Dr. Bruce Zobel founder of the Cooperative Forest Tree Improvement Program in Texas and its leader from 1951-1956.

Dr. J.P. van Buijtenen directed the program from 1961-1966, 1968-1993 and organized the Western Gulf Forest Tree Improvement Program in 1969.

FIFTIETH

PROGRESS REPORT

OF THE

COOPERATIVE

FOREST TREE IMPROVEMENT

PROGRAM

By

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TABLE OF CONTENTS

INTRODUCTION

With the 50th annual report, the Texas Forest Service and the Western Gulf Forest Tree Improvement Program (WGFTIP) celebrate over half a century of tree improvement in the Western Gulf region of the United States. The program at Texas A&M dates to the hiring of Dr. Bruce J. Zobel in July of 1951. The first annual report, published in October of 1953, covered the end of 1951, all of 1952, and most of 1953. That annual report emphasized several themes that were to set the tone for the program throughout its history. First and foremost, tree improvement was organized as a regional, cooperative effort with financial contributions from twelve industrial sponsors. Despite the fact that only one of these companies, International Paper Company, still exists under the same name, tree improvement across the South has successfully followed this model ever since. A second theme was education. The first annual report announced that fellowships had been awarded to two deserving students: Franklin Cech and J. P. van Buijtenen. These two students would do much to shape the future of forest genetics. A third theme with staying power was the choice of problems for investigation. The first annual report outlined research projects on wood specific gravity, geographic variation, and drought-hardy strains of loblolly pine.

During the last 50 years, the program has passed several milestones. While the effort was a regional, cooperatively funded program from the beginning, the Western Gulf Forest Tree Improvement Program did not actually come into official existence until 1969. At that time, the Texas Forest Service combined resources with several existing industry and state efforts. These old hands, were joined by several other organizations and state agencies to form the core of the existing tree improvement cooperative. Separate cooperatives were also created for hardwood timber species and trees used in urban landscapes.

The combined efforts of the members of the WGFTIP program resulted in the identification of more than 3,400 first-generation loblolly pine selections and 1,000 first-generation slash pine selections. Nine hundred eighty progeny tests have been established to evaluate 3,367 loblolly pine parents. Three hundred six progeny tests of other species have also been planted. Many of these tests have been evaluated and 1,631 advanced-generation loblolly and slash pine selections have been identified. Innovations within the program included use of breeding groups to sub-line the breeding population, advancing-front orchards, complementary breeding and testing for advanced-generation improvement, extensive use of stepwise screening for rust resistance in the slash pine program and an operational early testing protocol for loblolly pine. The WGFTIP was quick to adopt the use of wax grafting for loblolly pine and operational top-grafting for breeding purposes. The program was also the first to list its genetic resources with the national Germplasm Resource Information Network and thereby document a gene conservation plan for loblolly pine.

Despite the importance of these technical innovations, the most substantial contribution made by the members of the cooperative has been in the production of genetically improved seed and the subsequent impact that this seed has had on the regional wood supply. The production of the Texas Forest Service's program, since the first crop was collected from a specially thinned seed production area in 1957 combined with that from orchards belonging to the other members from the time of the cooperative's inception in 1969 to the present, totals enough seed to have planted 13 million acres. This is an area equivalent to the entire commercial forest land base for the state of Texas. Making modest assumptions about growth rates, rotation ages, and levels of genetic improvement, the tree improvement program can reasonably claim to have added 95 million tons of wood to the resource base in the Western Gulf region of the United States. This calculation is based on genetic improvement of only 10 percent while currently producing orchards typically exhibit 20 percent improvement in growth rates. Orchards now being established are predicted to have improvement in growth rates in excess of 30 percent and will have an even more substantial impact on the regional wood supply.

In recognition of the milestone represented by the 50th Progress Report of the Cooperative Forest Tree Improvement Program, the organization of this year's annual report has been modified to include a brief history of the Texas Forest Service's cooperative tree improvement program written by Dr. J. P. van Buijtenen with editorial input from Drs. Bruce Zobel and William Lowe. Each of the sections that follow is prefaced with some of the program's historical accomplishments.

The brief historical account included in this annual report fails to mention many, many, important people in the life of the program. This includes technicians, students, cooperators, and supporters, all who did their part to shape the character of the Cooperative Forest Tree Improvement Program of the Texas Forest Service. Three very significant omissions are Mac Parsons, Truitt Brookes, and Charles Moore: technicians in title only, each played a part in making the program work on a day-to-day basis and contributed significantly to the training of students and their better-educated supervisors. The truest sense of the contribution that all these people made over the years is best preserved in the previous forty-nine annual reports. This year's progress report is dedicated to their collective (and cooperative) efforts.

HISTORY OF THE TEXAS FOREST SERVICE COOPERATIVE TREE IMPROVEMENT PROGRAM

by

J. P. van Buijtenen
(with editorial input from B. J. Zobel and W. J. Lowe)

Beginnings, 1950-1956

The crucial event in the origin of the Texas Forest Service Tree Improvement Program was a visit to Texas by the famous Swedish geneticist Ake Gustavson in 1950. He gave an inspirational talk on crop and tree breeding in Houston, which was attended by a number of industry leaders, the director of the Texas Forest Service, and the governor of the state. As a result of this presentation, the decision was made that the state would undertake such a program through the auspices of the Texas Forest Service. It was funded partially by Texas A&M University, partially by the Texas Forest Service, and partially by some of the major forest industries. From the beginning it was organized as a regional effort and operated in several states. Mr. Ernest L. Kurth, and Mr. Arthur Temple, Sr. were very instrumental in getting the program started and moving forward. Mr. A. J. Hodges also made critical contributions both monetarily and by providing greenhouse space and land for progeny testing at the now well-known Hodges Gardens near Many, LA.

As the first leader of the program, the Texas Forest Service (TFS) hired Dr. Bruce Zobel in 1951 when he was just completing his Ph. D. at the University of California at Berkeley (Figure 1). In the first few years, the program consisted of Bruce Zobel, heading up the program and stationed at Texas A&M, Ray Goddard at the newly created Arthur Temple, Sr. Research Area in East Texas, Mrs. Betty Dillon, the secretary as well as technician, and two graduate students Frank Cech and Hans van Buijtenen. Activities of the cooperative concentrated mostly on the areas of drought resistance, seed orchard management, superior tree selection and the genetics of wood specific gravity.

Figure 1. Dr. Bruce Zobel making control-pollinations in an ortet circa 1952.

The drought resistance orchard established at the Arthur Temple, Sr. Research Area in 1953 was of key importance, because many of the seed orchard establishment and management techniques we use now were developed there. When Bruce Zobel started that orchard we did not know how to graft pines, how far apart to plant the trees, or how much and what kind of fertilizer to apply. At the time this was strictly a research orchard. Many different techniques were tried, some of which are still used today. The TFS was also a major participant in the Southwide Geographic Seed Source Study sponsored by the Southern Forest Tree Improvement Committee and coordinated by Phil Wakeley of the USDA Forest Service (USFS).

Because there were no flowering grafts initially, much of the early breeding work was done in the woods on the original selections, which were scattered over several states. This was very time consuming and also led to some interesting adventures. As Bruce tells it, he and a graduate student were up in a tree, when the irate landowner showed up with a loaded gun. Bruce went down to pacify the landowner, while the student tried to hide in the crown with the tree visibly shaking. I will not tell who the student was, but can attest to the fact that Bruce's story was vastly exaggerated. The impact that Bruce had on the program is hard to overstate. He laid the foundation for the program and established the organization and operating procedures (no doubt Al Folweiler had a hand in that, too) much of which persisted for many years.

Claud L. Brown, 1957-1960

In 1956, Zobel left for North Carolina State University to establish their tree improvement program. He was succeeded at Texas A&M by Claud Brown (Figure 2). By that time Hans van Buijtenen had graduated and gone to the Institute of Paper Chemistry in Appleton, Wisconsin. Frank Cech completed his course work shortly afterwards and went to the Arthur Temple, Sr. Research Area, which enabled Ray Goddard to come to College Station to work on his doctoral degree. Frank Cech completed his dissertation and joined International Paper's program in Bainbridge, Georgia in 1957. Ray Goddard finished his degree in 1959 and accepted a position at the University of Florida. Another student, Holger Brix, joined the group and did some very interesting work on the physiology of drought resistance. Claud Brown continued the on-going work, but also started a number of new studies including investigations of tip moth resistance, tissue culture, vegetative propagation, flowering, crown pruning, and the grass stage in longleaf pine. In this

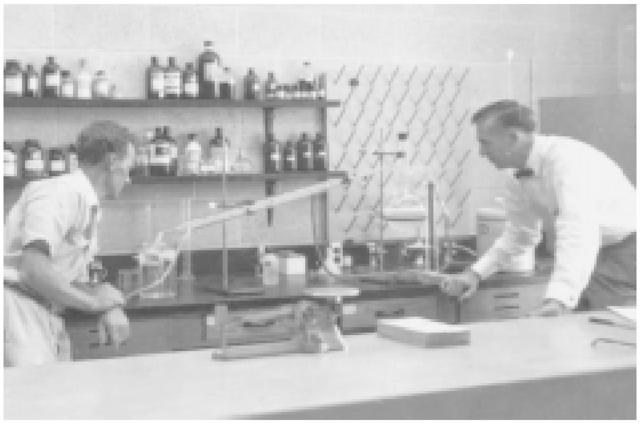

Figure 2. Holger Brix (left) and Claud Brown work in the Forest Genetics Laboratory.

last study he made crosses among longleaf x loblolly hybrids to determine how many genes controlled the grass stage. Based on the variability of height growth in the F2's, he estimated that 8 genes were involved.

J. P. van Buijtenen, First Term, 1961-1966

In 1960, Claud Brown went to the University of Georgia to pursue a career in tree physiology. Somehow Al Folweiler induced Hans to return from Wisconsin and take over the program. Many of the on-going studies were continued, but with the progeny tests beginning to yield a substantial amount of data a lot of effort went into quantitative genetic studies interpreting these data. Among other things, it was established that wood specific gravity was strongly inherited and negatively correlated with height and diameter, but positively correlated with straightness. In cooperation with the Southern Institute of Forest Genetics, a heritability study was undertaken to supplement the progeny test data.

The first economic analysis of tree improvement was also done during this period. This was brought on by the fact that the Texas Forest Service had numerous small seed orchards that appeared uneconomical, and the economic analysis was necessary to convince Director Folweiler that the TFS needed fewer and larger orchards. The minimum economical size appeared to be 15 to 20 acres, not far from current figures.

A tree physiologist, Richard H. Zimmerman was also added to the staff, working on the physiology of aging. This problem was (and still may be) too difficult for the available techniques.

The first work with hardwoods was also started during this period in cooperation with Champion Papers. Champion was using a lot of cottonwood in its furnish and needed a reliable supply. We undertook a selection and testing program and developed 10 good clones. The number of suitable sites, however, was limited and when Champion lost the contract with Time-Life for magazine stock the project was discontinued. One of the clones became very popular in Europe. Also, a portion of the clones has been used in hybrid breeding programs to support the fiber farm concept and were released by the USFS at Stoneville, MS.

In 1966 Hans accepted a position with the U S Forest Service in New Hampshire and interim management of the program was turned over to Ernest Long, who at the time was a field forester located in East Texas. Ernie later received his Ph. D. in forest genetics and was responsible for the operational portion of the Texas Forest Service program until 1980. Soon after Dr. Folweiler retired and Paul Kramer became the director of the Texas Forest Service in 1967, he made an offer Hans could not refuse. Hans returned to lead the program in 1968 (Figure 3).

Figure 3. Dr. J. P. van Buijtenen works inside a mist chamber in 1982.

Paul Kramer Shakes Things Up

After Al Folweiler retired and Paul Kramer took the reins of the Texas Forest Service, a number of changes took place in rapid succession. He established a hardwood program (1968), an urban tree improvement program, the Western Gulf Forest Tree Improvement Program (1969), and the Hardwood Cooperative (1971). He also instigated an expansion of TFS seed orchards with the goal of producing enough seed for 40 million seedlings annually. This was a major change in direction. It also proved that our foresight was not as good as we would have liked it to be. At the time we were growing more slash pine than loblolly pine at Indian Mound Nursery, maybe 60% slash, but the trend was down so the new orchard was about 60% loblolly pine. However, 15 years later we were growing less than 1 million slash pine per year.

The Early Days of the Western Gulf Forest Tree Improvement Cooperative

Shortly after the cooperative was established, John Robinson was hired to head up the program. The emphasis was on establishing the breeding population; in other words, tree selection and tree grading and tree grading and more tree grading. This phase lasted for several years, but was soon followed by seed orchard establishment and progeny testing. Early in the history of the cooperative we decided to drop the four-tester scheme of progeny testing and replaced it with a partial-diallel mating design. John Robinson was seriously injured during pollination season in 1980 when the top broke out of a second-generation selection he was attempting to pollinate. John was confined to a wheelchair after the accident, but the strength of his character made for a remarkable mental recovery if not a physical one.

William J. Lowe was hired to head up the hardwood programs in 1975 and was put in charge of the Western Gulf Forest Tree Improvement Program in 1977. One thing that was implemented soon afterwards was a formal review procedure. The idea was to go over each member's program in great detail on a regular schedule every three years. This turned out to be very useful. Normally, visits to the cooperators consisted of problem solving or training sessions, but we rarely looked at the program as a whole. The formal reviews were very helpful in keeping the objectives of the breeding program in tune with projected planting operations and to also track progress towards the goals set three years earlier.

Another idea that came up during that period was to divide the breeding population into small breeding groups to control inbreeding. The idea was conceived during an airport meeting in Atlanta about inbreeding, but it took several years to find all the bugs and get it implemented. A complementary mating and testing design was developed and implemented to improve program efficiency and avoid the problem of inbreeding in obtaining parental evaluations in the breeding population. The large available progeny test database was used to develop the breeding value procedures for estimating genetic gains. This allowed more realistic estimates of the value of tree improvement than percent superiorities that were previously used.

Research-wise, two major types of studies were undertaken during this period: one was a study carried out under the auspices of TAPPI to determine the desirable goals for wood quality. The results were very clear-cut. At that time, wood specific gravity was so much cheaper and easier to improve than any other wood trait and had so much more impact, that it was the only trait we needed to worry about for a while. Early testing was another area that received major emphasis, and procedures were developed to eliminate part of the families at the seedling stage and save considerable cost in progeny testing. Unfortunately, the techniques were not accurate enough to pick the final winners with confidence.

The Hardwood Program

Ron Woessner was hired in August 1968 as the Associate Geneticist with responsibility for hardwood tree improvement. The hardwood research effort, which had begun in 1962 with cottonwood, was expanded to include sweetgum, sycamore, and green ash. One major emphasis of the program during this time frame was the establishment of a series of species-site trials to attempt to elucidate site requirements for the hardwood species. One of Ron's contributions to the program was hiring Van Hicks, Jr., as a hardwood silviculturist in 1970 and Joe Hernandez as his field assistant in 1971. Except for a brief period when Joe went into business with a brother, he has been one of the hardwood program's major assets for the last 31 years.

The Urban Tree Improvement Program.

The Urban Tree Improvement Program was started in the early 1970s as a cooperative effort between the Texas Forest Service, municipalities, and commercial nurseries in the state. At that time, the large majority of the planting stock used for urban environments was obtained from out-of-state without regard to its adaptability to the local conditions. Less than half of the planting stock survived the first year. The structure and procedure for this program were patterned after the older tree improvement programs.

To efficiently address the survival problem the decision was made to concentrate selection efforts upon local sources of native species. Whenever possible selections were made in urban environments. The municipalities and commercial growers were responsible for establishing and maintaining all of the progeny tests. Seed orchards were established using the parents identified as having superior survival and growth in the progeny tests. After flowering began in the seed orchards, an additional series of progeny tests were established to provide the data required for seed orchard roguing.

To maintain species diversity in the urban environment, it was decided to complete a single cycle of selection and testing for a number of species instead of completing multiple generations of breeding for a single species. Seed orchards are currently established for seven species. These species represent some of the most important trees planted in the urban landscape in Texas.

The Cooperative Hardwood Tree Improvement Program

The hardwood cooperative was formed in 1971. Prior to this time the Texas Forest Service had been studying the variation patterns in selected bottomland hardwoods in addition to cottonwood. Members of the pine cooperative with an interest in bottomland hardwoods joined efforts with the Texas Forest Service to expand the genetic base and preserve selected genetic material for future use.

Selection efforts were not as intensive as with the pine program. Seed was collected and progeny tests established to sample the Western Gulf region. Initially, second-generation selections were made and grafted into scion banks that were also designed for seed production. In addition to serving as a preservation area, the seed was collected from the scion banks for nursery use. Because of the limited demand for seed and to be more efficient, the members distributed the scion banks among themselves and shared the seed that was produced. Natural regeneration studies and a thinning study were also established in bottomland hardwood stands. These studies were designed to improve the management of the bottomland hardwood areas owned by the members.

From 1980 to the Present

Craig McKinley took over the daily management of the Texas Forest Service's tree improvement program in 1980 when Ernie Long left to work for International Paper Company. Craig was in that position until budget cuts and retirements in 1993 eliminated his position and that of several others including Tom Greene who was then serving as an assistant geneticist for the hardwood program. With Hans' retirement that same year, Bill Lowe took over responsibility for all of the Texas Forest Service and cooperative tree improvement programs. Perhaps one of the most painful parts of this transition was closing the Forest Genetics Laboratory that was the first facility built for the program's use in 1953 (Figure 4). In 2001, Bill Lowe retired and direction of the program was turned over to Tom Byram, who had started with the WGFTIP in 1978 as an assistant geneticist responsible for grading first-generation selections. The current staff includes Drs. Tom Byram and E. M. (Fred) Raley, Larry Miller, Joe Hernandez, Penny Sieling (all in College Station); I. N. Brown, Don Travis, Jr, and Gary Fountain (Magnolia Springs Seed Orchard); and Gerald Lively (Arthur Temple, Sr. Research Station).

Figure 4. The Forest Genetics Laboratory as it appeared in 1958.

WESTERN GULF FOREST TREE IMPROVEMENT PROGRAM

Highlights

- Six advanced-generation loblolly pine seed orchards and one slash pine seed orchard were established during the 2002 grafting season. The loblolly orchards had a predicted gain in mean annual increment for volume growth of 36 percent. The slash pine orchard had a predicted gain of 45 percent improvement in volume growth and should have only half as much rust infection as unimproved slash pine seedlings.
- In 2001, 40,680 pounds of seed were collected including 864 pounds of improved longleaf pine seed. The 2002 cone crop totaled 23,716 bushels of cones.
- Eight members are making crosses for the wood quality elite breeding population. Fifteen new parents were identified in 2002 to create three new diallels.
- Analysis of progeny tests with periodic measurements showed that age five height or volume/acre were equally efficient as selection criteria for improving age 20 volume per acre. By age 10, volume per acre was the better selection criteria.
- During the 2001/02 planting season Boise planted their last first-generation slash pine tests. Weyerhaeuser and Mississippi Forestry Commission will plant the last of their remaining slash pine tests in 2002/03. This will leave less than 30 first-generation slash pine parents to test.
- Louisiana-Pacific Corporation and Plum Creek Timber Company planted their last first-generation loblolly tests in 2001/02. This leaves less than 100 first-generation loblolly pine families to test.
- The cooperative identified 107 loblolly pine and seven slash pine second-generation selections in 2002. The total number of second-generation selections now totals 1,459 loblolly pine and 172 slash pine.
- Plum Creek and Boise participated in a southwide efficacy study of Imidan® and Capture® for the control of cone and seed insects.
- Boise and Temple-Inland Forest collaborated in a study to provide preliminary data on the exposure of cone collection workers to pesticides.

Seed Orchards

The need for commercial quantities of improved pine seed for reforestation was the initial impetus behind the Texas Forest Service's tree improvement program and continues to be the primary reason for the existence of the cooperative. One of the most important missions of the cooperative has always been to provide a mechanism for sharing the best plant material among members for the establishment of clonal seed orchards. Establishment of the first experimental grafted seed orchard was done at the very inception of the program. The development of the operational seed production program, however, was delayed for several years pending the development of many methods now taken for granted. Techniques to judge the relative merits of potential candidates had to be invented and superior selections identified. Grafting methods had to be developed for southern pines, which with their needle retention and heavy resin production initially proved to be difficult to graft. Indeed, the decision to emphasize grafted seed orchards for commercial production was not always a foregone conclusion.

In anticipation that the tree improvement program would depend on the use of grafted seed orchards, the first experimental orchard was established on the Arthur Temple, Sr. Research Area at Fastrill, TX in 1953. Much of the early work with spacing, cultivation and fertilization were carried out in this orchard that contained 18 grafted lines selected for putative drought resistance. The operational desirability of grafted seed orchards, however, was very much in doubt. The Seventh Annual Report of the Cooperative Forest Tree Improvement Program (1959) reported that 'the reasons for graft failure are numerous and will not be enumerated.' At this time, the experimental grafted orchard had not yet flowered and the cost of seedling seed orchards was projected to be only a fortieth of a grafted seed orchard ($.07 per control-pollinated seedling vs. $4.00 per graft in 1959 dollars). The next year's annual report (1960) stated that 'present emphasis [for orchard establishment] is on the use of control-pollinated seedlings.' Because clonal seed orchards have the ability to capture more genetic gain, efforts to improve grafting success continued unabated with 2,500 nursery bed grafts made in 1959. This effort obviously met with some success as the Eighth Annual Report of the Cooperative Forest Tree Improvement Program (1960) states that the establishment of four clonal seed orchards had been completed. These 21 acres of orchards included three loblolly orchards (superior, high wood density, and low wood density) and one superior slash pine orchard. This same annual report noted that seven-year-old grafts at the Arthur Temple, Sr. Research Area that were established at wide spacings, and heavily fertilized were producing substantial numbers of both female and male flowers (Figure 5). Grafted seed orchards have been the method of choice from that point until the cooperative reverted back to the use of seedling seed orchards to establish a minor species, longleaf pine, in the early 1990s.

Grafted seed orchards will be important for many years to come for the majority of the 500,000 acres regenerated annually within the Western Gulf region. They will likely be part of a regeneration strategy that includes vegetative propagation methods that include rooted cuttings (first attempted at the Forest Genetics Laboratory in College Station in 1954) and somatic embryogenesis.

Figure 5. Mac Parsons in the drought resistant seed orchard at the Arthur Temple, Sr. Research Area in 1958.

Orchard Establishment and Roguing

When the WGFTIP was formed in 1969, the members collectively operated a total of 500 acres of first-generation orchards averaging a predicted genetic gain of approximately 8 percent improvement for volume growth. Orchard acres under management rapidly increased, exceeding 2,000 in the year 1981. The first year that advanced-generation orchards containing both tested first-generation selections and untested second-generation selections were established was 1979 (the initial grafting for this orchard began in 1977). Members of the cooperative currently manage 2,380 acres of loblolly and slash pine orchards (Figure 6). Of the total, 1,135 (47 percent) are advanced-generation orchards.

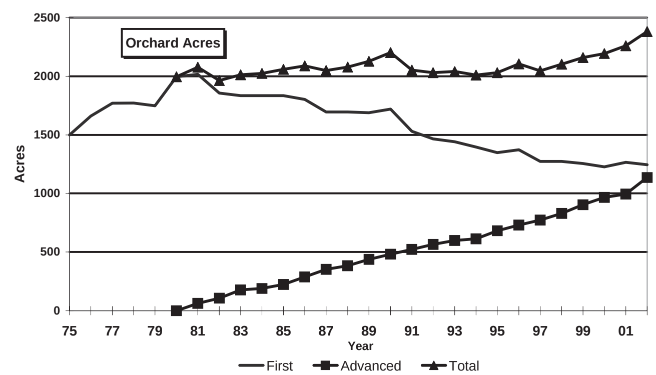

Figure 6. Seed orchard acres managed by the cooperative.

During the 2002 grafting season, seven members grafted seed orchards. This included Bosch Nursery, Louisiana-Pacific Corporation, Temple-Inland Forest, Plum Creek Timber Company, Weyerhaeuser Company, and Willamette Industries, which grafted a total of 123 acres of advanced-generation loblolly pine orchard blocks. These orchards contained a mixture of progeny tested first-generation and second-generation selections and will produce seedlings that are projected to grow 36 percent more wood per acre than unimproved material (Figure 7). Gain was also been made in stem straightness, with a projected improvement of 1.33 standard deviations in straightness score above the commercial checklot. The Louisiana Department of Agriculture and Forestry grafted an 18-acre slash pine orchard with a predicted performance of 45 percent in volume growth per acre above the unimproved slash pine commercial checklot. Dramatic improvements have been made in the slash pine program because improvement in rust resistance translates directly into more harvestable trees per acre.

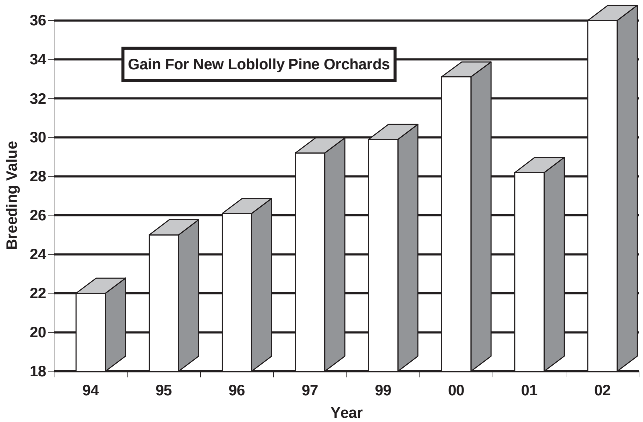

Figure 7. Gain in breeding value for volume growth averaged over new loblolly pine seed orchards by year of establishment.

Twenty-one acres of orchard were taken out of production. This consisted of 11 acres of loblolly pine orchard and an adjacent 10-acre block of slash pine orchard managed by the Mississippi Forestry Commission. This cleared ground will be grafted back to an advanced-generation loblolly pine orchard designed for North Mississippi. This shift in acreage allocation between slash and loblolly reflects the changing preference for loblolly over slash within their nursery program and the need for more of the North Mississippi seed source.

Roguing is intended to improve the genetic quality of existing orchards by removing inferior selections. Removal of live trees is generally limited to the summer months, subsoiling activities suspended, and stumps treated with Sporax®[1] (borax) to limit the danger of infection from annosus root rot (*Heterobasidion annosum*). For these operational reasons, roguing is generally delayed until data exists on several families within a seed orchard and a substantial number of clones can be eliminated in the same year. This sound operational procedure was ignored this past year because polymix data on a few second-generation clones indicated that they were not performing at the levels predicted from their parent's breeding values. When selections were identified that were performing below the unimproved checklot, they were removed even if a major roguing was not scheduled. Clones were recommended for removal in 33 orchards belonging to 11 of the members.

Orchard Yields

The Texas Forest Service and the programs associated with the WGFTIP since 1969 have produced enough seed over the life of the program to regenerate 13 million acres of forestland. This is equivalent to the total area of commercial forest in East Texas. With modest assumptions about improvements in growth rate (0.15 cords/acre per year) and rotation ages (20 years), an additional 95 million tons of wood can be accounted for in the Western Gulf region of the United States that would have been unavailable without the tree improvement program. The seed generated through the tree improvement program has had a positive impact on both industrial and small private landowners as this material has been distributed through both state and industry nurseries. Almost all of the 1.2 billion seedlings currently planted southwide each year are now a product of one of the three regional tree improvement programs.

The first seed produced by the Texas Forest Service tree improvement program was obtained from specially thinned and managed seed production areas, and cones were collected by climbing the trees with Swedish ladders (Figure 8). One hundred and ten bushels of cones were collected with this technique in 1957 at an estimated cost of $4.77 per bushel. The first real orchard crop of 10 bushels of cones was harvested in 1964. This has grown to an annual target of about 35,000 bushels for all members of the cooperative. In 2001, the cooperative harvested 35,480 pounds of loblolly pine seed and 4,336 pounds of slash pine seed (Figure 9). This was more than sufficient to meet the annual demand for 30,000 pounds of loblolly pine seed and to put some seed into storage. Yields, which have been below the historical average of 1.19 pounds of seed per bushel in three of the last four years, averaged a disappointing 1.01 pounds of seed per bushel. While seed yields are subject to many environmental influences, it appears that the averages calculated prior to the implementation of latest changes in pesticide regulation may be too optimistic for use in long range planning.

Figure 8. Climbing with Swedish ladders circa 1955.

The 2002 cone harvest was below annual demands totaling 18,966 bushels of loblolly pine cones and 4,750 bushels of slash pine cones. Early indications are that the seed yields in 2002 will once again be below expectations.

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[1] 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.

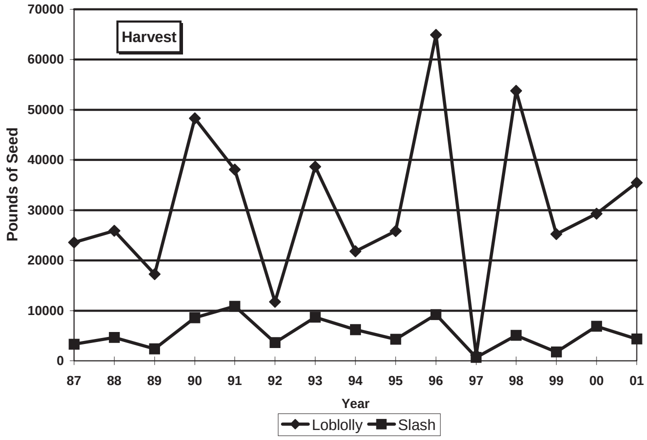

Figure 9. Pounds of seed harvested by the cooperative from 1987 to 2001.

The 2001 season was the first year that the longleaf pine seedling seed orchard managed by the Mississippi Forestry Commission produced a meaningful cone crop. This 13-year-old orchard produced 950 bushels that yielded 864 pounds of seed. Only 80 bushels of longleaf pine cones were harvested from the Mississippi Forestry Commission longleaf pine orchard in 2002. Experience garnered from cone collection in natural stands leads to the expectation that longleaf pine cone crops will be even more cyclical than that of other species. Indeed, this year's poor longleaf pine crop followed an outstanding harvest in the previous year. It was impossible, however, to determine if this was part of the expected cycle or just the result of a poor crop year as the cone crops collected from all of the other orchards at this location were very disappointing in 2002.

Many of the industrial members collect their orchards as open-pollinated half-sib families while most of the state organizations and some of the smaller companies collect their crops as orchard mixes. Regardless of the collection strategy, all organizations are placing increasing emphasis on collecting only the very best families so the reported harvest represents only a portion of the available crop that could have been collected.

Wood Quality Elite Breeding Population

Crossing for the wood quality elite breeding population started in 2001. Backward selection will eventually be used to identify approximately 30 individuals from each breeding region that combine improvement for both wood specific gravity and volume growth. These individuals will be bred in small diallels and planted in block plots to form a population for forward selection. To date, eight members have been involved in this program, either collecting pollen or making crosses among parents from three different breeding zones. The first seed for this population was collected in 2002 and it is anticipated that a sufficient number of crosses will be completed to go to the field with block plantings in 2004. Seedlings from this program will be planted concurrently with pedigreed seedlings produced for the mainline and super breeding group programs.

Progeny test data was used in 2002 to identify an additional 15 parents divided among three breeding regions for this program (Table 1). Pollen will be collected from these parents in 2003 and crossing will begin in three new wood quality elite breeding diallels in 2004. One of these diallels represents the first parents selected to support this breeding program from the South Louisiana/South Mississippi breeding region. Infusions into this population will be made as new selections become available. The economic index shown in Table 1 was used to compare trade-offs between volume growth and wood specific gravity. This index was calculated for assumptions from a kraft pulp mill[2] and is expressed in terms of dollars saved per ton of pulp produced.

Table 1. Average performance of the loblolly pine parents in the elite breeding populations for improvement in volume growth and wood specific gravity.

Zone	Parents (number)	Volume[1] (%)	Specific Gravity[2]	Economic Index (Kraft Pulp)[3]
Arkansas	11	19.5	0.023	$13.69
North Louisiana	5	25.3	0.018	$13.43
Texas	18	19.8	0.031	$16.69
South MS/ South LA	5	24.7	0.030	$16.30

[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] Savings per ton of kraft pulp produced from a land base of fixed size for wood with improvements in both volume and specific gravity.

[2] Lowe, Wm., T.D. Byram and F.E. Bridgwater. 1999. Selecting loblolly pine parents for seed orchards to minimize the cost of producing pulp, Forest Science 45(2): 213-216.

Maximizing Gain from Rooted Cuttings

Vegetative propagation through the production of rooted cuttings was first attempted at the Forest Genetics Laboratory in College Station in 1954. At that time, rooted cuttings were seen as one method of preserving and multiplying copies of desirable genotypes for inclusion in open-pollinated production seed orchards. If mature trees could be propagated, then this material could also be used as a shortcut for progeny testing. Air layering and traditional grafting were other equally esoteric methods used to accomplish this goal. A clean room to handle needle bundles under sterile conditions for vegetative propagation was added to the Forest Genetic Laboratory in 1958 by Claud Brown. Dr. R. H. Zimmerman was hired in 1962 and charged with investigating the physiological basis for aging. In retrospect, this was an ambitious task indeed as the factors that underlie this phenomena are still not fully understood after 40 years of study.

Vegetative propagation is one method of maximizing gain in the deployment population. While seed orchards only take advantage of general combining ability, vegetative propagation or clonal forestry can use all of the genetic variation present including general and specific combining abilities and epistasis caused by favorable gene combinations. Unfortunately, untested clones are random samples drawn from the distribution of possible performance levels equivalent to that represented by control-pollinated seed. An important question then becomes how many clones need to be propagated per control-pollinated family to insure that there is a reasonable chance that at least one of the very best individuals is captured.

Probability and level of confidence (LOC) analyses can be used to answer two important questions for clonal propagators: 1) for a family with a limited number of clones, how certain can one be that at least one top genotype will be present, or conversely, 2) how many ortets must be established to ensure that one or more of the best genotypes in a family will be available for field testing? The answer to the first question is important if one needs to decide given a limited number of clones, if they are likely to include the outstanding genotype the experimenter hopes to identify. The answer to the second question is important during the design phase of the program when deciding how many clones per family are required. The first question can be answered by deriving the LOC in having established at least x desirable genotypes in a stool bed with a fixed number of ortets. The answer to the second question can be found by solving the LOC equation for n (the number of ortets needed) given a pre-selected level of confidence.

Since the number of individuals within a family is limited only by the ability to produce seedlings from a desired cross, there are potentially an infinite number of individuals within a family. If one assumes that the genotypic values of these individuals are normally distributed about the family mean, then the mathematical characteristics of a normal distribution can be used to calculate the number of ortets in a given sample size that are likely to have genotypic values above some threshold. This threshold can be defined either as some best percentage of individuals or by a genotypic value some number of standard deviations above the family mean.

If each ortet is an attempt to include a desirable genotype (dg), the binomial probability of including x number of desirable genotypes in a sample of n ortets is then:

$$\textit{probability (inclusion)} = \left[\begin{matrix} n \\ x \end{matrix}\right] [\textit{prob. (dg)}]^x [\textit{prob. (no dg)}]^{n-x} \qquad [1]$$

where x is the target number of desirable clones to be identified and n is the total number of unique ortets initially established in the stool bed. This equation can be manipulated to provide the level of confidence (LOC) that a given sample size contains clones with the desired performance level:

$$LOC = 1 - \sum_{r=0}^{x-1} \left[\begin{matrix} n \\ r \end{matrix}\right] [\textit{prob. (dg)}]^r [\textit{prob. (no dg)}]^{n-r} \qquad [2]$$

The number of unique ortets within a family required to achieve a given LOC in having included at least one desirable genotype can also be estimated:

$$n = \frac{\ln[1 - LOC]}{\ln[\textit{prob. (no dg)}]} \qquad [3]$$

The analyses derived in this study have many applications in clonal forestry. For example, the decision of whether or not to include a particular family in clonal tests could be based on the likelihood that a desirable genotype has been captured in a limited number of clones (Equation 2 and Figure 10). A high LOC indicates that the number of ortets is sufficient to begin testing. However, a low LOC suggests that the risk of not capturing one of the best genotypes is high and more rootable ortets should be obtained either by increasing the rootability of the family or by establishing a greater number of ortets.

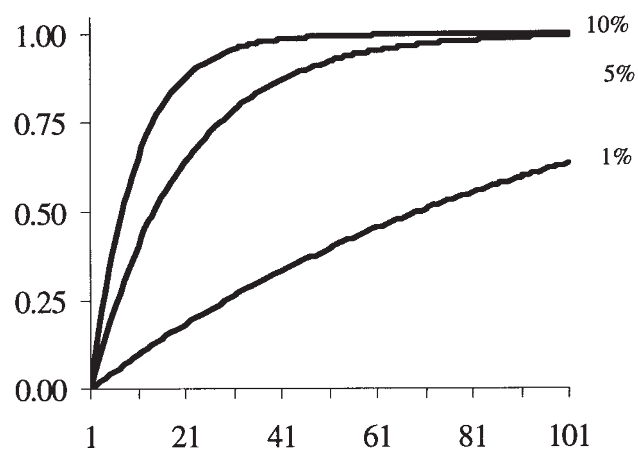

Figure 10. The level of confidence (LOC) in having captured one or more desirable genotypes in the top 1, 5, and 10% of clones given a varying numbers of rootable ortets. Number of ortets on the x axis and probability on the y axis.

LOC analyses can also be used in decisions regarding the allocation of stool bed space. If a breeder has the resources to establish a limited number of ortets then the decision on how these ortets are distributed among multiple families must be made. Equation [3] can be used to estimate the number of ortets that must be established in each family to achieve a given LOC that a desirable genotype has been captured.[3]

Breeding and Progeny Testing

The Texas Forest Service established the first progeny test in 1952/53 with less than spectacular results. This test, planted on the A. J. Hodges Experimental Area near Many, Louisiana, consisted of six open-pollinated loblolly pine families from parents selected for superior growth and form compared to an equal number of check trees selected in the same stands. The planting design consisted of two replications of 100-tree plots. Fifth-year results summarized in the Seventh Progress Report of Cooperative Forest Tree Improvement Program (1959) showed that the superior trees outperformed the checks for height in only two of the six comparisons and for diameter in only one case. Superior trees, however, had significantly smaller limbs than did the checks, showing that gain could be made in form.

Data from early progeny tests pointed out a number of deficiencies to the tree improvement staff. First and foremost was the need to make the process of superior tree selection more effective and less subjective. To this end, training sessions were held during April 1959 for industry cooperators involved in the tree selection program. Furthermore, selection criteria were formalized to compare the ratio of bole and crown volumes among candidate trees and check trees. The second major shortcoming apparent to the tree improvement staff in these early tests was the disadvantages of using open-pollinated progeny tests where only a fraction of the additive genetic variation is displayed.

The initial progeny testing program had several objectives. The first plantings were intended to demonstrate that tree improvement was practical and the benefits would be economically justifiable. To some extent the need to show quick results determined the choice of wood density and drought resistance as the initial traits selected for improvement. In addition to demonstrating the practicality of tree improvement and identifying superior individuals for inclusion in production populations, progeny tests were also needed to estimate the levels of genetic control for various traits. This information was vital for estimating the number of selections needed, the number of progeny tests required, and the most efficient breeding and testing designs. These needs are still relevant today as indicated by the following two sections which highlight early selection criteria for growth and wood density. The following sections emphasize the progress in the applied progeny testing program intended to support the operational production population.

Early Selection Criteria for Volume

Early selection is critical to the long-term efficiency of any tree improvement program. Early selection for volume at rotation age may be based on any of the three growth traits: height, diameter or volume. For loblolly pine, early height has traditionally been the selection criteria of choice in many tree breeding programs. The justifications for using height are that it is a good predictor of volume at rotation age and is less affected than diameter by competition. Heritability for height is also higher than that for diameter or volume. Furthermore, height is more closely correlated with tree form traits and wood density than either diameter or volume.

The WGFTIP, however, has always used early volume as a selection criterion for rotation-age volume. Since volume per unit area takes survival into account, as well as growth rate, it was intuitively appealing. Earlier studies also suggested that the composite trait, volume per unit area, was as good a predictor of rotation-age volume as a selection index derived from separate evaluations of height, diameter and survival. Because newer test data is now available, this issue was revisited. The objectives were 1) to estimate heritabilities for potential early selection criteria (5- and 10-year height, diameter and volume), 2) to estimate heritabilities for the breeding objective (15- or 20–year volume), 3) to estimate genetic correlations between selection criteria and the breeding objective and 4) to evaluate implications of these parameters on the selection criteria in the operational breeding program.

This study was based on three 20-year-old tests and nine 15-year-old tests established by four members of the WGFTIP: Georgia Pacific Corporation (now Plum Creek Timber Company), International Paper Company, Potlatch Corporation, and Weyerhaeuser Company. The Georgia Pacific data were 5-, 10-, 15- and 20-year measurements from one test. The test was comprised of ten replicates and ten-tree row plots. The International Paper Company data were from five genetic tests with each test comprised of six replicates and six-tree row plots. Three tests were measured at 5, 10, and 15 years and the other two tests were measured at 5, 10, 15 and 20 years. The Potlatch Corporation data were from five tests measured at 5, 10 and 15 years. Each test was comprised of 12 replicates and six-tree row plots. The Weyerhaeuser data were measurements from one test of 12 replicates of five-tree plots measured at 5, 10, and 15 years. All the twelve tests were measured for height and diameter. Volume was calculated using volume equations developed by the WGFTIP.

Average family-mean heritability estimates at 5 years were largest for height while those for diameter and volume were slightly lower and quit similar (Figure 11). At 10 years, average family-mean heritability estimates were largest for diameter followed by volume and smallest for height. Few difference in correlations existed between 5-year traits with volume at 15 or 20 years, but they were slightly higher for volume than the other two traits (Figure 12).

[3] A fuller treatment can be found in Myszewski, J. H., F. E. Bridgwater and T. D. Bryam. Determination of the minimum number of stool bed ortets required to capture a desirable genotype from full-sibling family crosses. Southern Journal of Applied Forestry (In press).

Correlations of 10-year traits with 20-year volume per acre were highest for volume followed by diameter and were smallest for height (Figure 12).

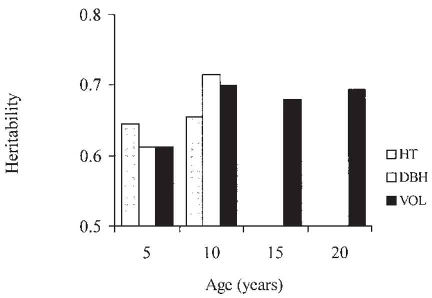

Figure 11. Average family-mean heritability estimates for height, diameter, and volume per hectare.

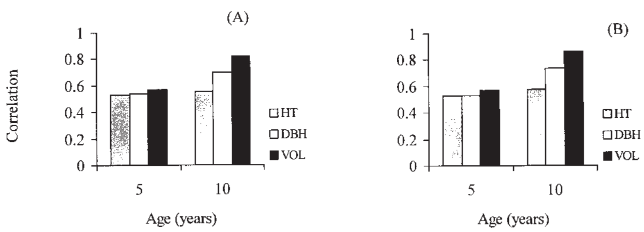

Figure 12. Family mean correlations of early growth with A) 15-year volume and B) with 20–year volume.

Little difference existed in efficiencies of selection between 5-year traits with volume at 15 or 20 years. Efficiencies of selection of 10-year traits for 15 or 20-year volume per acre were highest for volume followed by diameter and least for height (Figure 13).

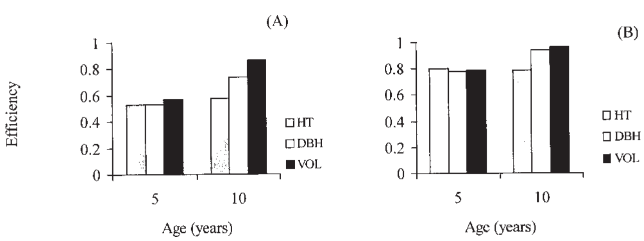

Figure 13. Mean efficiency of selection per year estimates of early growth with A) 15–year volume and B) efficiency of selection per year estimates of early growth with 20–year volume.

In summary, the results based on family means suggest that any of the selection criteria will work equally well at age 5. By age 10, volume is a better selection criterion than diameter or height for selecting volume per acre at 15 or 20 years. Thus, the current practice of using per acre volume as the early selection criteria for volume per acre at maturity is efficient.

Wood Density

Wood density was one of the first traits identified by the Texas Forest Service for investigation and the description of the planned research program made up a prominent part of the first annual report. This trait was selected because of its impact on both lumber quality and pulp yield and because it was hoped that the research would provide some rapid results. In fact, the first forest genetics Ph.D. dissertation written at Texas A&M centered on the physiological causes for variation in wood specific gravity. In what would be judged as an anomaly in today's world of short rotations and high juvenile wood content in harvested logs, individuals with both high and low wood densities were identified and established in seed orchards very early on.

Wood density continues to be an important trait in today's tree improvement program. The cooperative's objective is to sample specific gravity for all parents in at least one of the three progeny tests in which it appears. Checklots and advanced-generation selections are sampled in each test regardless of whether the test is used for the estimation of parental breeding values. Currently, 132 balanced control-pollinated progeny tests have been sampled for wood density and breeding values are available for 1,367 loblolly pine and 239 slash pine parents.

Optimum Selection Age for Wood Density in Loblolly Pine [4]

Wood density or specific gravity is the most important wood quality trait because it is well correlated with major strength properties of sawn timber and with pulp and paper properties. Previous studies indicate that heritabilities and age-age genetic correlations for wood density traits are generally high. These results imply that selection for wood properties may yield greater genetic response and may be made earlier than for growth traits. It has been suggested that wood density could be selected as early as age 2 in ordinary tests and short-term tests, but a major limitation of these studies is that the age at which genetic gain is maximized (optimum selection age) was not estimated. Knowledge of age trends of age-age genetic correlations and heritabilities is critical for determining the optimum selection age. Wood density is difficult and more expensive to assess than growth traits, and hence data on all ages up to harvest are rare. Age trends of genetic parameters for wood density determine its potential use for early selection in loblolly pine. The study described here was the first to report on the optimum selection age for wood density traits in loblolly pine.

The data were from two tests established by International Paper Company. Each of the two tests was comprised of three replicates and 12-tree row plots. Systematic thinning was carried out in the tests at age 10 years. The data used for density determinations were collected

[4] For a fuller treatment see Gwaze, D. P., K. J. Harding, R. C. Purnell, and F. E. Bridgwater, 2002. Optimum selection age for wood density in loblolly pine. Canadian Journal of Forest Research 32(8): 1393-1399. The study described here was done on material provided by International Paper Company and data that was made available to the authors by the North Carolina State University.

in 1992 when the tests were 27, 28 and 29 years of age. Pith-to-bark 12 mm cores of wood were extracted from the mid-whorl closest to breast height (1.3 meters) from randomly selected trees within a plot using an increment borer. The increment cores contained between 25 and 27 growth rings from the pith reflecting their age and the sampling height. Six trees were sampled per family in each test. Intra-ring density information was obtained using a direct scanning X-ray densitometer. Within each growth ring, data were partitioned into earlywood and latewood using a density criterion of 480 kg/m^3. This value was determined empirically by separating earlywood and latewood by ocular examination and determining the density for each segment. Latewood proportion was calculated by dividing the latewood width with the ring width. The average core density was obtained by weighting the average ring density with the respective ring width. Rings affected by compression wood, heartwood or resin streaks were removed prior to analyses. Rings 1-4 had large numbers either missing or partially sampled as core samples had missed the pith and these were omitted from the analyses. Therefore, core density at 5 years was average ring density for the 5th ring from the pith, while core densities for subsequent ages were weighted ring densities for that year and all younger ages. The weighting used was the basal area of each growth ring using ring width data and assuming that each growth ring after the first ring was perfectly circular. The data were highly unbalanced, and only families represented in at least 2 replications on each site were included in the analyses. The total number of trees included in the analyses was 605 comprising 63 families from 83 parents. The following logarithmic equation was fitted to age-age genetic correlations between core density at younger ages and core density at 25 years:

$$r_g = ß_0 + ß_1 * \log_e(\text{younger age}/25) \qquad [4]$$

The regression equation was fitted in order to extrapolate correlations at ages not assessed and to generally correct for irregularities in the correlations.

Heritability for core density ranged from 0.20 to 0.31. The relationship between heritability estimates for core density and age was non-linear ($h^2 = 0.465 – 0.0525*Age + 0.000370*Age^2 - 0.0000764*Age^3$; $R^2 = 0.44$). Although the R^2 was low, the above relationship was significant (P = 0.018). Age-age genetic and phenotypic correlations for core densities were positive and strong (range: 0.6 - 1.0). Genetic and phenotypic correlations were similar at older ages, but at younger ages genetic correlations were much higher than their phenotypic counterparts, indicating that phenotypic correlations decreased more rapidly as age difference increased. Age-age genetic correlations for core density were moderately described by the logarithm model ($r^2 = 0.62$), while the phenotypic correlations were well described by the same model ($r^2 = 0.88$) (Table 2). The estimated regression slope for the genetic correlations was significantly lower than that of phenotypic correlations ($P < 0.05$). The slope of the age-age genetic correlations was smaller than that obtained in growth traits implying that wood density could be selected earlier than growth traits.

The optimum selection age for core density was estimated to be 5 years when calculations were based on genetic correlations, and the optimum selection age was robust to changes in the length of breeding cycle. Optimum selection age derived assuming a constant heritability across ages was similar to that derived taking into account the age-related heritability trends. Optimum selection age based on phenotypic correlations was 1-2 years higher than that based on genetic correlations. The study confirms that selecting at very young age is effective for wood density. Extrapolating to ages younger than 5 (the youngest age measured in the current study) suggested that selecting at 1-2 years may be effective for core density. In the future, possibilities of early selection for wood density at ages younger than 5 should be explored. Early selection for core density would result in a correlated increase in early wood density, but less progress in latewood density or latewood proportion at 25 years (Table 3).

Table 2. Results of fitting age-age correlation linear models for core density.

Independent variable	Regression coefficient		Residual mean square	df	R^2
	Intercept (β_0) ± se	Slope (β_1) ± se			
Genetic correlation	1.03 ± 0.014	0.098 ± 0.018	0.0014	18	0.62
Phenotypic correlation	1.05 ± 0.014	0.210 ± 0.018	0.0014	18	0.88

Table 3. Genetic and phenotypic correlations between core density (core) at ages 5-7 years and earlywood density (EW), latewood density (LW), ringwood density (ring) and latewood proportion (prop) at 25 years.

Age	Genetic correlations					Phenotypic correlations				
	EW	LW	Ring	Core	Prop	EW	LW	Ring	Core	Prop
5	0.81	0.15	0.59	0.75	0.54	0.16	0.21	0.20	0.62	0.10
6	0.80	0.25	0.62	0.90	0.48	0.20	0.22	0.23	0.73	0.12
7	0.87	0.33	0.67	0.93	0.48	0.22	0.25	0.27	0.78	0.15

First-Generation Breeding and Progeny Test Establishment

One of the original goals of the Texas Forest Service's tree improvement program was to identify a minimum of 25 highly selected individuals to support the breeding program for each of three species (loblolly, slash, and shortleaf pines). The Eighth Progress Report of the Cooperative Forest Tree Improvement Program (1960) stated that half this number of trees had been located. This stated goal was for families selected for superior growth and fails to account for the fact that selection was one of the program's driving principles from its onset. By the time that the Eighth Progress Report was written in 1960, seed had been collected from hundreds of trees including those selected for drought resistance and wood density. Collection trips had been made to Mexico and pine species from as far away as Asia had been planted for evaluation in Texas. In addition to exotics tested as pure species, several hybrid pines had also been tested. The outcome of this early venture into exotics and hybrids was that while some sources had excellent growth rates, almost all succumbed to drought or the dramatic changes in temperature experienced during the fall. Nothing outperformed pure lines of the southern pines, which included slash pine and Virginia pine, both exotics in Texas.

The goal of 25 excellent selections to support the mainline breeding program was eventually expanded to 100 selections per cooperative member for each orchard type (species and provenance combination) that they operated. To meet this rather more ambitious target, approximately 3,400 loblolly and 1,000 slash pine were eventually selected. Much smaller programs were also maintained for shortleaf pine, longleaf pine, and Virginia pine.

Once selected, the next step in the program was to progeny test the potential candidates. Many progeny test designs have been tried ranging from the first test that consisted of two replications of 100-tree plots to the current design of forty replications of single-tree plots. Many early tests were planted with six replications of four-tree row plots. When it became apparent that this provided too few observations, ten replications of ten-tree row plots were favored. This design was in use when the cooperative started in 1969, but soon gave way to 12 replications of six-tree row plots. One significant change that occurred in the 1980s was that the tree spacing was reduced to 6 x 8 feet in an attempt to minimize replication size. While the first control-pollinated progeny test was planted in 1959/60, the use of open-pollinated seedlings continued to be the dominant progeny test design for many years. A significant reason for this, one with potential relevance in this era of increasing pesticide regulation, was that the lack of cone and seed insect protection made seed yields particularly unreliable. Each change in test design was an attempt to make the progeny-testing program both more effective and more efficient. As each design, however, involves compromises between desired results and operational constraints, it is unlikely that the ultimate test design will ever be determined.

Since the inception of the tree improvement program the Texas Forest Service and the other members of the WGFTIP have established a total of 1,300 pine progeny tests. These tests occupied approximately 3,750 acres and have included in excess of 2,200,000 individuals (Figure 14).

Figure 14. Ron Campbell, International Paper Company, surveys one-year-old seedlings in one of the cooperative's regional polymix test of second-generation selections. The test is located adjacent to IPCo's Bluff City Nursery in Nevada Co., AR.

Slash Pine

Slash pine, an exotic in most of the Western Gulf region, was recognized as an important species for reforestation almost from the beginning of the program. A seed production area was established on the E. O. Siecke State Forest in 1956. The first superior selections for slash pine were made prior to 1957 and the first seed orchard for this species was grafted by 1960. One of the main reasons that this species was adopted so early in the history of the tree improvement program was because of its early success when planted in southeast Texas. One of the first uses of slash pine in Texas was at the E.O. Siecke State Forest in 1926. Slash pine was also widely planted by the Civilian Conservation Corp in the 1930s. These stands contained an extraordinarily large proportion of high value poles and sawlogs making this a very desirable species for reforestation. In 1961 the seed production program was reviewed and the decision was made to increase the emphasis on slash pine. This situation came full circle in the 1970s with the realization that rust-related mortality was devastating operational plantings and that silviculture practices could ameliorate several factors that had impeded loblolly from growing well on phosphorous deficient flatwoods sites.

At first an attempt was made to use the same breeding and field design then used for loblolly pine. By the mid 1970s it became apparent that selecting for growth and form alone would be insufficient. In fact, rust-related mortality was becoming such an important factor that even in progeny tests the best early predictor of age 15 volume was the family infection level at age 5. The decision was made to screen all of the cooperative's 1,000 slash pine selections at the USDA Forest Service Resistance Screening Center and to reject the poorest performers. The 500 selections that passed this screening were then divided into breeding groups and were crossed in a partial diallel for field testing. Rust resistance remains such an important criteria for selection in this species that at age 5, no test is used for ranking families unless the test or the unimproved checklot has at least 30 percent infection.

As a result of its limited geographic range and its susceptibility to fusiform rust, slash pine is currently favored on flatwood sites in the Coastal Plain where phosphorous deficiencies are common and landowners choose to minimize their silvicultural inputs. Only time will tell whether this situation will reverse itself again, but selection for rust resistance has been very successful. The top twenty selections currently identified in the program have an average breeding value for volume growth of 50 percent more than the unimproved checklot. Slash pine, because of its inherent bole straightness, may have a higher value than loblolly pine on some sites if the desired crop is sawlogs grown on a short rotation.

Boise was the only member establishing a slash pine test in 2002 (Table 4). This test contained three diallels and represented the last planting required to complete the field testing of their first-generation selections. Of the six members with breeding programs for slash, two members had completed the establishment of all their first-generation selections in progeny tests by the end of the 2002 season, two more grew their last tests during the summer of 2002 and should complete their field test establishment with the 2002/03 planting season. The remaining two members in the slash pine program have seed in hand or are waiting for the last crosses to be collected and should complete their testing program soon.

Table 4. Progeny tests established during the 2001/02 planting season.

Cooperator	Number of Tests	Diallel by Location Combinations
<u>**First-Generation Loblolly Pine Tests**</u>		
Louisiana-Pacific Corporation	3	18
Plum Creek Timber Company	3	15
First Generation Loblolly Pine Total:	**6**	**33**
<u>**First-Generation Slash Pine Tests**</u>		
Boise Cascade Company	1	3
<u>**Virginia Pine Christmas Tree Tests**</u>		
Louisiana Department of Ag & Forestry	2	
Oklahoma Forestry Services	4	
Texas Forest Service	6	
Advanced-Generation Lobolly Pine Polymix Tests	Number of Tests	Number of Families
Arkansas Forestry Commission	1	53
International Paper Company	1	54
Potlatch Corporation	1	56

Loblolly Pine

The main emphasis of the Texas Forest Service and the WGFTIP members has always been on loblolly pine. This interest has been so central to the cooperative, that the willingness to support the mainline breeding and progeny testing program for this species has been one of the primary requirements for membership.

First-generation progeny testing efforts for this species are nearing completion with only two members planting new first-generation tests during the 2001/02 season (Table 4). These tests represent a combined 33 diallel by location combinations and were the last of the tests required to complete progeny testing of all of the first-generation selections belonging to Louisiana-Pacific Corporation and Plum Creek Timber Company. Progeny tests have now been established to evaluate a total of 3,190 first-generation selections. Of this number, 2,497 have been evaluated in balanced control-pollinated progeny tests (Figure 15) and an additional 693 were evaluated in open-pollinated plantings. In addition, a small number of first-generation selections will only be evaluated as polymix crosses included in advanced-generation progeny tests. Five of these selections were included in the advanced-generation polymix tests also listed in Table 4. There are currently less than 100 first-generation selections that remain to be tested by the cooperative.

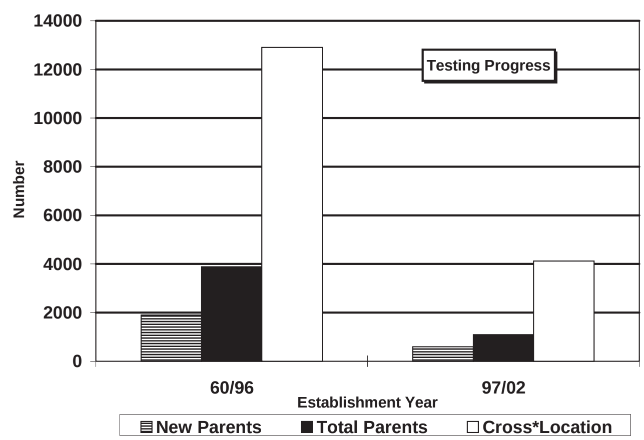

Figure 15. The number of loblolly pine crosses (total number of cross by location combinations), the total number of parents, and the number of parents established in tests for the first time from 1960/97 and from 1998/2002.

Performance of orchard-mix versus unimproved checklots. Cooperative progeny tests established before the late 1980s contained commercial checklots composed of seed collected in the 1960s. By the late 1980s these seed were losing germination capacity and exhibiting poor growth in the greenhouse. Concern that this poor performance might continue after field establishment and result in overestimation of gains resulted in the development of new checklots for each breeding region. These new checklots were comprised of ten clones with average volume production based on progeny test performance available at that time. Equal numbers of seed from each of the ten clones were bulked to form the new orchard-mix checklots.

Table 5. Performance of the unimproved and orchard mix checklots by breeding zone.

	Checklot							
	Unimproved				Orchard Mix			
Breeding Zone	N	BV	SD	SPGR	N	BV	SD	SPGR
East Texas	17	96.9	2.6	0.403	17	98.6	3.0	0.397
South Arkansas	48	93.6	5.6	0.405	48	93.4	6.7	0.394
North Louisiana	27	85.3	7.5	0.399	27	92.4	6.2	0.403
North Mississippi	9	92.2	5.4	0.365	9	96.0	5.4	0.368
South Louisiana	14	96.6	3.8	0.379	14	100.2	5.2	0.379
South Mississippi	20	91.5	5.2	0.379	20	100.2	5.2	0.379

Beginning in the late 1980s and early 1990s, progeny tests were established using both checklots, thus allowing a comparison of performance to be made between the checklots before permanently discontinuing the use of the older unimproved checklot. With the close of the 2001/02 measurement season, 10-year data was available on nearly 50 progeny tests containing both types of checks. Another 85 progeny tests had five-year data. The performance of the two checklot types for growth and wood specific gravity are shown by region in Table 5.

Differences between the orchard-mix checklots and the commercial checks were small for both growth and specific gravity. For growth the orchard-mix checklots were slightly better than the unimproved checks, with the largest differences apparent in North Louisiana and South Mississippi. First-generation selections will continue to be evaluated in reference to the average checklot performance within a region.

Virginia Pine

The Texas Forest Service and Oklahoma Forestry Services, in collaboration with the Texas Christmas Tree Growers Association, have been working together to polymix test second-generation selections from this species for use in Christmas tree production. These selections were identified either in progeny tests of Virginia pine managed for Christmas trees or in provenance studies designed to sample the natural range of this species. Virginia pine, one of the southern pines, is an exotic in the Western Gulf region so these selections will form the basis for a land race. Approximately 100 second-generation Virginia pine selections have been identified, 36 of which were included in this year's progeny tests. Two series of tests were established, one with five locations and one with four locations (Figure 16). These plantings will be evaluated for survival, growth, and graded for quality.

Figure 16. Virginia pine Christmas tree progeny test managed by James Robinson at the end of the first growing season.

Test Measurement and Second-Generation Selection Activity

Progeny test measurement and advanced-generation selection are the program components that most directly impact the amount of genetic gain available for use in the deployment population. As such, they are frequently acknowledged as the backbone of any tree improvement program. The first progeny tests were measured early and often because there were so many unknowns in the new program and there was a need to generate results quickly. Drought hardiness was chosen as one of the initial traits for investigation both because it was an economically important trait along the western fringe of the natural range of southern pine and because it could be evaluated on seedlings. The weather certainly reinforced this choice as Texas experienced one of the worst droughts since the Dust Bowl during the early 1950s. The drought was so extensive that drinking water had to be delivered to Dallas on rail cars. Several of the early annual reports stress both the good news, bad news aspect of the weather by citing that the drought testing program was doing very well while bemoaning the fact that establishment efforts for other types of tests were being detrimentally impacted (Figure 17). While improved silviculture has greatly reduced early mortality, survival continues to be an important trait in the WGFTIP. All evaluations are based on volume production per unit area, a composite trait that combines information on both growth rate and survival.

Figure 17. Bruce Zobel in a three-year-old progeny test located at New Baden in Robertson Co., TX, which was subjected to the 1954 drought as one-year-old seedlings. Drought resistant trees are in the plot on the left, susceptible trees were planted in the plot in front of Dr. Zobel.

The Texas Forest Service made the initial second-generation selections from 10-year-old progeny tests around 1968. The first 29 selections were from open-pollinated progeny of loblolly pine selected for wood density. While the overarching objective has always been to select the best individuals from the best families, it has not always been clear as to how this should be done. Advanced-generation selection techniques have changed as the progeny testing protocols have evolved. Early efforts assigned values to both family performance and the individuals' deviation from the plot mean and ranked the results. This was acceptable as long as all of the selections were made in open-pollinated progeny tests. When control-pollinated progeny tests became available, the selection method was altered to use mid-parent values rather than cross performance. When the progeny test design was changed from multiple trees per plot to single-tree plots, the procedure was changed again to rank individual tree performance relative to the replication average rather than to the family plot average. The cooperative anticipates making its initial third-generation selections in the near future from pedigreed block plots and the selection protocol will have to change again. This will be necessary to reflect the fact that some crosses with high breeding values will be among related parents and will likely express varying degrees of inbreeding depression. The one theme that has been consistent throughout the use of all of these different protocols is the need for field verification. There remain many aspects of tree growth and form that cannot be easily captured by any system that records a limited number of measurements.

During the 2001/02 measurement season, the cooperative measured 109 progeny tests consisting of 85 loblolly pine tests, 11 slash pine tests, eight longleaf pine tests and four shortleaf pine tests. Of this total, 27 were five-year-old loblolly pine tests containing a total of 267 parents, 141 of which were evaluated for the first time (Figure 18). The number of new first-generation parents evaluated for the first time with age 5 measurements peaked in 1998/99 and will continue to decline as the cooperative completes the remaining first-generation progeny testing. Twenty-two of the 109 tests were evaluated for first-year survival. Six of these tests were second-generation polymix tests and three were regional mixed first- and second-generation polymix tests.

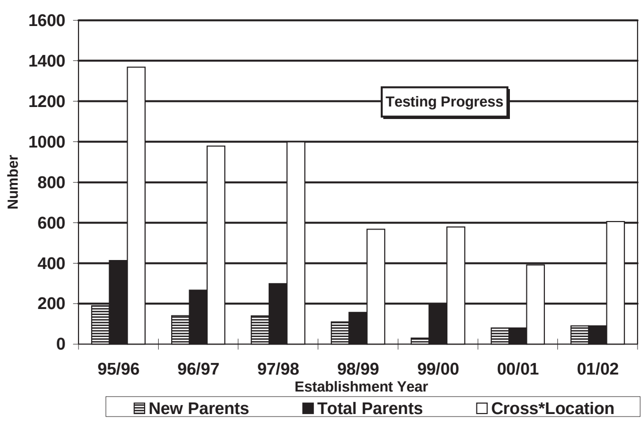

Figure 18. The number of loblolly pine crosses (total number of cross by location combinations), the total number of parents, and the number of parents established in tests for the first time in each of the last six years. The 1996/97 establishment year represents the progeny tests that were evaluated in 2001/02.

From the 52 progeny tests eligible to be screened for second-generation selections, nine cooperators identified 107 loblolly pine selections and seven slash pine second-generation selections. The loblolly pine selections originated in 35 breeding groups and contributed to the breeding population in all of the cooperative's breeding zones. Currently, selections have been identified in 88 of the cooperative's 116 loblolly pine breeding groups.

International Paper Company contributed the majority of the selections in 2001/02 with 19 individuals identified from the combined International Paper/Champion International breeding populations. The Mississippi Forestry Commission contributed 18 selections, while Temple-Inland Forest and Weyerhaeuser Company tied as runners-up for third with 16 selections each from their respective programs. The Louisiana Department of Agriculture and Forestry identified 15 selections. The cooperative now has identified a total of 1,459 loblolly pine and 172 second-generation slash pine selections (Figure 19).

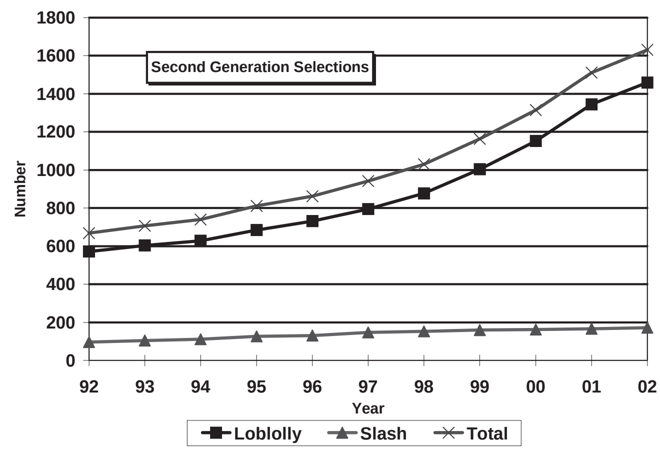

Figure 19. Cumulative numbers of second-generation selections in the cooperative.

Second-Generation Breeding and Testing

The WGFTIP was the first of the southern pine tree improvement cooperatives to subdivide the breeding population into breeding groups and to adapt a complementary breeding design. The decision to do this was made in about 1978 although it took several years to work out the details. Subdividing the breeding population was seen as necessary to ensure that unrelated individuals would be available for the production population. By maintaining relatives within breeding groups inbreeding depression could be isolated in the breeding population. Because breeding groups were set up after breeding had commenced, the need to assign all related selections to the same breeding group resulted in some very large groups. The average first-generation breeding group was restricted to 25 individuals. The target for second-generation breeding groups is eighteen, fifteen forward selections and three backwards selections.

With the implementation of breeding groups, a complementary mating system was adopted. In this scheme, one set of crosses and field tests would be used to rank parents and another set of crosses and field plantings would be generated for selection purposes. To this end the cooperative has been establishing replicated polymix tests of advanced-generation selections to rank parents while establishing block plots of pedigreed-crosses for advanced-generation selection. The first polymix tests were planted in 1989/90. Unfortunately, most of these tests were dropped from the program after a severe ice storm in 2000; however, data from these plantings was used for selecting parents for advanced-generation seed orchards. Unfortunately, the corresponding block plots have not yet reached measurement age. The first block plots of pedigreed crosses with supporting five-year-old polymix test data will become available for third-generation selection in 2003.

All of the cooperative members, with the exception of Louisiana-Pacific Corporation, have identified second-generation selections and are actively involved in the second-generation breeding and testing program. Louisiana-Pacific Corporation joined the effort late and has recently completed establishment of all of their first-generation progeny tests. The oldest of their tests has not yet reached measurement age.

During the 2001/02 planting season one series of advanced-generation tests was established with the Arkansas Forestry Commission, International Paper Company, and Potlatch Corporation each planting one location (Table 4). Once again, the strength of the regional approach to test establishment was confirmed as none of these organization had sufficient seed to plant a test on their own. By combining resources, all were able to field test some of their most advanced selections.

The number of tests will be greatly reduced in the second generation compared to the first generation. This is the result of two factors. First, the use of polymix crosses to evaluate parents reduces the number of crosses per family from four to one. Second, the use of a single-tree plot design has greatly increased the number of sources that can be evaluated in each test. This year's advanced-generation tests contained only about 50 parents and were of modest size compared to recent progeny tests, which have sometimes consisted of more than 100 parents. At least three times the number of field plantings would have been required to test an equivalent number of first-generation parents.

Pedigreed crosses among the parents selected for second generation are being established in block plots to provide the population from which the third generation will be selected. These block plots are replicated only for insurance purposes and each member is responsible for establishing the crosses necessary to perpetuate their own breeding groups (Figure 20).

Additional Activities

Additional activities is a catch-all category for activities participated in or supported by the members of the cooperative that are distinct from seed production and the main line breeding and progeny testing programs. Items in this category emphasize program enhancement through training (Contact Representatives' Meeting), supporting research (Seed Orchard Pest Management Subcommittee) and program management (Formal Reviews).

Figure 20. Randy O'Neal, Arkansas Forestry Commission, with seedlings produced from second-generation crosses that will provide third-generation selections to reconstitute their breeding groups for the next cycle of breeding.

Contact Representatives' Meeting

Training has been an integral part of the tree improvement program's mission from the very beginning. The very first annual report announced that graduate fellowships had been awarded to two outstanding students, Franklin Cech and J. P. van Buijtenen. Almost all of the early annual reports note the general excitement about the potential of tree improvement while deploring the fact that rapid gains in the science were being hampered by the lack of 'men trained in forest genetics.' The first formal instruction for employees of industry organizations contributing to the tree improvement program was held in April 1959 when a series of training sessions were held on superior tree selection. That same year, a field trip for administrative personnel from cooperating industries was held in May at the Arthur Temple, Sr. Research Area and plans were announced to make this an annual event. These early training sessions evolved into the annual Contact Representatives' Meeting, which is still held in May.

Boise Cascade Corporation hosted the 2002 Contact Representatives' Meeting in Lake Charles, LA. The meeting was well received with attendance at or near record levels. The theme for this year's meeting was vegetative propagation. Dr. Joe Weber of Boise, who gave an overview of their vegetative propagation program and discussed its integration into their tree improvement program, opened presentations around this theme. Dr. Barry Goldfarb of North Carolina State University presented recent developments in vegetative propagation and clonal research. Jennifer Myszewski, Ph.D. candidate at Texas A&M, presented decision criteria for selecting an appropriate number of clones for a vegetative propagation program. These presentations were reinforced with visits to Boise's seed orchard and rooted cutting facility

Figure 21. Jeff Donahue explains Boise's rooted cutting program to the attendees at the 2002 Contact Representatives' Meeting.

(Figure 21). The group also visited a research test site where slash pine seedlings and containerized rooted cuttings were planted. The site, established by Dr. Mike Messina with the Texas A&M Forest Science Department, will be used to quantify slash pine survival, growth and physiology as affected by planting date, year of planting and environmental factors.

Other topics covered at this year's meeting included population genetics and seed orchard pest management. Dr. Floyd Bridgwater (USDA Forest Service Southern Institute of Forest Genetics) discussed development and current status of the Founder Project to which many cooperators have agreed to supply plant material to be used in the development of genetic markers useful in characterizing the commercial population of loblolly pine. Texas A&M Ph.D. candidate Mohamed El Rababah, working in Dr. Claire Williams' laboratory, presented his findings on the population dynamics of loblolly pine. His research supports the theory that the current loblolly pine population across the South developed from two distinct populations, or refugia. The line of demarcation between these populations may be somewhat farther east than the Mississippi River, the current reference point in comparisons made between eastern and western sources of loblolly pine.

On the seed orchard front, Dr. Tom Byram gave an update of results of the Asana® Rate Study. Results show good control of seedbugs, even at low rates; however, there was little or no coneworm control except at the highest rate examined. John Taylor, Integrated Pest Management Specialist with the USDA Forest Service Forest Health Protection Unit in Atlanta, GA, gave an update of activities of the Seed Orchard Pest Management Subcommittee. The meeting ended on a high note as guest speaker Dr. Robert Krieger (University of California-Riverside) generated a lot of excitement and discussion with his enlightening presentation on measuring pesticide exposure for risk assessment.

The arrangements for the supper and social hour were made by the Louisiana Department of Agriculture and Forestry and the Louisiana Forest Seed Company.

Seed Orchard Pest Management Subcommittee

Members of the cooperative continued to support the activities of the Seed Orchard Pest Management (SOPM) Subcommittee in 2001. The members were involved in four major projects sponsored by the subcommittee and many members also provided support to individual scientists working on related projects.

Efficacy Studies

Data collection was completed for the 2001 southwide Asana® rate study that compared 0.19, 0.10 and 0.03 #ai/ac to an untreated control in six orchards (three in the Western Gulf region and three in the eastern United States). The objectives were to determine if lower than labeled rates could be used effectively to control cone and seed insects while avoiding build up of scale insects. Initial results indicated that any application rate controlled seed bugs. Treatments had a positive impact on first-year conelet survival and percent good seed, both indications of seed bug control. Only the heaviest rate controlled coneworms and this control was significantly different only when the one slash pine orchard was excluded from the data set (Figure 22). Calculating the number of good seed per original flower (obtained by multiplying flower survival* cone survival * number of seed * percent good seed) indicated that any level of treatment provided some benefit. Treated areas had between 15 and 20 more good seed per original flower than the untreated control (Figure 23). Scale build up was observed at the 0.10 and 0.19 application rates.

While meaningful, the control of coneworms obtained with the high rate of Asana® was less than desired indicating that use of this chemical alone may not give satisfactory results. A potential caveat to this conclusion is that the large areas of each orchard in the study were left untreated or treated at levels expected to be less than optimal. This occurred because the aerial application of the pesticide

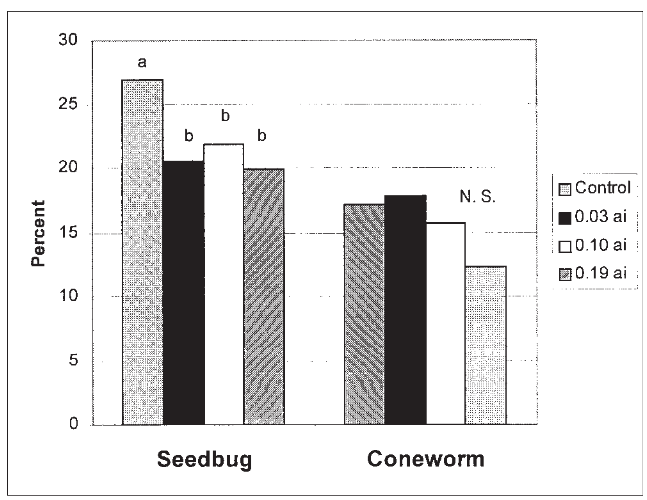

Figure 22. Results from the Asana® rate study showing A) the percent seed damaged by seedbugs as determined by x-raying seed extracted from healthy cones and B) the percentage of total cones collected damaged by coneworms.

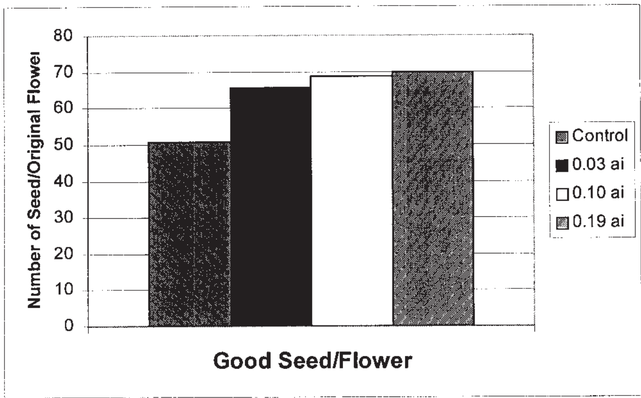

Figure 23. Number of good seed estimated for each original flower. This synthetic trait was obtained as the product of first-year flower survival, second-year cone survival, seed extracted per cone, and percent good seed.

required extensive use of untreated buffers between treatments. When the area in the buffers was added to the untreated control, approximately half of each orchard was untreated. The organizations participating in this study incurred both direct cost of installing the study and a significant opportunity cost in lost seed. Organizations participating in this study were International Paper Company (2 orchards), Florida Division of Forestry, Mississippi Forestry Commission, Temple-Inland Forest, and Weyerhaeuser Company.

A similar protocol was used in 2002 to compare operational applications of Imidan® and Capture® to untreated controls. Imidan® was registered for cone and seed insect control based on its performance when applied to single trees with hydraulic sprays, but this was the first time it had been evaluated when applied by air. The decision to include Capture® as the operational standard was based on the fact that coneworm populations were low during the season when this chemical was evaluated in a previous southwide study. Organizations participating in this study included Plum Creek Timber Corporation (2 orchards), Boise Cascade Company, and the North Carolina Forest Service. Many people were involved in making this project possible. Once again, Dr. Alex Mangini (USDA Forest Service- Forest Health Protection) was essential in seeing that the study was properly installed. Others involved with cone damage classification and seed x-ray analysis include Dr. Don Grosman (Texas Forest Service), Dr. Dan Miller (USDA Forest Service – Southern Research Station) and Don Duerr (USDA Forest Service – Forest Health Protection). Gowan Corporation most kindly provided the Imidan® used in this study. Evaluation of the data is just beginning.

Worker Exposure

Critical information needed to evaluate the safety of any pesticide is the level of occupational risk to workers. This risk is impacted by such factors as the kinds of jobs performed, the amount of contact with treated foliage, and the transfer rate of the chemical to the worker's body. With this knowledge, standards are set for the kinds of personal protective equipment required and the safe length of the reentry interval after application. When hard data is lacking, the US Environmental Protection Agency (USEPA) must make very conservative assumptions to insure worker safety. With these facts in mind the Seed Orchard Pest Management Subcommittee participated in two initiatives in 2002.

The first of these efforts was a survey of organizations collecting cones in 2001 to assess the number of workers exposed to pesticides. Surveys were returned by 17 organizations that used 16 different contractors. On average, 2.5 contract crews were used per orchard (range 1-9) with 3.9 workers per crew (range 1-22). The average number of days worked was 18.1 for the crew member picking cones from aerial lift equipment and 15.5 days for the crew members gathering cones from the ground. Company crews, which primarily picked research cones, spent less time harvesting than did contractors. By extrapolating from the survey, it is estimated that there were approximately 350 contract workers involved southwide in the cone harvest.

The second effort was a pilot scale study to examine the feasibility of determining the amount of pesticides actually being absorbed by individual workers during cone collection. A preliminary worker exposure and dislodgeable foliar residue study was conducted during the 2002 collection season in cooperation with Dr. Bob Krieger, a University of California-Riverside toxicologist. Contract crews working in Boise Cascade Company and Temple-Inland Forest orchards were monitored. Both of these orchards had received midseason applications of Guthion® followed by a late season application of Asana®. Guthion® residues present on the needles at the time of collection was determined and the amounts present in the workers urine were quantified using biomonitoring. While this study was useful to determine the range of pesticide residues expected, it was only intended to determine the feasibility of conducting a larger study capable of meeting the rigorous standards required by the USEPA. It is expected that this larger survey will be performed in 2003.

Other Activities

The members of the tree improvement community continued to provide in-kind support to several scientists on the SOPM subcommittee working on cone and seed insect problems. A very brief survey of these activities include: 1) an efficacy study of Steward® and Mimic® for coneworm control conducted by Dr. Alex Mangini in a Plum Creek Timber Company Orchard, 2) a duration and rate study of emamectin benzoate applied through injections conducted by Dr. Don Grosman in a Texas Forest Service orchard, 3) follow up of the Asana® rate study by Drs. Don Grosman and Steve Clark in Temple-Inland Forest and Mississippi Forestry Commission orchards to evaluate different methods of controlling scale insects, and 4) a study of the ecology of acorn weevils in oak seedling orchards by Dr. Dan Miller.

The Seed Orchard Pest Management Subcommittee is a loosely organized working group of the Southern Forest Tree Improvement Committee. It consists of people interested in the management of seed orchard pests and includes representatives from the Pacific Northwest, the USDA Forest Service, the three southern tree improvement cooperatives and the forest products industry. Anyone concerned about the control of seed orchard pests is welcomed to attend the meetings and to participate in the committee's projects.

Formal Reviews

The Formal Review is one of the cooperative's most important tools for assisting individual members with the management of their programs. These reviews, which were first conducted in 1977, are scheduled every three years and are intended as both an evaluation of past accomplishments and as a planning tool for the next three years. The Formal Review consists of both a field assessment and an office evaluation and is not intended to trouble shoot daily operations but rather is designed to review each program's strategic goals. The office portion of the review provides the opportunity for managers with different ranges and scopes of responsibility to evaluate long-range plans. The cooperative staff participates by contributing knowledge on the regional status of the tree improvement program. The process, however, is not only directed toward the review of the member's program, but also provides an opportunity for the members to evaluate the quality of service received from the cooperative staff and to provide a mechanism for the staff to stay current with the member's changing priorities.

In 2002, Formal Reviews were conducted for Boise, Deltic Timber Corporation, Louisiana Department of Agriculture and Forestry, Mississippi Forestry Commission, and Temple-Inland Forest. The nature of the reviews has changed somewhat as the number of advanced-generation breeding programs have multiplied. In addition to the advanced-generation mainline breeding program, which involves a complementary breeding and mating schemes, all members are supporting elite super-breeding group populations. Several members within each breeding zone are also supporting an elite population for the improvement of wood quality. Some members are also making crosses to supply material for vegetative propagation programs. Keeping up with the status for all of these various breeding programs is mostly a matter of tracking and proper documentation. Verifying that records are accurate and that all concerned are aware of the multiple facets of the advanced-generation breeding program is becoming one of the main focuses of the Formal Reviews. Four reviews are scheduled for 2003.

Highlights

- Louisiana Forest Seed Company joined the Western Gulf Forest Tree Improvement Program – Hardwood cooperative, increasing the membership to seven organizations.
- Joe Hernandez led a training session on hardwood grafting techniques at the Louisiana Department of Agriculture and Forestry Monroe Seed Orchard.
- Temple-Inland Forest identified three more cherrybark oak progeny tests for thinning to create seedling seed orchards.

Introduction

The Western Gulf Forest Tree Improvement Program – Hardwood Cooperative gained one member in 2002 with the addition of Louisiana Forest Seed Company. They have been associate members of the cooperative for many years and have long standing relationships with most of the current members. Their motivation in joining the cooperative is to ensure a dependable supply of improved hardwood seed to offer their customers. Seed orchards provide better control over the number of maternal parents and the species of the pollen parents than can be obtained with seed bought on the open market. This can be especially important for species like the oaks that hybridize easily. They also expect that the current trend of excluding seed collectors from wildlife management areas will continue to make one of the best sources of seed for bottomland hardwoods unavailable. In order to join the program, Louisiana Forest Seed Company agreed to actively participate in the progeny testing program and were assessed an entrance fee. They will establish rootstock for their first orchards in 2003 and will plant progeny tests as they become available.

The reasons for participating in the hardwood cooperative are varied and have changed over time. Hardwood management has had limited economic appeal in recent years because of low stumpage prices. The low value of hardwood sawlogs has been determined by the interaction of supply, demand, and quality. While it is too early to make firm predictions, this situation may be changing. The area in upland hardwoods is predicted to increase while the area in bottomland hardwood is expected to decrease[5]. The area of quality hardwoods available for harvest, however, is expected to decline even more rapidly that the total resource supply as more areas are set aside for wildlife management, reservoir impoundment, and water pollution abatement. Traditionally, a large part of the hardwood supply has come from harvesting mixed pine-hardwood stands. This source of hardwood is also disappearing as many of these stands are converted to pine plantations. A positive development is that demand may be increasing with the recognition that the coastal plains can yield quality hardwoods capable of competing with those from the Appalachian region in the eastern US. This is the result of a new drying process that can eliminate problems caused by enzymatic and fungal stains frequently encountered with hardwood sawlogs from the Western Gulf area. If these changes in supply and quality translate into demand, then prices should follow and provide a renewed impetus for hardwood tree improvement.

Tree Improvement

Progeny Testing

The Western Gulf Forest Tree Improvement Program maintains 32 active hardwood progeny tests (Table 6). These plantings fall into two groups according to test age; those planted before 1986 and those planted after 1994. The older active tests are cherrybark oak, water/willow oak, green ash and sycamore. These plantings consist of open-pollinated tests of the ortets. These tests were established to generate family data and to provide a source for second-generation selection activity. These goals will have been met as these tests are measured for the last time as they reach age 20. At that point in time, they will be released for other uses. Several water/willow oak and cherrybark oak progeny tests that fall in this category have already been converted into seedling seed orchards (Figure 24). In 2002, Temple-Inland Forest identified three additional cherrybark oak progeny tests for conversion into seedling seed orchards.

Table 6. 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	3
Water/willow oak	1

Figure 24. Matt Lowe (right) and Larry Miller survey a Temple-Inland Forest cherrybark oak progeny test thinned to serve as a seedling seed orchard.

[5] Wear, D. N. and J. G. Gries, 2002. The southern forest resource assessment: Summary report. Gen. Tech Rep. SRS-54. USDA Forest Service. 103p.

Table 7. Fifth year results from the Nuttall oak progeny tests measured in 2001/02.

Location (Co./Par., State)	Plantation Average			
	Survival (%)	Height (m)	Diameter (cm)	Volume (dm^3)
Lonoke, AR	94.1	2.41	1.71	0.264
Desha, AR	92.8	2.15	1.62	0.199
Sharkey, MS	93.5	1.97	2.55	0.349
Richland, LA	93.0	0.55	-	-

The majority of the younger progeny tests maintained by the cooperative are of first generation Nuttall oak selections. This tree has only been recognized as a separate species since 1927 and grows primarily in the drainage of the Mississippi River and its tributaries from the boot heel of Missouri southward. The cooperative has established 22 plantings to evaluate 216 selections from this species. Most of the ortets selected for this species have been preserved through grafting into scion banks by the Texas Forest Service and the Mississippi Forestry Commission. When all tests for this species reach age 5 in 2003/04, both backward (tested parents) and forward selections (the best progeny from the best parents) will be available for establishing seed orchards. This species is currently favored for bottomland planting and restoration because it exhibits good survival on a range of sites, even when under extreme levels of competition. Three of the younger plantings, two sweetgum and one sycamore test, are evaluations of second-generation selections. These plantings were established in conjunction with the North Carolina – Industry Cooperative Hardwood Research Program and evaluates second-generation selections from both programs.

Seven progeny tests were scheduled for measurement during the 2001/02 measurement season. This included two age 20 sycamore tests and four age five Nuttall tests (Figure 25). Because of limited resources, measurements on the two sycamore tests were delayed until the 2002/03 measurement season.

Location results for the four Nuttall oak progeny tests measured at age 5 are summarized in Table 7. Survival was excellent, exceeding 90 percent at all four locations. Growth, however, was acceptable at only three of the locations. In five years, the Richland Parish site grew only 0.5 m in height. This result serves to illustrate the fact that hardwood silviculture is extremely site dependent. The test in Richland Parish is located on a poorly drained silt-clay site that should be ideal for this species.

Seed Orchards

In recent years, the desire to maintain habitat in streamside management zones with quality hardwood species has been a motivating factor for hardwood tree improvement. In order to meet this need, the cooperative has thinned older cherrybark and water/willow oak progeny tests for conversion to seedling seed orchards and has initiated an extensive Nutall oak progeny-testing program. Several of the cooperative's existing oak orchards are also reaching the age at which significant acorn production is expected (Figure 26).

Temple-Inland Forest identified three more cherrybark oak progeny tests for thinning to seedling seed orchards. The same protocol will be used in these orchards as used in previous conversion efforts. Only the best tree per plot will be left in the best 50 percent of the families. Additional trees will be removed to adjust spacing. These plantings, located on adjacent areas in Tyler County, TX , were established on a very high quality bottomland hardwood

Figure 25. French Wynne, Potlatch Corporation, in a five-year-old Nuttall oak progeny test in Desha Co., AR.

Figure 26. Gary Alldread in the Mississippi Forestry Commission's cherrybark oak grafted seed orchard at their Winona Nursery.

Figure 27. One of the Temple-Inland Forest cherrybark oak progeny tests slated for conversion into a seedling seed orchard.

Figure 28. Joe Hernandez leads a hardwood grafting training session at the Louisiana Department of Agriculture and Forestry Monroe seed orchard.

site. The tests, currently range in age from 22 to 26 years, had a range in average plantation height from 14.3 to 18.9 m at age 20 (Figure 27). Current plans are to use some of the logs removed when the tests are thinned for a mill study to quantify the value of hardwood lumber from young plantation grown hardwoods.

Major seed orchard expansions are underway or will soon be undertaken by the Louisiana Office of Agriculture and Forestry and by the Louisiana Forest Seed Company. As the Nuttall oak progeny testing program is completed, several members anticipate grafting orchards for this species. In anticipation of this grafting activity, a one day training session on grafting hardwoods was held this past year at the Louisiana Office of Agriculture and Forestry's Monroe Seed Orchard (Figure 28).

Selections and Scion Banks

Second-generation selections have been completed for six species (Table 8). Efforts are being directed to insure that existing selections are preserved and that seed is collected to evaluate performance in open-pollination progeny tests. The number of parents in advanced-generation progeny tests is also noted in Table 8. The cooperative attempted to establish the first such progeny tests for green ash in 2002. This effort failed because of poor seed germination, but seed was recollected in 2002 and the cooperative will sow the progeny test again in 2003. The Texas Forest Service will grow the seedlings and the Arkansas Forestry Commission, Louisiana Forest Seed Company, and the Mississippi Forestry Commission will establish plantings.

Table 8. 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[1]	0	32
Sweetgum	84	37	69
Sycamore	70	12	24
Cherrybark oak	62	0	0
Water/willow oak	44	0	0
Yellow-poplar	12	0	0

[1] 35 of these selections are female and 36 are male.

URBAN TREE IMPROVEMENT PROGRAM

The Urban Tree Improvement Program's objective is to select local sources of native species for use in the urban environment of Texas. The program was started in the early 1970s as a cooperative effort between the Texas Forest Service, municipalities, and commercial nurseries in the state. At that time, the large majority of the planting stock used for urban environments was poorly adapted to local conditions and less than half of the planting stock survived the first year.

To efficiently address the survival problem the decision was made to concentrate on a population improvement strategy. Selections were identified and open-pollinated progeny tests were established by municipalities and commercial growers. Seed orchards were established using the parents identified as having superior survival and growth in the progeny tests (Figure 29). After flowering began in the seed orchards, an additional series of progeny tests will be established to rogue seed orchards. Species established in orchards and the year of establishment are shown in Table 9.

Figure 29. The live oak seed orchard maintained by the Texas Forest Service at Hudson, TX to support the urban tree improvement program.

Table 9. Species established in orchards for the Urban Tree Improvement Program by location.

	Year Established	
Species	**Hudson**	**Indian Mound Nursery**
Shumard Oak	1989	1988
Live Oak	1988	1981
Bald Cypress	1991	1981
Magnolia	1998	1992
Bur Oak	1991	1999
Chinkapin Oak	1996	
Cedar Elm	1994	1994

PERSONNEL

There were no additions or deletions to the cooperative staff during the past year. This represents a novel situation within the program, which has almost always seen some turnover in students if not in permanent staff. The last year in which there were no new additions to the staff was 1986 when a state hiring freeze resulted in new vacancies but no new employees. The most recent year in which there were neither additions nor deletions in personnel to report was in 1967. This stability was beneficial this year as the staff continues to grow into their new responsibilities and learn to work together as a team after the major changes experienced in 2001.

There were, however, changes in the close working relationship the cooperative has enjoyed with Drs. Floyd Bridgwater of the USDA Forest Service and Claire Williams in the Forest Science Department. Dr. Bridgwater started a year's sabbatical in October from his active role as Project Leader of the Institute of Forest Genetics. Dr. Williams also started a sabbatical in September. Both will maintain offices and continue research projects on campus during their leave.

The staff now includes the following:

T. D. Byram .... WGFTIP Geneticist
L. G. Miller .... Assistant WGFTIP Geneticist
E. M. (Fred) Raley .... Assistant WGFTIP Geneticist
P. V. Sieling .... 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. .... Research Specialist
G. F. Fountain .... Aide to Specialist

PUBLICATIONS

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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 2002 include the Arkansas Forestry Commission, Boise, The Bosch Nursery, Inc., Deltic Timber Corporation, International Paper Company, Louisiana Department of Agriculture and Forestry, Louisiana-Pacific Corporation, Mississippi Forestry Commission, Oklahoma Forestry Services, Plum Creek Timber Company, Potlatch Corporation, Temple-Inland Forest, Texas Forest Service, Weyerhaeuser Company, and Willamette Industries, Inc.

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 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 (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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