP second-generation selections.

Second-Generation Loblolly Pine Breeding and Testing

The second-generation breeding and testing program continues to be one of the cooperative's most successful examples of collaboration. Each member is responsible for creating polymix cross families from selections in their own breeding groups. Seedlots are pooled on a regional basis and members work together to produce test seedlings and establish field plantings. The benefits of this system were never more apparent than in 2006 when seed were sown for three regional polymix test series, two in Arkansas and one in North Louisiana. Members working with the South Arkansas population were so successful with their 2004 crossing/2005 seed harvest that two series of tests were required to get all available polymix families tested. The regional polymix test series planted in North Louisiana was the first advanced-generation growth and form evaluation for this region. One location of the South Arkansas polymix test was planted in North Mississippi.

The Arkansas Forestry Commission grew seedlings for one of the Arkansas/Oklahoma loblolly polymix test series in their greenhouse facilities at Bluff City. Germination was excellent resulting in enough seedlings for three tests. The Arkansas Forestry Commission, Potlatch Forest Holdings, Inc. and the Oklahoma Department of Agriculture, Food and Forestry collaborated during the fall and winter of 2006 to establish one test each containing 74 families. This test contained a mixture of first- (4), second-

(60) and super-breeding group selections (10). The second polymix tests series for this region was grown by the Oklahoma Department of Agriculture, Food and Forestry in their greenhouse in Idabel (Figure 14). The Arkansas Forestry Commission, Plum Creek Timber Company, Potlatch Forest Holdings, Inc. collaborated to establish one test each of this series containing 61 second-generation families. In addition, a fourth location containing 55 families was established by the Mississippi Forestry Commission during the winter of 2006.

Figure 14. Justin Jones of the Oklahoma Department of Agriculture, Food and Forestry with seedlings from one of two Arkansas/Oklanoma/North Mississippi advanced-generation loblolly pine progeny test series.

First-time evaluations of second-generation selections made in the North Louisiana region will be available in five years time thanks to the collaboration of members in that region, both past and present. Seed for this test series were grown by Forest Capital Partners, LLC, in their greenhouse facilities in DeRidder, LA. The Louisiana Department of Agriculture and Forestry and Weyerhaeuser Company, collaborated with Forest Capital to establish three tests locations containing 94 polymix families (Figure 15). Several of these families are from former member Bosch Nurseries, the parents of which are being preserved by the state of Louisiana in their scion bank. To allow for the comparison of performance across regions, ten families from the Arkansas polymix test series were included in this test series, bringing the total number of tested families to 104. In addition ten North Louisiana families were included in the second series of Arkansas polymix tests, including the Mississippi location. This cross-regional testing was made possible by the superb seed handling efforts of the cooperators in these regions, resulting in excellent seed germination in all test series. All future tests will contain families from adjacent regions. This is being done to provide data to guide deployment to neighboring zones and linkages between populations.

Figure 15. Clem Lambeth (middle left) and Bob Purnell (middle right) inspect one location of the first advanced-generation loblolly pine progeny tests established for the North Louisiana breeding region.

Selection Population Establishment for the Advanced-Generation and Elite Populations

With polymix testing serving the primary purpose of ranking selections, the second part of the advanced-generation breeding program is the establishment of pedigree crosses to form the selection population for the next cycle of breeding. These crosses are planted in un-replicated block plots containing either 100 trees at one location or 49 trees divided between two locations. Breeding for these crosses were originally initiated when adequate flowers or pollen were available. The cooperative altered the pedigree program by dropping the random crossing scheme in 2005 in favor of delaying crosses until some performance information is in hand. Pedigreed crossing schemes are now initiated after three-year height measurements are made and parents are added or deleted based on fifth-year volume growth. While this adds more time between cycles, it greatly improves the efficiency of the breeding and testing program and reduces the number of backwards selections that need to be included in subsequent generations.

In addition to the pedigreed crossing, breeding groups are paired and the best individuals are crossed to create unique selections for the deployment population. These super-breeding group crosses, based on backward selections, should have high breeding values and can be designed to provide out-crossed selections from inbred parents. Crossing in the super-breeding groups, pedigree crossing for the mainline breeding population, and crossing for the Wood Quality Elite selection populations are occurring simultaneously. Seedlings from all of these families are intended for establishment in selection plots. In 2005/06 the Arkansas

Forestry Commission established four plots, their fourth set in as many years, from which third-cycle and super-breeding group selections may be made in 2010. The Texas Forest Service also established block plots in the winter of 2005/06. With 23 plots, this is the first series of pedigree, super-breeding group and Wood Quality elite crosses planted by the Texas Forest Service. Block plots were established in the winter of 2006/07 by Potlatch Forest Holding, Inc. and International Paper Company. Potlatch Forest Holdings, Inc. established 21 plots of super-breeding group crosses in their fifth series of block plots. In addition International Paper Company sowed seed for 24 plots in Arkansas and 67 in Texas. When crosses made for these elite populations are among members of the same breeding group, they will also be used for the mainline breeding population. Fewer block plots will be established for the mainline breeding program as crosses are designed with polymix data in hand.

Status of the Loblolly Pine Breeding Population

The rate of genetic gain in a breeding program is determined by two components: the presence of adequate genetic variation and population size/structure. Genetic variation for almost every economically important trait so far studied in the southern pines has been more than adequate. Population size needs to be large enough to maintain sufficient genetic variation in the breeding population so that continued improvement through a number of breeding cycles is guaranteed and to allow selection pressure to be applied when designing the deployment population. These demands have to be balanced against the competing need to keep the population size manageable. Smaller populations are possible when only one trait with large amounts of variation is manipulated. Larger populations are required when multiple traits are improved simultaneously, especially if the traits are poorly correlated.

Population size and structure must also be manipulated to ensure that enough genetic variation is maintained to meet future economic and environmental requirements. One way to do this is known as Multiple Population Breeding[2] where different populations are selected for different traits. The WGFTIP strategy to deal with this need is to divide the population into breeding zones and to further subdivide each of these breeding populations into self-contained breeding groups. The economic breeding objectives are the same in each of these populations, but the environments in which selection is conducted vary and so the adaptive traits are under different selection pressures.

A number of parameters can be used to characterize populations. The most straight-forward is the Census Number or the actual count of individuals. In a closed population where relatedness builds in subsequent breeding cycles, another important metric is the Status Number. This is calculated from the average coancestry and is an estimate of effective population size. This is the number of unrelated individuals that would maintain the same degree of genetic diversity as the related population in question. Status Num-

2 Namkoong, G. 1976. A multiple-index selection strategy. Silvae Genetica 25: 199-201; Namkoong, G. 1997. A gene conservation plan for Loblolly pine. CJFR 27:443-437.

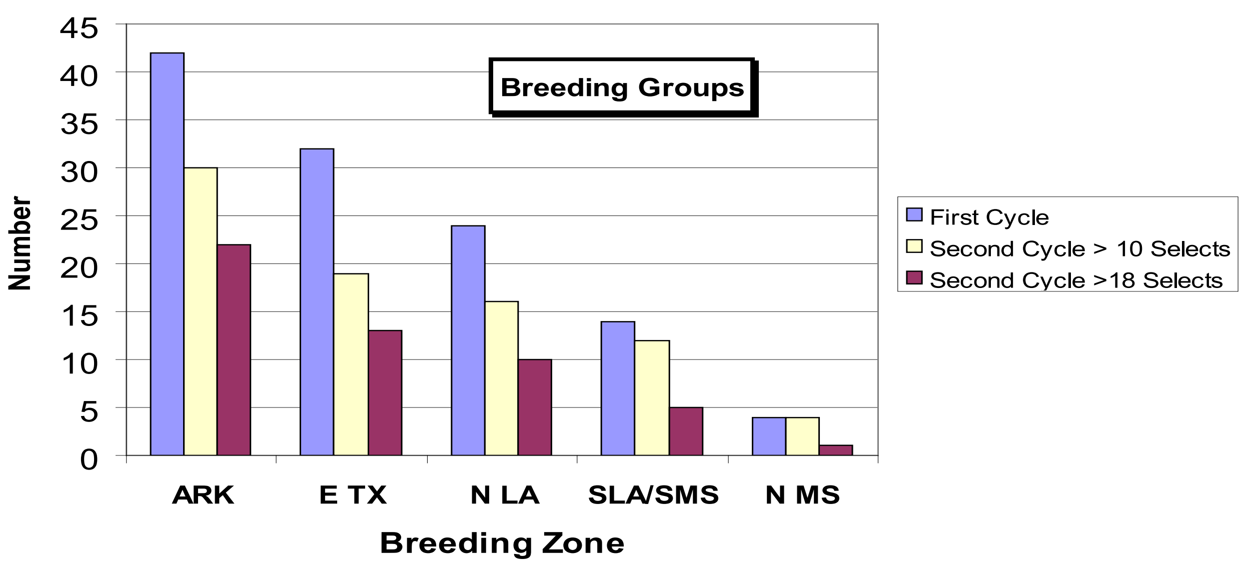

Figure 16. The number of completed breeding groups in each region. The number of breeding groups will be the same in each subsequent generation as sufficient selections are identified to reconstitute the population. Second-generation breeding group statistics show the number that have 10 or more selections (can be carried forward on their own) and fully reconstituted with 18 or more selections

Table 1. The number of Breeding Groups (BG) and average Census Number, Status Number and Relative Status Number by breeding region for the current second-cycle population.

	Breeding Zone					
	AR	TX	N LA	S LA/S MS	N MS	Total
No. of BGs	31	28	17	13	4	93
Census No./BG	22.5	19.1	18.9	17.3	16.5	19.8
Status No./BG	8.3	7.8	7.7	6.9	6.6	8.1
Relative Status No.	0.37	0.41	0.41	0.40	0.40	0.39

ber will always be less than Census Number when any of the individuals within the group are related. The number of unrelated breeding groups (BG) in each region is also an important gauge of the population from which the deployment population can be drawn. The current system of designing open-pollinated seed orchards with separation between relatives requires a minimum of ten unrelated selections. As individuals within breeding groups become more closely related due to common ancestry, the minimum number of breeding groups required to support a deployment zone will be ten. Seed orchards designed for specific deployment zones can also recruit individuals from neighboring zones and are not dependent solely on local selections.

The first-generation population for loblolly pine within the WGFTIP consists of 3,123 individuals for which performance data in growth and form progeny tests were collected. These individuals are considered to be unrelated so the Census Number and the Status Number are equal. This population was originally divided into 116 Breeding Groups each with a minimum of 24 selections. The intent is to reconstitute each to the Breeding Groups with a minimum Census Number of 18 individuals before each subsequent round of breeding. To date, selections have been made in 93 Breeding Groups, 51 of which have been fully reconstituted and an additional 30 of which have 10 or more selection (Figure 16). Eight Breeding Groups have been deleted or combined with other groups because they contained few outstanding individuals. Fifteen groups have not yet had any selections identified, mostly because the progeny tests for these groups are still young. Completing the second-generation selection efforts in the remaining groups will be a high priority in the next few years.

Status Number declines relative to the Census Number as the degree of relatedness within groups increases. This is true both within groups and for the population as a whole. The second-cycle loblolly pine breeding population currently consists of 1,843 individuals, mostly second-generation selections plus some outstanding first-generation parents. These 1,843 individuals have a Status Number of 722 or a Relative Status Number (Census Number/Status Number) of 0.39. The third-cycle breeding population will be even more closely related as selection pressure is exerted to make multiple selections from only the very best families. Furthermore, the best parents and grandparents will be reused when they have high breeding values that can be exploited through a 'back-cross' scheme. To date, 63 third-cycle parents have been identified in five different South Arkansas Breeding Groups. This population has a Census Number of 63 and a Status Number of 18.5 for a Relative Status Number of 0.29. Third-cycle selection activity has been completed in only two of these groups.

The number of Breeding Groups, average Census Number, Status Number, and Relative Status Number are shown for the major breeding regions in Table 1. To keep track of relatedness in subsequent generations, the cooperative is maintaining coancestry matrices for all individuals in the breeding population. The first use to which these matrices have been put is to quickly identify related individuals considered for inclusion in advanced-generation seed orchards. They are also being used to plan crossing schemes for the selection population where the goal is to build inbreeding at a controlled rate by including some crosses among relatives in each generation. Because loblolly pine suffers severe inbreeding depression, successfully getting seedlings from crosses among close relatives is difficult. Therefore the program will emphasize matings among more distant relatives such as crosses among cousins or crosses among individuals and their grandsires. These relationships are easily discerned with the help of these coancestry matrices.

Wood Quality Elite Population

The Wood Quality Elite Population is an attempt to rapidly improve both growth rate and wood quality for the deployment population by managing a highly selected elite population. Backward selection has been used to identify 62 individuals from four different breeding zones that combine high breeding values for these traits (Table 2). Individuals are selected based on a pulp yield index score that weights improvement in specific gravity approximately seven times more heavily than improvements in growth rate. The index values are expressed in terms of dollars saved per ton of pulp produced. The intent is to eventually identify 30 selections from each of the four breeding zones to create an elite population with 120 individuals. Identifying individuals that combine outstanding growth rate and high wood density has not been straightforward as few parents, even in our large base population, have acceptable levels for both traits. Filling out the population will only be done as desirable individuals can be identified and may eventually involve using relatives.

Crosses are being made and seedlings planted in selection block plots. Individuals will be identified from among the seedlings generated by crossing this material and after breeding values are estimated in growth and yield

Table 2. Average performance of the loblolly pine parents in the Wood Quality elite breeding population.

Zone	Parent (number)	Volume[1] (%)	Specific Gravity[2]	Economic Index (Kraft Pulp)[3]
Arkansas	17	15.4	0.025	$13.51
North Louisiana	11	23.6	0.021	$14.10
Texas	24	18.8	0.028	$15.31
South MS/ South LA	10	21.7	0.032	$17.63

[1] Breeding value expressed as change in mean annual increment at age 20 compared to an unimproved checklot performance.
[2] Absolute change in specific gravity compared to an unimproved checklot.
[3] Reflects expected savings per ton of kraft pulp produced from a land base of fixed size for wood with improvements in both volume and specific gravity.

progeny tests, that the selections can then be used for orchard establishment and further breeding.

A unique component of the Wood Quality Elite Population is the collaboration with CellFor, Inc. to use clonal testing as a basis for selecting individuals within control-cross families. The expectation is that having multiple observations on genetically identical individuals over multiple locations will allow a much more accurate evaluation of phenotypes. This could be especially valuable in simultaneously improving a low heritability trait like volume and specific gravity which appears to have little or no correlation with growth at the population level. To date, six cooperative members have provided control-pollinated conelets from 10 different crosses to CellFor for this project. In turn, CellFor has successfully initiated 9,816 cell cultures from eight crosses, four from East Texas and four from South Arkansas. CellFor will provide a minimum of 30 lines from each of these crosses for field testing. The cooperative could establish its first two series of clonal evaluations for within-family selection in the fall of 2008.

The process of successfully obtaining tissue cultures from immature conelets involves close coordination between the field and the laboratory. Second-year conelets have to be harvested in June or July at just the right stage of development and shipped 'overnight' to the laboratory. Orchard managers from the Arkansas Forestry Commission, Deltic Timber Corporation, Potlatch Forest Holdings, Inc., Oklahoma Department of Agriculture, Food and Forestry, Temple-Inland Forest, and the Texas Forest Service have worked closely with CellFor employee Margarita Gilbert and others in her company to expedite this process. That this has been done with very few logistical problems has to be credited to the conscientious commitment of everyone involved.

This collaborative project has the potential to benefit the cooperative members in a number of ways. In addition to the possible benefits of improving within-family selection in this important population, the cooperative is building experience with new technology. Members with no direct interest in clonal forestry are acquiring direct experience with this new form of planting material and the WGFTIP will develop a shared database of varietal lines from local material. Direct experience with clones will help all of the cooperative members to develop realistic expectations for this type of planting material. Of the six organizations contributing to the breeding effort so far, four do not have a clonal development program of their own. Three are state organizations that have no intention of participating directly in clonal deployment programs.

This elite population is being used to develop and compare techniques that may ultimately be used in the mainline breeding population. Selection block plots of seedlings from the same crosses established in the clonal trials will also be planted. Polymix seedlings created from both the clonal line selections and from individuals identified in the seedling selection block plots will eventually be evaluated in the same progeny tests. Marker-assisted selection (MAS) for wood quality traits is also likely to be available shortly. MAS at the seedling stage and accelerated breeding will also be incorporated in the same population. This will allow gain in breeding value from multiple selection methods to be compared directly.

Virginia Pine

A fourth series of Virginia pine tests was established with polymix seed in the fall of 2006 to evaluate candidates for Christmas tree production (Figure 17). Seed were sown by the Texas Forest Service during the summer of 2006 to produce four tests of 32 new families. The states of Oklahoma and Louisiana planted one 30-replication test each. The Texas Forest Service planted two locations. The 105 parents selected for this program were identified in progeny tests planted in Oklahoma and Texas from parents originally selected in the species' natural range. These individuals were from the best performing seed sources in local plantings and represent the creation of a landrace for this exotic species. Selections were grafted by the Texas Forest Service and the Oklahoma Department of Agriculture, Food and Forestry in their scion banks. The total number of selections established in this second cycle of polymix tests is now 86. The best performing parents are going into the first grafted seed orchard in the region established by the Texas Forest Service to supply the local Christmas tree growers with well adapted seedlings.

Figure 17. Joe Hernandez of the Texas Forest Service plants a Virginia pine Christmas tree test on Brushy Creek Farms, owned and operated by David Conovaloff, near Bowie, TX. This site north and west of Fort Worth emphasizes the need to develop a landrace for this exotic species.

Additional Activities

Contact Representatives' Meeting

The 2006 Contact Representatives' Meeting was held May 17-18 at Temple-Inland Forest's Scrappin' Valley Lodge north of Jasper, TX. This annual meeting emphasizes training, information exchange, and technology transfer. Invited presentations include speakers from within the membership and from related projects outside the cooperative. The excellent facility that Temple graciously made available added substantially to the quality of the 2006 gathering (Figure 18).

Figure 18. Terry Rucker, Penny Sowell, Alex Mangini and Jennifer Myszewski enjoy Temple-Inland Forest's hospitality at their Scrappin' Valley facility.

The meeting was opened by Dr. Matt Lowe, Research Project Manager in Temple's Applied Research and Development Group, who provided an overview of Temple-Inland Forest and their research programs. Issues emphasized in company research relate to the current and future wood supply and its uses. Dr. Brian Roth gave a summary of the University of Florida Forest Biology Research Cooperative's PPINES project. Dr. Jimmie Yeiser (Stephen F. Austin State University) reviewed herbicide use with emphasis on application to progeny testing. Dr. Bob Weir described CellFor's business and their activities related to their cooperative membership. Dr. Don Grosman (Texas Forest Service) presented the results of his insecticide injections studies (Figure 19). His work has expanded from seed orchard trees to protection of standing timber from beetle attacks. Rick Barham, leader of International Paper Company's Nursery and Orchard Group, gave a brief update of the company's land divestiture plan, including timelines and potential impact to his group.

Figure 19. Dr. Don Grosman of the Texas Forest Service demonstrates pesticide injection directly into the tree bole.

Figure 20. Jim Tule with Temple-Inland Forest welcomes cooperators to the Clyde Thompson Nursery.

The field trip, sponsored by Temple-Inland Forest's Nursery and Orchard Group, was to their Clyde Thompson Nursery site (Figure 20). During the tour, attendees viewed CellFor, Inc. somatic seedlings in nursery beds, witnessed the recovery of progeny test trees blown down the previous fall by Hurricane Rita and walked through a young test of varietal seedlings. The recovery of the progeny test was made possible after many man-hours spent staking and trussing affected trees and resulted in saving a test of high value to the program. Along the tour, Dr. Jennifer Myszewski (USDA Forest Service) gave an assessment of developing wood quality technologies and Dr. Don Grosman demonstrated several tree injection systems. Following the tour, a social and supper were provided by Temple-Inland Forest.

Presentations on the second day of the meeting were given by Al Lyons (Hancock Forest Management) on the integration of silviculture and tree improvement under their TIMO model, and by Dr. Jeff Wright, who provided an update on ArborGen and the various services they provide, including the implementation of a clonal testing program. A roundtable presentation on the destruction and lessons learned from hurricanes Katrina and Rita was given by Robert Stewart (Mississippi Forestry Commission), Tommy Sims (Plum Creek Timber Company), Steve Smith (Weyerhaeuser Company) and Jim Tule (Temple-Inland Forest). Apparent from the discussions was the utter devastation of the storm and the resilience and fortitude of all of the individuals impacted. Lastly, Dr. Alex Mangini (USDA Forest Service) gave a review of the results of several of his seed orchard insect control tests as well as an update of anticipated registration changes and/or cancellations of chemical currently used by seed orchard managers as part of their IPM programs.

The 60 participants in the meeting were eligible to receive 9.0 Category I SAF continuing education credits.

Seed Orchard Pest Management Subcommittee

The Seed Orchard Pest Management Subcommittee (SOPM) of the Southern Forest Tree Improvement Committee is a small, loosely organized group of entomologists and tree improvement practitioners from the southeast and the Pacific Northwest. The committee meetings are open to anyone who wishes to attend and many orchard managers across the South are *ad hoc* members as they have participated in numerous pesticide use surveys and regional efficacy studies for various cone and seed insect control methods. The group serves three important functions. It coordinates seed orchard level research on the control of cone and seed insects, serves to facilitate information exchange on behalf of the tree improvement community, and provides a contact point between entomologists and seed orchard mangers. It also provides a forum through which the three southern tree improvement cooperatives collaborate on the common problems of seed orchard pest management. The SOPM continues to support the collaboration and the further development of good working relationships between all parties concerned with the management of cone and seed insects.

In 2006, the SOPM committee coordinated the field portion of an extensive and innovative worker exposure study. This research project was conducted by Dr. Bob Krieger and staff of the Personal Chemical Exposure Program (PCEP), Department of Entomology, University of California, Riverside. The research measured cone harvester pesticide exposure for risk assessment. The Environmental Protection Agency (EPA) will then have this data available when determining realistic reentry intervals (REI) following pesticide applications. Without data, the EPA must use a set of very conservative, health protective assumptions to establish REIs for seed orchards. Preliminary data from the PCEP research indicate extremely low worker exposure unlike those experienced in many food crop harvest activities. The study was innovative in that it was the first time that an EPA-approved protocol was used to monitor workers with extensive and critical participation of the groups being monitored at several widely separated installations simultaneously.

The goal was to collect urine samples for a total of 100 worker-days from cone harvesters employed in seed orchards treated with Asana®[3]. This goal was far exceeded with a total collection of 305 samples representing workers performing a range of seed orchard tasks. Samples were collected from cone harvesters working in the crowns and on the ground. In addition, samples were collected from mowers, mechanics, supervisors, lift operators, and refuelers. Pesticide residue samples were collected from foliage and from equipment. It was also possible to generalize the study to different chemistries by including orchards

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[3] Mention of trade names is solely to identify material and does not imply endorsement by the Texas Forest Service or the Western Gulf Forest Tree Improvement Program, nor does it imply that the discussed use has been registered.

using both Asana®, a synthetic pyrethroid, and Guthion®, an organophosphate.

This comprehensive set of samples will give a very complete assessment of pesticide risk to seed orchard workers present during the harvest season. With this data, it should be possible to calculate generalized transfer rates for many types of pesticides and to set guidelines for determining exposure-based REIs for conifer seed orchard workers. Analysis has not been completed, but several anecdotal observations have been offered by the study organizers. Firstly, there was a very high level of competence exhibited by the participants in their use of pesticides. Secondly, initial analysis of a small number of samples indicated that pesticides were present only at extremely low levels at or near the detection thresholds for the laboratory protocols. These initial observations are being confirmed. Environmental insecticide exposure during cone collection is associated with risk on the basis of dose (amount absorbed/person). When all of the samples have been analyzed, valuable new perspectives on pesticide exposure for our workplace will be available.

Weyerhaeuser Company, MeadWestvaco, Smurfit-Stone Container Corporation, Plum Creek Timber Company, Louisiana Department of Agriculture and Forestry, and the Texas Forest Service participated in the field portion of this study. Drs. Bob Krieger and John Taylor (USDA Forest Service) collaborated on funding the work. Dr. Krieger is overseeing the laboratory portion of the data collection and analysis. Much of the record keeping and documentation was ably done by Ms. Helen Vega, James Keenan, Yanhong Li, Sasan Mosadeghi, Melinda Bigelow, Zhenchan Chen (UC Riverside) and Shirley Gee (UC Davis). The tree improvement community owes a debt of gratitude to all who participated in this important study (Figure 21).

*Figure 21. Participants in a pre-implementation planning session for the worker exposure study. The group shown includes Van Hicks (Louisiana Department of Agriculture, Food and Forestry), Fred Raley (WGFTIP), Helen Vega and Bob Krieger (UC Riverside), Steve McKeand (NC State), Chris Rosier (*Smurfit-Stone Container Corporation), *and Liz Bupp (MeadWestvaco).*

The SOPM subcommittee continued to communicate our needs to the pesticide industry. This was the second year that most orchards depended solely on multiple applications of synthetic pyrethroids for control of cone and seed insects. As expected, several of these orchards developed outbreaks of secondary pests. The SOPM continue to promote the registration of tebufenozide, marketed under the trade names of Mimic® and Confirm®, for use in conifer seed orchards. This insect growth regulator is a 'soft' pesticide selective against moths. The use in conifer seed orchards was lost when the supplier discontinued the production of Mimic®. The SOPM has been working to have conifer seed orchard uses transferred to Confirm® which has the same active ingredient in a different carrier formulation. If this new formulation can be shown to be effective, it would broaden our ability to use integrated pest management strategies.

Entomologists on the committee conducted several research projects in operational orchards belonging to members of the tree improvement cooperatives. Dr. Alex Mangini (USDA Forest Service) continued his long-term collaboration with Plum Creek Timber Company by evaluating novaluron in their Hebron orchard in Louisiana. Dr. Don Grosman (TFS) evaluated emamectin benzoate injections in orchards across the South. The efficacy data that he has developed through this collaboration is being used to support registration for this novel chemical/application method. If this happens in late 2007 as projected, it will be the first new chemical/application technique made available to us in decades. Dr. Dan Miller (USDA Forest Service) continued to have dramatic successes in improving the effectiveness of artificial pheromone lures. With better lures, monitoring insect populations with traps can be improved and pesticide application may be timed more effectively[4]. This work also opens the possibility of controlling insect populations through mating disruption, a technique that was found to be unsuccessful with the previous pheromone formulations.

Formal Reviews

Formal reviews were conducted in 2006 for Plum Creek Timber Company, Weyerhaeuser Company, CellFor, Inc. and Hancock Forest Management. These companies represented a cross section of the current commercial interests with membership in the cooperative. Weyerhaeuser is one of the only remaining integrated forest industries still participating in the WGFTIP. Plum Creek, a publicly traded Real Estate Investment Trust (REIT), and Hancock, a privately held Timber Investment Management Organization (TIMO), represent investment organizations specializing in

[4] Spray timing based on trap catches and degree-day models was shown to be effective in Hanula, J.L., G. L. Debarr, J. C. Weatherby, L.R. Barber, C.W. Berisford. 2002. Degree-day model for timing insecticide applications to control Dioryctria amatella (Lepidoptera: Pyralidae) in loblolly pine seed orchards. Canadian Entomologist. 134(255-268).

timberland portfolios. CellFor, Inc. is a regeneration company producing seedlings for varietal forestry without either a landbase or seedling nurseries of their own. Needless to say, the model originally developed for the Formal Review process, which concentrated on quantifying projected seedling demands, orchard replacement schedules, and progeny testing targets is no longer adequate. The periodic review of strategic goals, however, and the discussion about the necessary resources required from both the member and the cooperative to meet these objectives is even more valid (Figure 22).

Figure 22. Johnny Pullman, Terry Burk, and Jimmy Heard of Weyerhaeuser inspect a second-generation selection made in their North Louisiana breeding population during the Formal Review conducted for their organization.

Formal Reviews serve the dual purpose of evaluating member programs and providing feedback to the staff on the needs of the individual members. This has been invaluable as the cooperative has struggled to stay abreast of the emerging priorities in the rapidly changing business environment. Reviews scheduled for 2007 include three state agencies, a REIT and a regeneration company.

Figure 23. Dr. Dag Lindgren and Finnvid Prescher discuss seed orchard strategy with Larry Miller.

Visiting Scientists

The Western Gulf Forest Tree Improvement Program with the help of Jim Tule and Greg Garcia of Temple-Inland Forest and the faculty of the Forest Science Department at Texas A&M University were fortunate to host a week long visit from Dr. Dag Lindgren, Professor in the Department of Forest Genetics and Plant Physiology, SLU Umëa, Sweden and Finnvid Prescher, from Svenska Skogplantor AB (Figure 23). This was one of several stops they made in the southeastern US to discuss seed orchard methodologies and seed deployment strategies. The cooperative appreciated the opportunity to show off the results of a visit from Dr. Lindgren's predecessor, Åke Gustavson, who is credited with providing the impetus for the State of Texas to start the program that hired Dr. Bruce Zobel in 1951.

USDA Forest Service Southern Institute of Forest Genetics

Forest Tree Molecular Cytogenetics Laboratory[5]

Poplar is an ecologically and economically important forest tree in North America. Furthermore, because it is fast growing and produces large amounts of biomass/acre, it has the potential to be an alternative to corn for producing biofuels. Poplar trees can also sequester significant amounts of carbon from the atmosphere and thus help reduce global warming.

Poplar is considered a model forest tree for genomics as it has a relatively small genome (480 Mb/1C) compared to pine, which has 40 times more DNA. Poplar has 19 chromosomes and has recently been sequenced using a shotgun method. If the genome sequence is complete we would expect 19 discrete DNA sequences. But current genome assembly consists of 2,447 sequences (called scaffolds). This suggests that gaps exist and a complete genome sequence has not been realized. This number of sequences leads to some ambiguity in assigning gene placement and order on chromosomes. For example, the 5S rDNA site could not be definitively assigned to a chromosome with sequence data alone.

The Forest Tree Molecular Cytogenetics Laboratory, Southern Institute of Forest Genetics, Southern Research Station, USDA Forest Service, is involved in physically locating and validating the hypothesized positions of the scaffolds using fluorescence *in situ* hybridization (FISH). Previously we have demonstrated that FISH is feasible in poplar, and it can be used for validating the scaffold positions.

[5] Contributed by Dr. Nurul Islam-Faridi, USDA Forest Service from work done in collaboration with L. Gunter, S. DiFazio, D. Nelson, and J. Tuskan

A DNA sequence search (BLASTN) against the genome assembly indicated that any of the following linkage groups (LGs) could contain the 5S rDNA site: LG-I, LG-II, LG-IV, LG-XI or LG-XVII. Four unique bacterial artificial chromosome (BAC) clones were selected from each of the above LGs for FISH. A dual-color FISH was conducted with two BAC clones from each LG followed by a second FISH re-probing of the same slide with a 5S rDNA clone (Figure 24). After a series of FISH experiments the BAC clones of LG-XVII were found to be co-localized with the 5S rDNA clone, and none of the remaining LGs was associated with the 5S rDNA site.

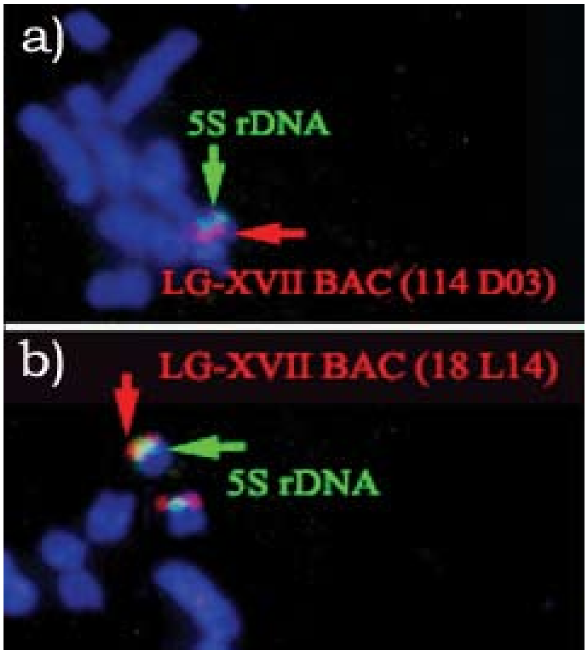

Figure 24. FISH with LG-XVII BAC and 5S rDNA clones on poplar chromosome spread. a) LG XVII BAC 114 D03 co-localized with 5S rDNA site and b) BAC 18L14 co-localized with 5S rDNA site.

A second BLASTN search indicated that two of the following LGs could contain the 18S-28S rDNA sites: LG-I, LG-II, LG-IV, LG-XIV, LG-XV and LG-XVI. FISH experiments were carried out as described above. One of the 18S-28S rDNA sites was identified on LG-XIV. The remaining five LGs showed no association with the second 18S-28S rDNA site. Further research is needed to assign the second 18S-28S rDNA site to a specific linkage group.

Properly aligning of the scaffolds to the 19 linkage groups of the genetic map is prerequisite for correct and complete characterization of the poplar genome. Placement of coding sequences on the physical map will provide an invaluable tool for cloning economically and ecologically important genes.

SIFG Research in Quantitative Forest Genetics[6]

Dr. Jennifer Myszewski from the Southern Institute of Forest Genetics evaluated the potential of sonic transmission in standing trees to determine if this property can be used as a surrogate for stiffness in a tree breeding program. Sonic transmission has been shown to be directly related to Modulus of Elasticity (MOE) which is a measurement of stiffness and closely related to differences in microfibril angle. Acoustic transmission is measured by tapping a probe implanted in the tree and measuring the time interval required for the signal to be detected at a second probe located at a known distance along the bole. The manufacturer claims that the correlation between acoustic velocity measured in standing trees is highly correlated with MOE (r=0.71). Before differences in sonic transmission can be used in a breeding program, a number of questions need to be answered. Are there differences in sonic transmission of sufficient magnitude and repeatability to allow heritable differences to be detected among families? How large a component is genotype by environment interaction? Is the equipment robust enough to be used by field crews and can data be collected efficiently?

To answer these questions, the Southern Institute of Forest Genetics obtained permission to use a series of three control-pollinated progeny tests established by International Paper Company in southeast Texas. These tests, located in Trinity, Cherokee, and Polk counties, were planted in 2000/01 each with 40 replications of single-tree plots. Two tests consisted of 45 control-pollinated families from 16 parents, while the third location consisted of only 33 families. Survival, height and diameter were measured at age 5 (Table 3). A subset of eight parents, each in four crosses, that were represented across all three locations were sampled for acoustic transmission using the Fakopp Stress Wave Timer. Sampled trees were disease free and without forks. Acoustic transmission was measured at two radial directions on each tree over a length of 1 m at breast height. Measurements were averaged for each tree. At two locations a few of the readings were outside the range of expected values for wood and these outliers were excluded from the data. Variance components were estimated for each location using the software packages DIALL and DIALLC[7] and single location heritabilities were calculated. The number of trees sampled was 242, 410, and 295 at each of the three locations.

[6] Contributed by Dr. Jennifer Myszewski, formerly with the USDA Forest Service

[7] Schaffer, H.G., and Usanis, R.A. 1969. General least square analysis of diallel experiments. A computer program DIALL. N.C. State Univ., Genet. Dept., Res. Rep. 1.

Single location individual heritabilities for the averaged acoustic velocity were moderate and large enough to be useful in an applied breeding program (Table 3). These values are twice as large as usually seen for volume, but slightly smaller than individual tree values calculated for specific gravity. A multiple-location analysis has not yet been completed so the genotype by environment component has not yet been estimated. The relationship between traits also needs to be determined.

The data collected so far appears to be promising. Field protocols, however, need to be further refined to avoid outliers and to arrive at easier methods of collecting observations on the large numbers of trees required to estimate parental breeding values. With these needs in mind, the WGFTIP staff plans to sample an additional series of tests next summer from another provenance. The ultimate goal is to incorporate stiffness along with breeding values for volume, straightness, and wood specific gravity into a sawlog index for ranking candidates for inclusion in seed orchards.

Table 3. Plantation locations and average performances for tests used in the evaluation of acoustic velocity as a surrogate for stiffness. There were significant differences among families for height, volume, straightness and acoustic velocity. Survival and diameter were not analyzed.

Test	Location (County, St)	Survival (%)	Height (m)	DBH (cm)	Volume* (dm^3)	Straightness Score	h^2 Acoustic Velocity
1107	Trinity, TX	95.1	5.6	8.5	10.8	2.6	0.40
1108	Cherokee, TX	87.4	5.9	9.0	11.6	2.6	0.42
1109	Polk, TX	74.3	5.0	7.9	6.6	2.4	0.50

* Volume per planted tree

HARDWOOD TREE IMPROVEMENT PROGRAM

The oaks have received increased emphasis within the Western Gulf Forest Tree Improvement Program – Hardwood cooperative as these species have been a consistent part of regional regeneration programs. This year, the cooperative established progeny tests to evaluate the second-generation cherrybark oak orchards maintained by the Arkansas Forestry Commission, the Mississippi Forestry Commission and the Texas Forest Service. Seed was recollected in 2006 to sow the second series of tests in 2007. The two test series will evaluate approximately 56 of the 60 families included in these extremely important advanced-generation seed orchards.

The cooperative also measured the third in a series of five Nuttall oak experiments after the tenth growing season. This provided performance data on 115 parents from this species. With this data in hand, the Arkansas Forestry Commission prepared 18 acres for Nuttall oak orchard at their Baucum Nursery site and will begin grafting in 2007. The Arkansas Forestry Commission also made plans to establish five acres of orchards for both water and willow oak in 2007. The Baucum site has an additional 17 acres slated for future hardwood orchards and will also have progeny tests and demonstration plantings. The Mississippi Forestry Commission, the Texas Forest Service, the Louisiana Forest Seed Company and the Louisiana Department of Agriculture and Forestry all have plans to establish Nuttall oak orchards as soon as scion material can be multiplied from the limited number of ramets in the scion banks.

Progeny Testing

The members of the WGFTIP-Hardwood program currently maintain 22 Nuttall oak progeny tests, one advanced-generation progeny test for sycamore and two advanced-generation progeny tests for sweetgum. Progeny tests are abandoned as they reach age 20 or earlier if they are off site or express severe disease symptoms. The last hardwood progeny tests were planted in 1999/00. As a result, the number of progeny tests maintained by the cooperative has been steadily declining. This situation is changing as the cooperative begins evaluating the second-generation selections that make up most of the hardwood orchards. These forward selections were identified from outstanding families in open-pollinated progeny tests planted with seed collected from the ortets. While these forward selections represent a substantial genetic improvement over wild seed, additional genetic gain can be made through progeny testing the orchards and roguing poor performers.

Figure 25. The Arkansas Forestry Commission cherrybark oak orchard at the Baucum Nursery.

Cherrybark Oak

In 2006 the Arkansas Forestry Commission, the Mississippi Forestry Commission, and the Texas Forest Service worked together to collect seed from their advanced-generation cherrybark oak orchards (Figure 25). One of the difficulties with hardwood tree improvement is that acorns store poorly and need to be planted in the same year they are collected. As a result, it is necessary to delay orchard testing until the majority of the clones reach maturity and then a good seed year is still required. The seed crop in the cherrybark orchards was outstanding in 2005 and adequate in 2006 (Figure 26). Seed was primarily collected by the Arkansas Forestry Commission and the Mississippi Forestry Commission. The Texas Forest Service seed crop was lost late in the season due to drought.

Figure 26. Representative sample of the 2006 cherrybark oak acorn crop that followed the outstanding 2005 crop.

Sufficient seed was collected in 2005 for the Texas Forest Service to sow 49 families in the greenhouse in 2006. Germination was adequate to eventually establish 43 families in four progeny tests. These plantings were another example of what can be accomplished through cooperative programs. Seed collection was coordinated by three members. The seedlings were grown in one facility (Figure 27). Six members then worked together to establish four locations. Tests were planted in 2006/07 by the Arkansas Forestry Commission, the Mississippi Forestry Commission, the Texas Forest Service and Temple-Inland Forest working together and by the Louisiana Department of Agriculture and Forestry working with the Louisiana Forest Seed Company (Figure 28).

Figure 27. Joe Hernandez in the Texas Forest Service shadehouse with the cherrybark oak progeny test series from the advanced-generation seed orchards.

Seed was collected again in 2006 for a second series of tests to be field planted in 2007/08. This collection represented 13 families not in the previous series, 10 families included as connectors between series and two families that were only in two locations in the first series. When this second round of tests are planted, 56 of the 60 selections included in this population will be represented in field trials. The four remaining families were selected late in the program, they are represented by only limited numbers of younger grafts, and will probably be removed when the orchards are rogued.

Figure 28. Joint progeny test establishment effort between Temple-Inland Forest who provided the site and planting crew and the Texas Forest Service that provided the oversight and will take over measurement.

Nuttall Oak

The cooperative began measurement on the third of five progeny tests series for Nuttall oak after the tenth growing season in 2006. Data from two of the four locations were available prior to this year's grafting season (Table 4). Survival through age 10 remained excellent and there were significant difference among families for all of the traits evaluated. When data from these tests were combined with data from previous series, rankings were available for 115 families. Ninety-five additional families will be added to the database in the next two years.

Table 4. Ten-year results from two Nuttall oak progeny tests in the third of five series. Family differences were significant at the 10 percent level for all traits analyzed.

Location (Co., State)	Survival (%)	Height (m)	DBH (cm)	Vol (dm^3)
Lonoke, AR	93.4	7.7	9.5	19.5
Sharkey, MS	92.0	5.2	6.5	6.6

Seed Orchards

The Arkansas Forestry Commission took the lead in the seed orchard establishment effort in 2006. They prepared 18 acres for Nuttall oak orchard establishment at their Baucum Nursery site (Figure 29). The Nuttall oak program is unique in the WGFTIP-Hardwood cooperative as first-generation selections were grafted into scion banks at the same time seed was collected for testing. The intent was to design seed orchards with backward selections of proven parents and therefore capture more genetic gain in one round of progeny testing. The top thirty families from the 115 parents with 10-year-old test data were targeted for inclusion in the first large-scale orchard establishment program for this species. The scion material was collected from scion banks maintained by the Mississippi Forestry Commission and the Texas Forest Service. Five of these thirty parents have been lost and forward selections were made in the Arkansas Forestry Commission's Lonoke County progeny tests to represent these lines.

Figure 29. George Rheinhardt with the Arkansas Forestry Commission reviewing the future Nuttall oak orchard site.

Initial grafting will be done in pots (Figure 30). Scion collections from limited number of ramets will initially restrict the number of positions established. Over the next few years, the Arkansas Forestry Commission orchard will be expanded as scion material multiplies and with the addition of new families from the remaining two progeny test series. As scion becomes available, additional Nuttall orchards will be established by the Louisiana Department of Agriculture and Forestry, Louisiana Forest Seed Company, the Mississippi Forestry Commission, and the Texas Forest Service.

Figure 30. Randy O'Neal with the Nuttall oak seedlings he grew for use as rootstock in the Arkansas Forestry Commission orchard.

Limited quantities of seed are being collected from both orchards and some of the older progeny tests that have been converted to seed production areas by the members. Crop protection during seed maturation and collection represent some of the biggest deterrents to the implementation of hardwood tree improvement. Many hardwood seed store poorly and nurseries are restricted to sowing from the current year's harvest. Seed crops are subject to losses late in the season due to drought and insect predation. Loss to wildlife continues to limit the utility of collecting seed from nets placed under the trees. Deer, hogs, squirrels, crows, and jays are among the biggest problems. Some seed can be collected directly from the crowns (Figure 31) but this strategy is limited to species such as sweetgum and sycamore that produce fruiting bodies with multiple seed. Research in hardwood seed orchard management is a wide-open area.

Figure 31. The Louisiana Department of Agriculture and Forestry collects seed in the Texas Forest Service Hudson sweetgum orchard. The organizations share seed from the joint collection effort.

PERSONNEL

There were several staff changes in 2006. Don Travis, Jr. retired after 32 years in tree improvement. Don started with Kirby Forest Industries, Inc. in 1974 and worked in their program for 13 years. He was hired by the Texas Forest Service in 1988 where he was lead technician at the Magnolia Springs Seed Orchard. As a part of his legacy, he can claim to have grafted orchards that contributed to a significant portion of the total reforestation in East Texas. Gary Fountain also left the Magnolia Springs Seed Orchard after working with the tree improvement program for 10 years. The Texas Forest Service was fortunate to be able to fill these positions with two outstanding people from within the agency. The Texas Forest Service tree improvement program was pleased to have Hubert Sims and Walter Burks join the staff at Magnolia Springs Seed Orchard. Dr. Jennifer Myszewski resigned from the USDA Forest Service, Southern Institute of Forest Genetics. Dr. Myszewski has moved to the Dallas area where she is pursuing a career in health care. The Texas Forest Service and WGFTIP staff now include the following people:

T. D. Byram …………………......….. WGFTIP Geneticist

L. G. Miller ……………….. Assistant WGFTIP Geneticist

E. M. (Fred) Raley ………... Assistant WGFTIP Geneticist

P. V. Sowell ……………………………… Staff Assistant

J. G. Hernandez …………………… Research Technician

G. R. Lively ………………………… Research Technician

I. N. Brown ………………………….. Research Specialist

H. Sims ……………………………… Research Technician

W. Burks …………………………..… Resource Specialist

Vacant ………………………………... Resource Specialist

PUBLICATIONS

McKeand, S. E., E. J. Jokela, D. A. Huber, T. D. Byram, H. L. Allen, B. Li, T. J. Mullin. Performance of improved genotypes of loblolly pine across different soils, climates and silvicultural inputs. Forest Ecology and Management. In Press.

van Buijtenen, J. P. and T. D. Byram. A random walk through the history of breeding for wood quality. 28^{th} Southern Tree Improvement Conference. In press.

COOPERATIVE TREE IMPROVEMENT PROGRAM MEMBERS

Western Gulf Forest Tree Improvement Program Membership

Pine Program

Full members of the Western Gulf Forest Tree Improvement Pine Program in 2006 include the Arkansas Forestry Commission, CellFor, Inc., Deltic Timber Corporation, Hancock Forest Management, Forest Capital Partners, LLC, International Paper Company, Louisiana Department of Agriculture and Forestry, Mississippi Forestry Commission, Oklahoma Department of Agriculture, Food and Forestry, Plum Creek Timber Company, Potlatch Forest Holdings, Inc.,Temple-Inland Forest, Texas Forest Service, Weyerhaeuser Company. ArborGen joined the WGFTIP as a Sustaining Member.

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

Hardwood Program

The WGFTIP Hardwood Program includes the Arkansas Forestry Commission, Louisiana Department of Agriculture and Forestry, Louisiana Forest Seed Company, Mississippi Forestry Commission, Potlatch Forest Holdings, Inc., Temple-Inland Forest, and the Texas Forest Service.

Urban Tree Improvement Program

The Urban Tree Improvement Program has received past support from the following municipalities and nurseries: Aldridge Nurseries (Von Ormy), Altex Nurseries (Alvin), Baytown, Burleson, Carrollton, Dallas, Dallas Nurseries (Lewisville), Fort Worth, Garland, Houston, LMS Landscape (Dallas), Plano, Rennerwood (Tennessee Colony), Richardson, Robertson's Tree Farm (Whitehouse), and Superior Tree Foliage (Tomball).

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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.

The 2006 staff of the Texas Forest Service tree improvement program with the sign commemorating the founding of the program in 1951. From left to right I.N. Brown (kneeling), Larry Miller, Fred Raley, Joe Hernandez, Penny Sowell, Hubert Sims, and Tom Byram. Not shown: Gerald Lively and Walter Burks.