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46th PROGRESS REPORT OF THE COOPERATIVE FOREST TREE IMPROVEMENT PROGRAM

TEXAS FOREST SERVICE

FORTY-SIXTH

PROGRESS REPORT

OF THE

COOPERATIVE

FOREST TREE IMPROVEMENT

PROGRAM

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TEXAS FOREST SERVICE
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INTRODUCTION

In the Western Gulf Forest Tree Improvement Program — Pine, 1998 was the year of the drought. In a large part of the Western Gulf Region, no significant rainfall was recorded from February through August and high temperatures exceeding 100° F began in May. The weather had both direct and indirect effects on the cooperative's pine tree improvement program.

Drought-related mortality will make it necessary to replant a number of one-year-old progeny tests. For some members, the loss of these plantings was particularly disheartening because they represented the last required first-generation progeny tests. Drought-related mortality was also observed in two and three-year-old tests; however, none of the older plantings were lost. Some scion bank trees with critical control-pollinated crosses were also lost to a combination of drought stress and bark beetle attack. This will delay the completion of test establishment in some breeding groups by a minimum of two years.

The drought also had a detrimental effect on the seed production program. Drought-stressed trees in older seed orchards were especially susceptible to attack by bark beetles such as *Ips* spp. The long-term seed production capacity of the cooperative was not significantly affected: increased costs were incurred for sanitation and pesticide applications to protect healthy trees. Smaller cone size resulted in a reduced bushel harvest. More importantly, despite the fact that most new orchards were irrigated, rootstock growth in 1998 was disappointing. This will affect several members as the 1999 grafting season is scheduled to be one of the busiest in the history of the cooperative. Of the ten members planning to establish new orchards in 1999, four will delay grafting until 2000. The remainder will begin grafting in 1999; however, small rootstock will make field grafting more difficult, and a greater amount of transplanting will be required.

There will be indirect effects of the drought on the cooperative's tree improvement program as well. Both drought-related mortality in operational plantations and wildfires have increased the number of acres scheduled for planting. In some areas of the cooperative, it is estimated that up to 65 percent of the operational plantations established in 1997/98 will have to be replanted. While wildfire damage was not as severe in the Western Gulf Region of the United States as in other parts of the country, a significant number of acres were destroyed. These factors combined to cause an increased seedling demand. For some organizations, this increased demand is in addition to the increased demands that have occurred as a result of shorter rotations.

Wood quality has been a concern of the cooperative since its founding. Recent efforts have been directed toward calculating the economic value of changing specific gravity relative to improving volume growth for pulp production. A recent event in the Western Gulf Region of the United States is the shift to smaller logs for solid wood products. The impact of using younger trees for the production of plywood, laminated veneer lumber, oriented strand board, and studs has stimulated an increased interest in the importance of wood quality as an objective for the tree improvement program. The status of improving wood quality within the context of the current breeding program is described below.

The remainder of the report reflects the members' efforts to accelerate both the breeding cycle and the rapid transfer of increased genetic gain into the production program. The timely measurement of the record number of progeny tests established over the last few years has made these goals achievable. Information on previously untested first-generation and second-generation selections is making it possible to design new orchards with higher gain, rogue existing advanced-generation orchards, and design new super-breeding groups to support the production population. One of the most exciting developments in the cooperative is the commitment of the members to drastically shorten the breeding cycle in the next generation. Record numbers of second-generation selections were made in 1998, and most of these selections were immediately top-grafted to stimulate early flower production. Rapid test evaluation for second-generation selections and top-grafting in the same season promise to shorten the breeding cycle significantly.

The Western Gulf Forest Tree Improvement Program — Hardwood members maintained projects emphasizing tree improvement and natural-stand management. In 1998, the Louisiana Department of Agriculture and Forestry produced seedlings for the fifth and final series of Nuttall oak progeny tests. After this series of tests is planted, the members will have established 22 progeny tests to evaluate a total of 220 Nuttall oak selections. The Mississippi Forestry Commission and the Texas Forest Service continued establishing Nuttall oak scion banks for preservation. Forty-eight percent of the original selections have been grafted. The best selections, based on progeny test performance, will be established in seed orchards.

Interest in hardwood fiber production has increased throughout the South. The members of the Hardwood Program are cooperating with the North Carolina — Industry Cooperative Hardwood Research Program to establish southwide tests using sycamore and sweetgum second-generation selections from both programs. In 1998, Temple-Inland Forest established the first of these tests for sycamore in the Western Gulf Region. The first combined second-generation sweetgum progeny tests will be grown in 1999. Temple-Inland Forest also initiated a project to evaluate the potential for intensive management to produce hardwood fiber.

Data were collected from three green ash progeny tests that were thinned five years ago. Either 25 or 50 percent of the trees was removed in each of the thinning treatments. No growth responses were observed for either thinning treatment when compared to the unthinned control in any of the tests.

The members of the Urban Tree Improvement Program maintained the last series of progeny tests for chinkapin oak and cedar elm. These tests will provide the information and selections required to complete seed orchard establishment for 12 species. After the seed orchards begin production, an additional series of tests will be established for roguing purposes. This will result in an additional increase in genetic gain. Two live oak tests have been established using seed collected from the orchards; however, it will be a few years before all of the seed orchards produce a sufficient amount of seed to complete establishment of this cycle of testing. Additional progeny tests will not be established until that time. Seed is being collected from the seed orchards or the best ortets to produce operational seedlings for the members. In 1998, 4,860 improved seedlings were produced for the members. In the future, all of the seed required by the members will be produced from the seed orchards.

Based on progeny test data, 312 selections have been made for the Urban Tree Improvement Program. Only five of these selections have not been preserved in the seed orchards established for the program. The severe drought in 1998 caused some mortality in the seed orchards; however, the Shumard oak, live oak, sweetgum, baldcypress, and cedar elm seed orchards remain over 90 percent stocked. The magnolia, chinkapin oak, and bur oak seed orchards remain about 70 percent stocked. Grafting efforts in 1999 will attempt to complete these seed orchards and preserve new selections from the progeny tests that will be evaluated during the 1998/99-measurement season.

WESTERN GULF FOREST TREE IMPROVEMENT PROGRAM

Highlights

- Ten members established rootstock for orchard expansions in 1999, and six members cleared ground for orchard expansions to be grafted in 2000.

- The seed harvest in 1997 was the lowest in the cooperative since 1972. The poor crop in 1997 was offset somewhat by a record harvest in 1996 and an average harvest in 1998.

- Eight super-breeding groups to support the production population have been designed for five members.

- An evaluation of the relative contribution of wood density and volume production to pulp mill productivity indicates that improving density is more important than previously thought.

- The first slash pine second-generation polymix tests were established by Boise Cascade Company and the Texas Forest Service.

- Slash pine demonstration plantings comparing some of the most rust-resistant families in the cooperative to unimproved checklots exhibited the predicted reduction in fusiform rust infection levels.

- The measurement and evaluation of progeny tests and top-grafting of second-generation selections in the same season have the potential to shorten the next breeding cycle by six or seven years.

Introduction

The 1998 activities of the Western Gulf Forest Tree Improvement Program — Pine will have long-term effects on the seed production program. Ten members established rootstock to graft new orchard blocks in 1999, and six members cleared ground for orchard expansions to be grafted in 2000. Establishment of these new blocks of advancing-front orchards is timed to take advantage of a large increase in new progeny test data. The size of most new loblolly pine orchard blocks has also been increased to accelerate the rate of orchard turnover. Shortening the management cycle for orchards will allow genetically obsolete orchards to be phased out of production much more quickly and is a relatively simple way to rapidly capture new genetic gains identified in the breeding program.

The cooperative has made a concerted effort to establish progeny tests as rapidly as possible. This effort has provided new progeny test information on previously untested parents. As most of these parents are not in orchards, they represent new material for inclusion in the production program. These tests are also the source of selections for the next cycle of improvement. New second-generation selections were identified in record numbers in 1998. Most selections were simultaneously grafted into scion banks for preservation and top-grafted to promote early flowering. The effort to measure tests, analyze data, identify selections, and to top-graft within the same season will significantly reduce the time required for the next cycle of breeding.

Field testing in the slash pine program was delayed until parents could be evaluated at the Resistance Screening Center for resistance to fusiform rust. This evaluation has been completed, and the establishment of progeny tests containing pedigreed crosses among parents that passed the screening has started. In addition, the first polymix tests of second-generation slash pine selections were planted in 1998.

Five-year measurements from demonstration plantings established with some of the cooperative's most fusiform rust-resistant slash pine parents were also encouraging. In these plantings, observed fusiform rust infection levels among improved families were equal to the values predicted from their progeny test performance.

Wood quality is becoming an increasingly important issue for members of the tree improvement program. The impact of specific gravity on papermaking has long been understood. The difficulty has been in calculating economic weights for improvement in specific gravity relative to improvement in volume production. The work of Borralho, Cotterill and Kanowski[1] was used as a framework to develop indexes combining these traits for loblolly pine. By using cost structures for specific mills, deployment populations can be designed for particular end-products. Current trends indicate that the use of smaller logs for solid wood products will make wood quality an increasingly important area of concern for tree improvement.

[1] Breeding objectives for pulp production of Eucalyptus globulus under different industrial cost structures. 1993. Can. J. For. Res. 23:648-656.

Seed Orchards

Very little seed orchard establishment or roguing occurred in 1998. Members took advantage of the poor cone crop to rogue 31 orchards in 1997. As a result, very few orchards would have benefited from additional roguing in 1998. Many members also used 1997 to clear space for new blocks of advancing-front orchards. Ten members established rootstock in 1998 for grafting new orchard blocks in 1999. In addition, six members have plans for additional orchard expansions in 2000 (Figure 1). This concentrated effort of orchard replacement and expansion is occurring in the context of scheduled advancing-front orchard replacement. However, the number of acres has been increased to take advantage of a large amount of new progeny test data from both first-generation and second-generation progeny tests and to assist some program's relocation to new sites. This effort also reflects the cooperative's commitment to accelerate orchard replacement schedules to maximize the rate at which genetic gain identified in the breeding population is transferred to the production population (Figure 2).

Figure 1. Greg Garcia, Louisiana Pacific Corporation, surveying the 24 acre expansion site scheduled for grafting in 2000. This site is adjacent to the 24 acres that will be grafted in 1999.

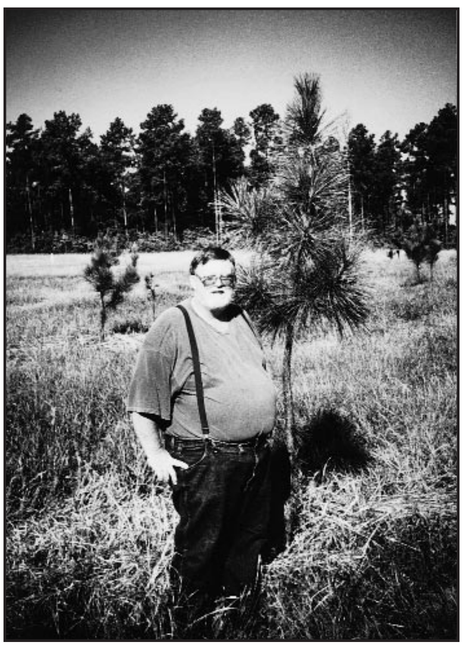

Figure 2. Johnny Pullman beside a three-year old graft in Willamette Industries' third block of advancing-front orchard they have established since joining the cooperative in 1984.

Unusual weather significantly impacted the seed orchard programs during the last few years. The spring freezes in 1996 made the 1997 seed harvest the poorest harvest per acre of orchard in the cooperative's history. This was somewhat offset by the record seed harvest in 1996 and an average cone harvest in 1998. The 1998 drought resulted in a number of seed orchard trees being attacked by bark beetle, and crews were kept busy with sanitation and protection activities. This will have little long-term impact on the seed production capability of the older orchards. A more significant effect was the reduced growth of the rootstock established in 1998 for field grafting in 1999. Despite the fact that most of the new orchards were irrigated, the extreme heat and drought resulted in less than normal growth. Consequently, many rootstocks will be small and grafting will be more tedious. Orchard establishment efforts will be delayed by four members but will be started as planned by the remainder of the members.

The year ended with Hurricane Georges wreaking havoc on the Gulf Coast. Several progeny tests were damaged in Mississippi (Figure 3). As most of these tests were older and had been evaluated for growth at least once, very little information was lost. Of the three seed orchard complexes at risk from this storm, the Mississippi Forestry Commission's Craig Seed Orchard suffered the most damage. The major effect on the older orchards was the loss of a few scattered trees which should not have any long-term impact on seed production capacity. Many of the younger trees in the new expansion orchard were root wrenched and had to be straightened and staked after the storm. The impact on these trees will not be known for some time.

Figure 3. A 20 year-old Mississippi Forestry Commision slash pine test damaged by Hurricane Georges. Most trees were broken at rust stem galls and would have been removed in a silvicultural thinning.

Orchard Establishment and Roguing

Only two organizations established new orchards in 1998, no orchards were reinstated, and none were removed from production. The Timber Company and the International Paper Company established a total of 56 acres of orchard to support regeneration programs for South Arkansas and South

Louisiana. The number of loblolly and slash pine seed orchard acres under management in the cooperative totals 2,102 acres and is composed of 1,273 acres of rogued first-generation orchards and 829 acres of advanced-generation orchards (Figure 4).

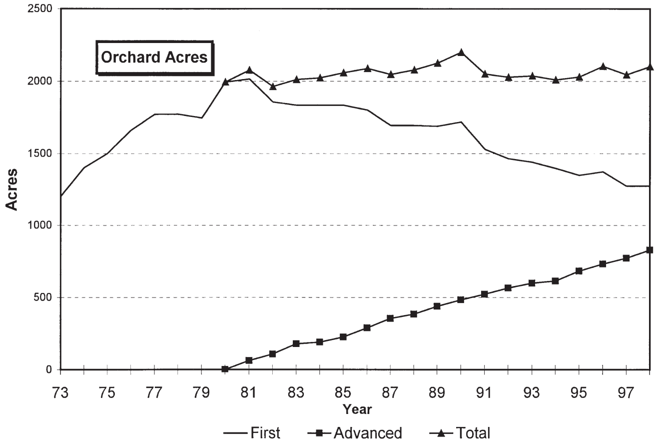

Figure 4. Seed orchard acres managed by the cooperative.

Four organizations rogued six loblolly pine seed orchards in 1998. This roguing improved the performance of these orchards by an average of 2.9 percent in breeding value for volume growth. This significant increase in performance resulted because more second-generation selections now have proven field performance, and it was not necessary to use the more unreliable predicted mid-parent values to evaluate clonal breeding values.

The first series of the long-term longleaf pine tests was measured after the tenth growing season in 1998. This allowed the Mississippi Forestry Commission and the Louisiana Department of Agriculture and Forestry to rogue the oldest blocks of their longleaf pine seed orchards. These seedling seed orchards were established concurrently with the long-term progeny tests, and the oldest blocks are now age ten. Neither orchard has produced a crop of cones, but both are under production phase management and limited cone production is evident. The Mississippi Forestry Commission longleaf pine seed orchard was thinned further by Hurricane Georges (Figure 5). The damage was not catastrophic as this seedling seed orchard was established at a high density to allow for roguing. An adequate number of trees survived the hurricane to maintain operational seed orchard stocking levels.

Figure 5. The longleaf pine seedling seed orchard at the Mississippi Forestry Commission's Craig Seed Orchard after Hurricane Georges.

Orchard Yields

After the record seed harvest in 1996, the 1997 crop was extremely disappointing (Figure 6). The 1996 flower crop was decimated throughout the region by a series of spring freezes. This not only affected cone production but also reduced pollen viability and seed set. Only four members collected loblolly pine seed in 1997, and only one member collected slash pine seed. The four members collecting loblolly pine seed harvested a total of 1,272 bushels of cones with an average yield of 0.88 pounds of seed/bushel. Results were slightly better in the slash pine program; 496 bushels of cones yielded an average of 1.38 pounds of seed/bushel for a total of 685 pounds. This was the poorest total harvest recorded since 1972 when only 375 bushels of cones were harvested by the cooperative. At that time there were only 1,044 acres of orchards in the program, and most of them were too young to contribute to the cone harvest.

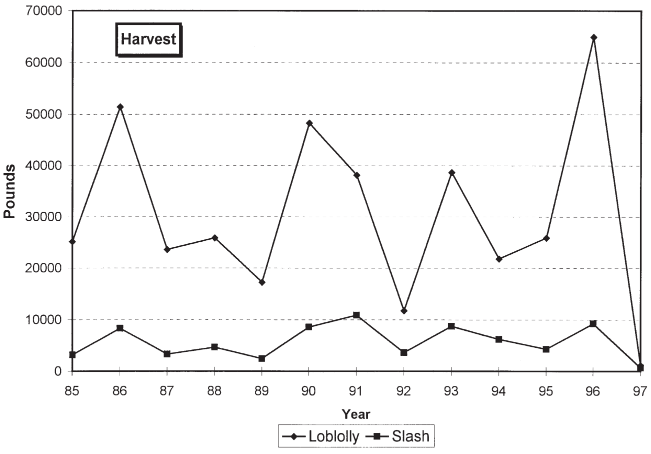

Figure 6. Pounds of seed harvested by the cooperative through 1997.

The 1998 cone harvest exceeded 50,000 bushels. The loblolly pine cone crop totaled 44,400 bushels including 17,400 bushels (41 percent) from advanced-generation orchards. The size of this harvest was especially encouraging because the acreage in older orchards is steadily declining as ground is cleared to make room for advancing-front orchard blocks. Consequently, members of the cooperative are becoming more dependent on younger orchards. Four members relied entirely on advanced-generation orchards collecting over 10,000 bushels of loblolly pine cones. Only the best families were collected in most of the older, rogued first-generation loblolly pine orchards. Cooperative members also collected 6,170 bushels of rust resistant slash pine cones. Virginia pine, shortleaf pine, and longleaf pine seed orchards were also harvested.

Super-Breeding Groups

Super-breeding groups provide the structure to cross the very best individuals from different breeding groups in combinations that would not be possible in the standard breeding scheme (see 43rd Progress Report of the Cooperative Forest Tree Improvement Program, page 8). These crosses will allow the selection of an elite population that will provide an additional level of genetic gain for use in the production program. These super-breeding group selections can be used in either traditional open-pollinated seed orchards or control-mass pollination programs. Super-breeding groups represent a dynamic population with the possibility of adding or deleting selections after each measurement season. To date, eight super-breeding groups have been designed for five members. Potlatch Corporation, the first member to have a super-breeding group, has established field plantings of super-breeding group crosses. International Paper Company collected the first seed from their super-breeding groups in 1998. During the past year, new super-breeding groups were designed for the Arkansas Forestry Commission, Champion International Corporation, and the Mississippi Forestry Commission. These organizations collected pollen in 1998, and they will make their first crosses in 1999.

Top-Grafting Study

A top-grafting study was initiated in 1996 by the Mississippi Forestry Commission in cooperation with D.L. Bramlett and F.E. Bridgwater of the USDA Forest Service. The major objective of the study was to evaluate the efficiency of promoting early flowering of immature loblolly pine scion material grafted in the tops of sexually mature orchard trees. A second objective was to compare the effects of loblolly and slash pine interstock. Graft take, first-year growth, and first-year flower production for the 1996 grafts were reported in the 45th Progress Report of the Cooperative Forest Tree Improvement Program. After one year, slash pine interstock appeared to be clearly superior to loblolly pine interstock. The grafts on slash pine had twice the survival, better growth, and nearly eight times the female flower production per living graft. However, because there was reason to believe that this performance was the result of the unusual spring weather in 1996, the study was repeated.

In both 1996 and 1997, scion material collected from twenty different loblolly pine second-generation selections was grafted onto five slash pine and five loblolly pine interstocks. In 1998, second-year observations were made on the 1996 grafts, and first-year observations were made on the 1997 grafts.

Almost all of the 1996 grafts that survived the first year were still alive at age two. Moreover, the percentage of grafts with female flowers and the number of flowers per graft between the two interstock species were approximately equal (Table 1). There was no difference between interstock species in the percentage of 1997 grafts that survived the first year (Table 2). This result contradicted the substantial difference in graft survival between the interstock species observed in the first year of the study. There was also no difference between interstock species for the percentage of one-year-old grafts with female flowers and the average number of female flowers per graft. Grafts on the slash pine interstock did grow slightly faster than the grafts on the loblolly pine interstock.

Table 1. Survival and percent of living grafts with female flowers for the 1996 top-grafting study.

Interstock Species	Year One			Year Two		
	Survival (%)	Grafts Flowering (%)	Average Number of Flowers/Graft	Survival (%)	Grafts Flowering (%)	Average Number of Flowers/Graft
Loblolly	25	43	1.6	21	86	10.5
Slash	58	94	12.9	51	84	11.9

Table 2. Results from the first year observations on the 1997 top-grafting study.

Interstock Species	Survival (%)	Grafts Flowering (%)	Average Number of Flowers/Graft	Growth (m)
Slash	91	58	5.09	0.73
Loblolly	88	67	5.08	0.57

The scion clones included in the top-grafting study were selections from the Mississippi Forestry Commission's second-generation breeding population. Because most of the selections had not flowered in the scion bank, the flowers produced in the study were used in the control-pollination program. While there was no difference between the interstock species in graft survival or total number of flowers per living graft, the installation of pollination bags was easier on the slash pine interstock. The additional growth of the scion material on the slash pine interstock apparently resulted in sturdier limbs for flower production. Both interstock species promoted female flowering on young scion material one and two years after grafting. Based on the results from this study, most second-generation selections identified in 1998 were top-grafted to promote early flowering at the same time they were grafted into traditional scion banks for preservation.

Wood Quality

Selection for wood quality was one of the earliest concerns of the cooperative. One of the first seed orchards established in Texas was designed with low wood density selections to support a groundwood paper mill. Interest in wood quality as a primary selection trait diminished in subsequent years as most organizations identified volume growth as the most important trait for genetic improvement. This decision was the result of a number of factors. Stumpage was most often sold on a volume or wet-weight basis, very few techniques were available for rapidly and economically evaluating wood quality, and its impact on product value was not always understood. More importantly, most organizations in the Western Gulf Forest Tree Improvement Program had integrated facilities producing a variety of solid wood, pulp, and paper products requiring wood with different characteristics. While product lines remain diverse and the economic value of wood quality remains uncertain, interest in wood quality is increasing. This coincides with a shift to a market dominated by younger trees with a higher percentage of juvenile wood.

Many components of both gross anatomy and cellular structure contribute to wood quality. At the whole tree level, these components include such things as bole straightness and the size, frequency, and distribution of knots. At the cellular level, wood specific gravity, wood chemistry, and microfibrillar angle are important. Tree improvement programs have traditionally stressed improvements in bole straightness, while wood specific gravity has received less emphasis.

Wood quality has been improved indirectly through selection for form as straighter pine trees have less reaction wood. First-generation selection pressure resulted in substantial improvement for straightness (Figure 7). Straightness scores in Figure 7 can not be compared across seed sources. Some sources (i.e. South Arkansas) that were naturally straighter exhibited less change in score. Selection pressure continues to be exerted on this trait in both the breeding population where straightness is a component in second-generation selection

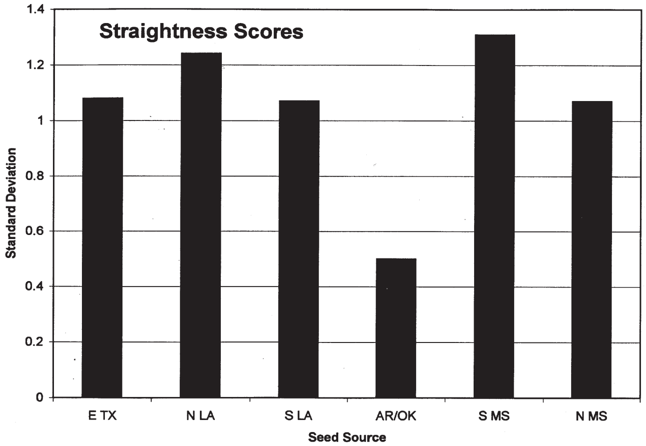

Figure 7. Average bole straightness scores in standard deviations compared to the unimproved commercial seed lot by seed zone from all first-generation loblolly pine progeny tests with significant differences at the 90 percent confidence level.

procedure and in the production population where this information is used in designing and roguing seed orchards.

Wood specific gravity is another indicator of wood quality impacting the strength of solid wood products and the yield and characteristics of pulp. The cooperative routinely estimates general combining ability performance for specific gravity on all parents. To date, this information has not been used as a selection criterion in the breeding program. Specific gravity performance is generally not available when second-generation selections are identified, so emphasis has remained on growth, form, and disease resistance. However, specific gravity data are available to the members to use when designing elite populations, seed orchards, and deployment populations.

The cooperative has general combining ability estimates for specific gravity performance on 878 parents. Parental performance, expressed as a difference between the predicted parental performance and the average of the unimproved checklot, ranges from -0.07 to 0.07. This difference is equal to approximately 700 pounds of dry matter per cord of wood. The correlation between breeding values for volume growth and specific gravity is slightly negative while form appears to be unrelated to either trait (Table 3).

Table 3. Pearson rank correlations among parental breeding values for volume growth, specific gravity, and bole straightness score.

	Specific Gravity	Bole Straightness
Growth		
Correlation	-0.13	0.01
Prob > |R|	0.0001	0.7521
Number of Obs.	878	781
Specific Gravity		
Correlation		0.02
Prob > |R|		0.6574
Number of Obs.		781

Correlation between traits indicates population trends; however, it does not predict how traits will be related in specific individuals. A negative correlation, such as that between volume and specific gravity, implies that improvement in one trait will result in a deleterious change in the second trait. However, where the correlation is less than perfect, individuals with desirable characteristics for both traits will exist. Identifying these desirable individuals will require screening a larger population than would be necessary to find an individual that is superior for a single trait. Therefore, breeding populations for improvement of multiple traits will have to be larger than those in which selection is for one trait. Simultaneously improving multiple traits requires assigning weights that account for the economic importance of each trait and their inheritance.

A separate problem is maximizing the profitability from the production population. In this case, parents with known performance can be used, and the population level genetic correlations are not important. Proper economic weights must be determined to evaluate tradeoffs between traits.

Selecting Loblolly Pine Parents for Seed Orchards to Optimize Pulp Mill Profitability

Although breeding programs for loblolly pine in the southern United States have traditionally emphasized increasing growth rates, there are opportunities to emphasize other traits when establishing deployment populations. This is possible because a deployment population is a highly selected subset of the breeding population. For example, growth rate and wood density influence the total cost of producing pulp and paper products at every stage of the process. Therefore, mill profitability should be maximized by selecting for both traits simultaneously in the deployment population.

Selecting for improvements in both traits is enhanced by using the optimum economic weights for each trait. Economic weights are the value of a unit change in a trait. For example, the economic weight for volume growth improvement in pulp production could be calculated in terms of dollars saved per tonne of pulp for each increase in growth of 1 m^3 of wood /ha.

Economic weights were estimated for growth rate and wood density for a variety of management schemes and pulping methods currently employed by members of the cooperative. It was assumed that the fiber supply for a pulp mill would come entirely from genetically improved trees, each mill would produce a single product, and that pulp would be sold at market prices. Thus, real profit could be increased only by reducing costs per unit of product. Production costs include the costs of plantation establishment and management, costs of harvesting and transport, and mill production costs. Profit is then the difference between income and costs. Wood density (kg of dry wood / m^3 green wood) and mill efficiency (kg of dry pulp / kg of dry wood) were used to estimate wood consumption at the mill (m^3 green wood / tonne of dry pulp).

Variable costs from three Kraft pulp mills, two groundwood mills, and one thermomechanical pulp mill were provided by several members of the cooperative (Table 4). As the costs for the thermomechanical mill were very similar to those for the groundwood mills, costs for these types of mills were averaged. Costs were discounted to the beginning of a rotation which ranged from 20 to 35 years. The same companies reported harvested volumes and variable costs of providing wood to the mill for six different operating scenarios whose average costs are presented in (Table 5).

Table 4. Mill costs and pulp yields for two pulping processes. Costs are in 1995 US $$.

Pulp Process	Number of Mills	Mill Cost ($ / m^3 of dry wood)	Pulp Efficiency (kg of dry pulp/ kg of dry wood)
Kraft	3	$53	0.51
Mechanical	3	$123	0.93

Table 5. Average wood costs and volumes for six different operating areas. Costs are in 1995 US $$.

Plantation establishment and management costs ($ / ha)	$905
Harvest and Transportation Costs ($ / m^3)	$17
Volume Growth (m^3 / ha)	218

The relative economic weights for the volume: density ratio calculated under these assumptions ranged from 1:4.8 to 1:8.5 for Kraft mills and from 1:6.8 to 1:12 for mechanical pulp mills. Results from average values are presented in Table 6.

Table 6. Estimated economic values for volume and density and their relative weights. Values are the cost savings in $ / tonne of dry pulp for an increase of 1 m^3 / ha in green volume of wood and a 1 kg / m^3 increase in wood density. Relative weights are economic weights for volume and density divided by the economic weight for volume.

Pulping Process	Economic Weight for Volume	Economic Weight for Density	Relative Economic Weights (Volume:Density)
Kraft	0.078	0.634	1 : 8.1
Mechanical	0.043	0.371	1 : 8.6

Deployment of Genotypes. The impact of using the estimated economic weights to select parents for seed orchards is illustrated for the Southeast Texas breeding population. This first-generation population has 118 select parents representing a range of breeding values for volume (185 to 287 m^3/ ha) and wood density (452 to 513 kg / m^3). Averages for the best 20 parents selected from this population based on the index, volume, and density are given in Table 7. Expected deviations from the unimproved checklot did not differ for volume or density for either the Kraft or the mechanical processes. This occurred because the ratios of economic weights were so similar that the same set of 20 parents was selected by indexes for both processes.

Table 7. Average breeding values and expected gains for the best twenty parents selected on the basis of the following: index values, wood volumes, and wood densities. Expected deviations from unimproved checklot differ for Kraft and mechanical processes only for the index.

Basis for Selection	Expected Deviation From Unimproved Checklot: Indexes ($ profit / tonne of dry pulp)		Volume (m^3 / ha)	Density (kg / m^3)	Expected Deviation From Unimproved Checklot (%): Index %		Volume %	Density %
	Kraft	Mech.			Kraft	Mech.		
Index	11.06	6.39	30.5	13.7	3.4	3.4	14.0	2.9
Volume	1.32	0.65	48.0	-3.8	0.4	0.3	22.0	-0.8
Density	10.78	6.24	24.7	14.0	3.3	3.3	11.3	2.9

Selection based on the index yielded the greatest expected gains in mill profitability. These gains came at the expense of lower volume gains as opposed to selections based solely on volume (30.5 m^3 / ha versus 48.0 m^3 / ha). This occurred because of the greater importance of wood density in determining mill profitability for both Kraft and mechanical pulping processes. Selecting the parents with the highest breeding values for volume alone and for the index incorporating both volume and wood density resulted in a very different set of parents (Figure 8). The parents with the highest breeding values for volume are those to the right of the vertical line while those with the highest breeding values for the index are indicated by the open boxes (Figure 8). Only six parents were common to the two groups.

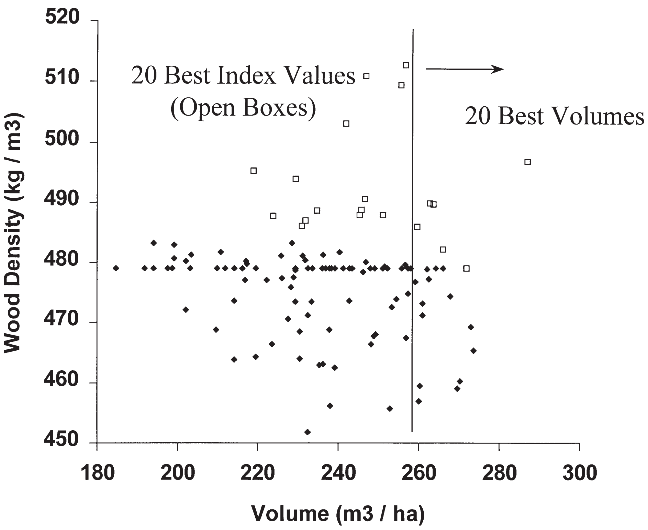

Figure 8. Breeding values for volume and wood density for 118 parents in a Southeast Texas breeding population. The 20 parents to the right of the vertical line have the highest breeding values for volume. The 20 parents represented by open boxes have the highest values for an index (see text) based on volume and wood density.

These results suggest that if seed orchard parents are selected to maximize pulp mill profitability, wood density must be given eight times greater weight than volume growth rate. In fact, selecting solely on the basis of wood density was nearly as efficient as selection based on an index in the study population. Wood density has a greater impact on mill profits because it affects harvesting, transportation, and milling costs while volume growth rate affects only plantation establishment and maintenance costs. Furthermore, the relative economic weights for volume growth rate and wood density were remarkably similar for two very different mill processes: Kraft and mechanical pulping.

This analysis indicated that the emphasis on specific gravity relative to growth rate should be increased when establishing seed orchards to support regeneration programs that produce trees destined for a pulp mill. However, individual producers of wood products should consider this decision carefully. First, this analysis assumed that pulp is the only product goal of plantation-grown wood. Thus, added growth did not add value except to increase the amount of pulp that can be produced from a hectare of land. Second, this analysis assumed that all of the pulp mill furnish would be obtained from genetically improved plantations established using seedlings from parents selected using these index weights.

First-Generation Breeding and Progeny Testing

The cooperative planted its first single-tree-plot progeny test in 1992. As confidence in the ability to establish these plantings correctly has grown, the number of tests established with this design and the number of genetic entries included in

Figure 9. Larry Miller, Temple-Inland Forest, in a two-year old loblolly pine planting of a single-tree-plot test in Jasper Co., TX.

each test has increased (Figure 9). In 1998, all of the standard progeny tests were established with single-tree plots, the largest of the first-generation tests containing entries from six partial-diallels. Adoption of this design has also reduced the number of seedlings needed per cross from 216 to 120 in the loblolly pine program and from 216 to 150 in the slash pine program. These factors have accelerated the establishment of first-generation progeny tests.

First-generation slash pine field testing was delayed until greenhouse evaluation for fusiform rust resistance could be completed. This has been accomplished, and diallel crossing among the successful parents is being vigorously pursued. This effort will be reflected in an increased number of slash pine tests established in the next few years.

A significant event in the slash pine program was the first measurement of the demonstration plantings comparing some of the most rust resistant slash pine families to two unimproved commercial checklots. Improvements in rust resistance were verified as observed rust infection levels were almost exactly as predicted. In addition, there appeared to be an increase in growth that was not entirely anticipated.

Slash Pine

Slash pine is a secondary species for the six members in the cooperative with slash pine breeding and testing programs. In recognition of this fact, the size of the breeding population was reduced by eliminating half of the first-generation selections based on greenhouse evaluations of fusiform rust resistance at the Resistance Screening Center. This first step has been completed, and the successful candidates have been divided into breeding groups. These parents will be field tested for rust resistance, growth, specific gravity, and form in partial-diallel crosses established in 50 replication single-tree-plot tests. All members in the slash pine program are making control-pollinated crosses to support this effort, and establishment of these tests should be completed within the next few years.

The only first-generation slash pine progeny test established in the 1997/98 planting season was planted by the Texas Forest Service (Table 8). This test included two diallels and was the last of the three plantings required for fifteen parents. The Texas Forest Service has only two first-generation diallels that have not yet been planted, and breeding has been completed for one of these. Four members plan to establish slash pine plantings in the fall of 1998. This will complete field establishment of approximately half of the first-generation slash pine progeny tests.

The slash pine program passed a major milestone in 1998 with the establishment of the first second-generation progeny tests. Boise Cascade Company and the Texas Forest Service planted three polymix slash pine tests with selections from both of their programs. Boise Cascade Company produced the seedlings and planted two locations while the Texas Forest Service planted the third location (Figure 10). These tests will provide data for the first proven second-generation slash pine selections in 2002.

Table 8. Progeny tests established during the 1997/1998 planting season.

Cooperator	Number of Tests	Number of Diallels
First-Generation Loblolly Pine Tests		
Boise Cascade Company	3	13
Champion International Corporation	1	2
Louisiana Dept. Agri. And Forestry	3	15
Oklahoma Forestry Services	1	2
Temple-Inland Forest	3	18
The Timber Company	4	11
Willamette Industries	3	12
First-Generation Slash Pine Tests		
Texas Forest Service	1	2
Second-Generation Loblolly Pine Tests		
International Paper Company	2	
The Timber Company	1	
Second-Generation Slash Pine Tests		
Boise Cascade Company	2	
Texas Forest Service	1	
Total	25	

Figure 10. Terry Rucker, Boise Cascade Company, and Bill Lowe reviewing one of the cooperatives first second-generation slash pine polymix tests.

Slash Pine Demonstration Plantings

Five-year measurements were taken on four slash pine demonstration plantings in 1998. These plantings were designed to demonstrate differences in fusiform rust resistance among three different sources of slash pine. These included unimproved commercial checklots from South Mississippi and Georgia. The Georgia source was similar to the unimproved material that was widely planted in the Western Gulf Region in the past. These were compared to an improved source consisting of ten families selected for high rust resistance. Plantings were maintained by Boise Cascade Company, Temple-Inland Forest, and the Louisiana Department of Agriculture and Forestry.

Four locations of the slash pine demonstration study were planted in the spring of 1993. Boise Cascade Company and the Louisiana Department of Agriculture and Forestry each have one location in Beauregard Parish, LA. Temple-Inland Forest has one location in Hardin County, TX, and another in Vernon Parish, LA. All four plantings were repeated in the spring of 1994. Each planting consists of two replications with large block plots (80-100 trees) from each source. The two Temple-Inland Forest plantings also include an improved loblolly pine source.

Significant differences among sources were found for volume growth, incidence of fusiform rust, height, and survival (Figure 11). Gains made through selection for rust resistance were evident when the improved slash pine source was compared to both of the unimproved sources. The ten families included in the improved source averaged approximately two standard deviations below the checklot for rust infection. Based on progeny test data, the expected level of rust infection for the improved source would be 24.3 percent, if 50 percent of the checklot trees were infected. If the checklot infection level is adjusted to 40 percent infection, the predicted value for the improved source shifts to 20.6 percent. Average levels of fusiform rust infection in the demonstration plantings were 37.0 percent in the checklot and 22.3 percent in the improved source.

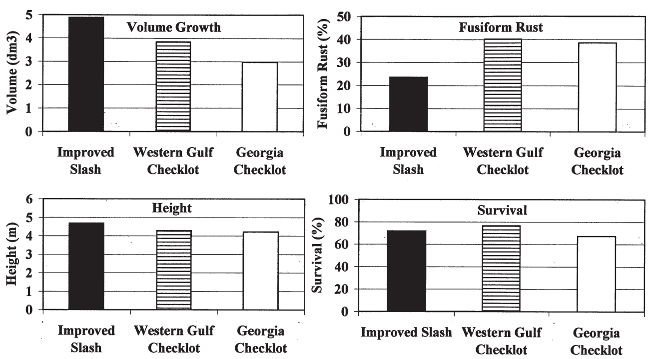

Figure 11. Volume growth, fusiform rust, height, and survival for the three sources used in the slash pine demonstration plantings. Data are based on five-year measurements made at four locations.

These results demonstrate the benefits of selection and progeny testing. Significant gains have been made in volume growth, rust resistance, and height growth for slash pine after only one round of selection and testing. These plantings will be useful in the future as a demonstration of the tangible benefits of a slash pine tree improvement program.

Loblolly Pine

The cooperative has made a concerted effort to complete the breeding and establishment of the field tests for the first-generation loblolly pine breeding population over the last several years. Five members have now completed this project. The Oklahoma Forestry Services would have been the sixth member to complete testing if their last three plantings had not been lost to drought-related mortality. Fortunately, because they had extra seed in inventory, two tests were regrown during the summer of 1998 and the final test will be reestablished in 1999. Four other organizations have completed breeding and will establish their last plantings as soon as the seed can be harvested. The remaining members are either backing up the last few crosses or attempting to finish breeding a few difficult selections. While several more years of test establishment will be required to complete this portion of the program, the majority of the cooperative's first-generation loblolly pine selections is now established in field tests.

During the 1997/98 planting season, the cooperative planted 18 first-generation loblolly pine progeny tests, ten tests less than last year (Table 8). However, the total number of tests established was misleading because most plantings included three or more diallels. Seventy-one diallel-locations were established in 1997/98, only one less than the number planted during the previous season. The plantings established in 1997/98 were sufficient to evaluate 273 parents, 170 of them for the first time (Figure 12).

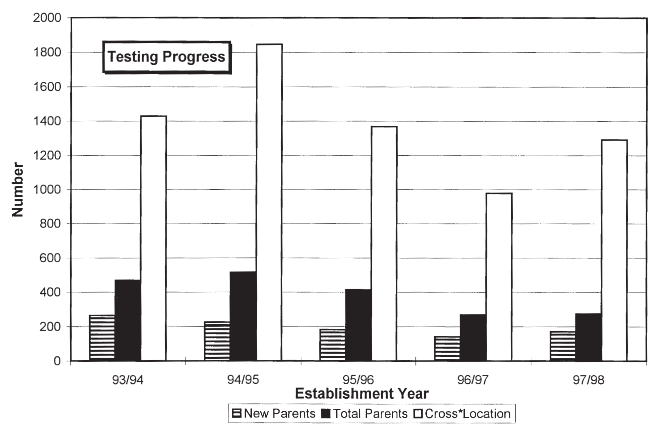

Figure 12. The number of loblolly pine crosses (total number of cross-by-location combinations), the total number of parents, and the number of parents established for the first time in each of the last five years.

The cooperative now has tests established to estimate general combining abilities on 2,166 parents. The population is evenly divided into tests that are older than age five which have been measured and tests younger than age five from which new data will be acquired in the next few years (Figure 13).

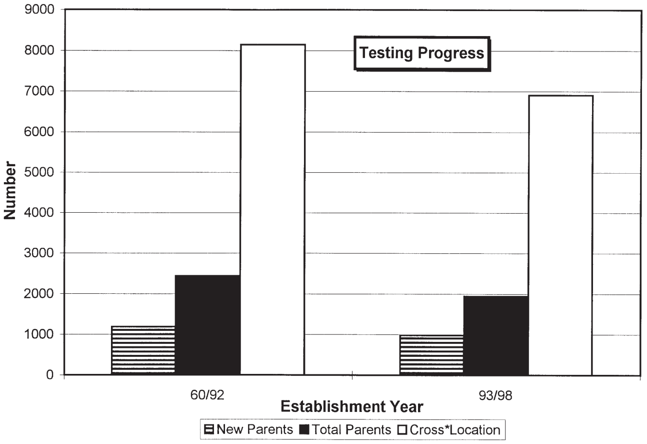

Figure 13. The number of loblolly pine crosses (total number of cross-by-location combinations), the total number of parents (cumulative total counting every year in which a parent was tested), and the number of parents established for the first time in the periods 1960 through 1992 and 1993 through 1998.

Lower Gulf Elite Breeding Population

The three southern pine tree improvement cooperatives are developing an elite breeding population for the Lower Gulf Region of the United States. The first step was to test the best loblolly pine selections from the coastal plains of Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas in common tests distributed throughout the region. The immediate objective was to identify the best parents for use in production populations. Pedigree crosses are also being made among parents from all three cooperatives to form the basis of an advanced-generation elite population. The project has been coordinated by Dr. S. E. McKeand of the North Carolina State University-Industry Cooperative Tree Improvement Program.

Polymix tests were established in 1997/98 to evaluate approximately 70 selections. Members of the Western Gulf Forest Tree Improvement Program planted two tests in the eastern part of the cooperative's operating area and three tests in the western part of the Lower Gulf. The two tests in the eastern part of the operating area, one in Washington Parish, LA, and one in Copiah County, MS, should supply information to support deployment decisions for South Mississippi, South Alabama, and Southeast Louisiana. These tests had good first-year survival and should provide excellent information. Three tests established in Hardin County, TX, Jasper County, TX, and Vernon Parish, LA, were intended to provide information on the possible movement of this population west. Unfortunately, only one of these tests survived this summer's drought.

Members of the Western Gulf Forest Tree Improvement Program collected pollen from the Western Gulf selections for pedigreed crossing to produce a population from which an advanced-generation elite population can be selected. Members of the North Carolina State University-Industry Cooperative Tree Improvement Program and the Cooperative Forest Genetics Research Program of the University of Florida are doing the actual breeding.

Test Measurement and Second-Generation Selection Activity

The cooperative measured a record number of progeny tests during the 1997/98 season. This included 31 first-year survivals, 46 five-year-old tests, and 50 older plantings. The older tests included ten-year-old measurements on the oldest series of the long-term longleaf pine progeny tests. This information was used to rogue the longleaf pine seedling seed orchards of the Mississippi Forestry Commission and the Louisiana Department of Agriculture and Forestry.

Thirty-eight of the five-year-old tests were control-pollinated loblolly pine tests that provided information on 382 parents, 228 for the first time. These tests are identifying new proven first-generation parents for incorporation into advanced-generation orchards. They are also a source of new second-generation selections. Because these selections are from previously untested families, they are expanding the genetic base of the advanced-generation breeding population.

In 1997/98, the cooperative made 88 second-generation selections. This was a record number of selections for a single year. Ten cooperators contributed 82 loblolly pine selections from 26 different breeding groups. In addition, one member identified six slash pine second-generation selections from two different breeding groups. This represented a significant commitment of resources by the members to measure tests early in the season. All tests for which data were transmitted to the cooperative staff by February were screened for second-generation selections prior to the end of grafting season (Figure 14). The second-generation selection population in the cooperative

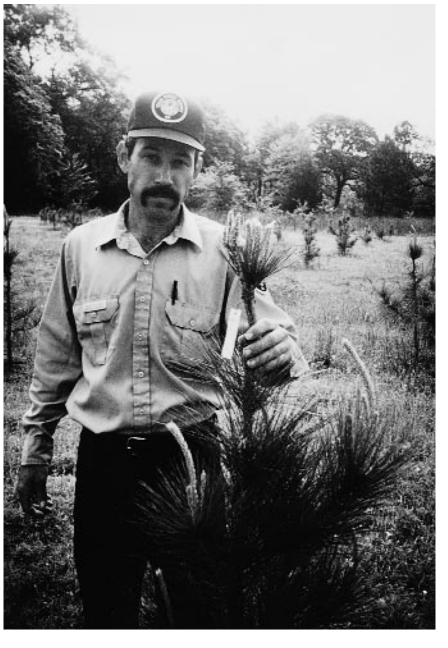

Figure 14. Gerald Lively in one of the Texas Forest Service's newest second-generation loblolly scion banks.

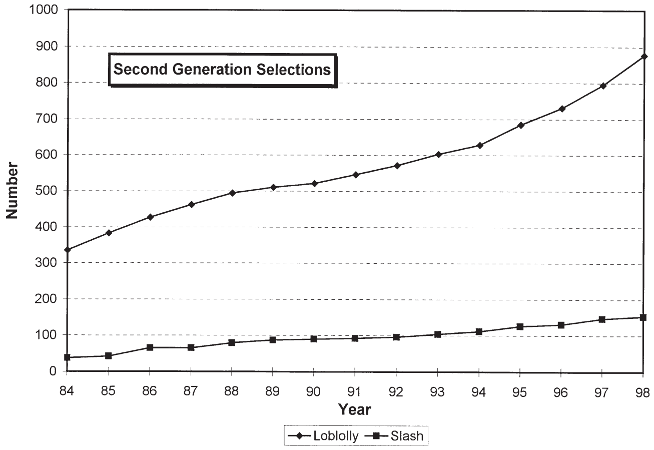

Figure 15. The number of second-generation selections in the cooperative.

currently totals 877 loblolly pine and 153 slash pine (Figure 15).

The cooperative's 1,000th second-generation selection was a loblolly pine identified in a Mississippi Forestry Commission test in Lauderdale County. This tree was 16.2 m (53 ft) in height with a diameter of 22.4 cm (8.8 in) at age 10. Despite this rapid growth, this selection belonged to only the fourth best family in the test. Selections from the best two families had been identified at age five.

Second-Generation Breeding and Testing

The cooperative's breeding and progeny testing program is becoming more diverse as members make the transition from first-generation to advanced-generation breeding. For many years, most members used either open-pollinated or partial-diallel control-pollinated progeny tests exclusively. The tests generally evaluated a relatively small number of parents with row plots using a modest number of replications. Most tests were established with two objectives: rank parents and provide a population from which to make advanced-generation selections.

Advanced-generation breeding uses a complementary scheme of polymix tests to evaluate parental performance and pedigreed crosses to form a population for selection (Figure 16). Members are establishing polymix tests on a regional basis. This requires a close coordination of seed inventories so that tests can be established rapidly. During the 1997/98 planting season, International Paper Company and The Timer Company established regional tests for second-generation loblolly pine selections in South Arkansas. Boise Cascade Company and the Texas Forest Service established the first slash pine second-generation polymix tests. The pedigreed-crosses are being established in block plots, as are the super-breeding group crosses. Because these block plots are not directly compared, they can be planted as soon as seed becomes available.

Figure 16. I.N. Brown, Texas Forest Service, in a three-year old second generation loblolly pine polymix test.

Top-grafting for Advanced Generation Breeding

One of the most exciting developments in the breeding and testing program is the member's commitment to shorten the breeding cycle. Over the last few years, almost all tests have been measured early enough in the year to allow evaluation and grafting of second-generation selections in the same season. This has had the effect of shortening the breeding cycle by one year. The members are making a significant effort to further shorten the breeding cycle by operationally top-grafting most new selections to promote early flowering. This should further shorten the breeding cycle by an additional five to six years.

Additional Activities

Contact Representatives Meeting

Champion International hosted the 1998 Contact Representative's Meeting held in Lufkin, TX. The main themes for the two-day meeting included intensive forestry, seed orchards, breeding, and progeny testing. Specific topics covered at the meeting were various aspects of intensive silviculture and its relationship to tree improvement (Mike Harrison, Lee Carroll, and Ron Honea), the occurrence of fusiform rust in the south (Dale Starkey), insect and disease research in the U.S. Forest Service (Kerry Britton), genomic mapping and tree breeding (Claire Williams), pecan breeding and conservation (L.J. Grauke) and top grafting (Bill Massie). Ronnie Fisher and Bill Jacobs hosted an excellent field trip to the Champion International orchard complex outside Livingston, TX. At the orchard, control mass-pollination technology was demonstrated by Robert Whitmire (Champion

Figure 17. Robert Whitmire of Champion International Corporation explaining control mass-pollination techniques to the attendees at 1998 Contact Meeting as Jacques Drapeau of Temple-Inland Forest looks on. The pollen injector was developed jointly by the two companies.

International) and Jacques Drapeau (Temple-Inland Forest). The field trip also included discussions of advancing-front orchards and intensive silvicultural practices (Figure 17).

Seed Orchard Pest Management Subcommittee

The Seed Orchard Pest Management Subcommittee held its annual meeting in Atlanta, GA, on November 18 and 19, 1997. Progress was reported for several ongoing studies. Although none of the studies produced definitive results, some new and improved control methods for seed orchard pests may be developed because of this research.

Larry Barber (USDA Forest Service) studied the effects of Orthene®[2] and Merit® applied as medicap implants on sand pine in Florida. The implants were made in 1995 and 1996, and the percentage of healthy flowers, ovules, and seed were recorded each year. No significant differences were detected among treatments although low insect infestation levels may have made it difficult to separate treatment effects.

Gary DeBarr and Alex Mangini (USDA Forest Service) conducted an efficacy study of Provado® used as a foliar application at the Weyerhaeuser Company seed orchard at Lyons, GA, and the Louisiana Department of Agriculture and Forestry seed orchard at DeRidder, LA. Conelet and cone mortality due to *Dioryctria* spp. infestation were compared in four treatment groups: two rates of Provado® (0.25 and 0.5 lbs. AI /acre-year), an Asana® standard, and an untreated control group. A hydraulic sprayer was used to make four foliar applications during the spring and summer of 1997. Materials and methods were the same at both locations, except spraying at the DeRidder seed orchard started about a week later than at Lyons. No differences significant at the five percent level were detected among treatments in either location. Some differences significant at the 10 percent level were found at the Lyons seed orchard, but the differences did not obtain the desired goal of 80 percent reduction in damage. The poor cone crop in 1997 probably affected the results of this study. The same treatments were repeated in 1998 at both orchards.

Formal Reviews

During 1998, the cooperative staff conducted formal reviews for five members. Formal reviews have been conducted since 1977 with the objective of analyzing individual member's long range plans and evaluating how well the cooperative is functioning to support these goals. Most members have now been through several reviews; however, the process is still one of the most effective ways for the cooperative staff to stay abreast of members' changing objectives. These reviews are also playing an important role in helping the cooperative maintain its focus as the program moves into advanced-generation breeding and testing.

Forest Genetics Research at Texas A&M University[3]

The loblolly pine genome is too large to sequence directly so cDNA sequencing (gene discovery projects) is often used as a substitute for whole-genome sequencing. However, using expressed sequences within a given tissue type may miss important aspects of the genic arrangements within the pine genome. Ph.D. student Chris Elsik (Figure 18) is conducting a comparative study among sequences extracted from 1) expressed sequence tags, 2) low-copy DNA clones, 3) clones from undermethylated regions within the low-copy portion of the genome, and 4) random clones from the total genome. She has found new retroelements, regulatory elements, and previously unknown homology to eukaryotic sequences.

Figure 18. Researchers Virginia Minihan and Chris Elsik have been instrumental in developing microsatellite markers in Dr. C .G. Williams' laboratory.

In 1998, two new methods for selecting and isolating portions of the pine genome were developed, and 40 enriched-copy libraries for GC-rich and AT-rich tri- and tetranucleotide repeat mofits were cloned. These were used to develop

[2]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 uses have been registered.

[3] Submitted by C.G. Williams

microsatellite markers. Many markers yielded a single PCR product with multiple alleles per marker. These markers are checked for Mendelian inheritance, polymorphism, and informative matings in the public RFLP mapping pedigree. They are then screened against a standard panel of major loblolly pine populations and related species.

A study to detect linkage between molecular markers and embryonic lethal loci was conducted by Sarah Hall. The study includes large numbers of selfed seed from each of three separate branches on the same tree. Branch-specific differences in segregation distortion were found.

Virginia Minihan is testing polymorphic markers in loblolly pine populations collected from across the natural range and from southern Africa. This project is studying genetic diversity, allele numbers, and possible founder effects among populations from the Atlantic Coast States, Western Gulf, the Lost Pines, and Zimbabwe.

Claire Williams is working with the Genetics Faculty at Iowa State University under the auspices of a Big 12 Faculty Fellowship. Sponsorship by the USDA-RSED, Winrock International, and a faculty minigrant from Texas A&M University allowed Dr. Williams to travel to Vietnam to lecture and to collect samples from a rare and endangered pine. This species, *Pinus krempfii*, is thought to be one of the most primitive members of the pine genus belonging clearly to neither the hard or soft pines.

Quantitative Trait Loci for Diameter[4]

A slash pine mapping population, consisting of 96 progeny of D4PC40, is being maintained by Temple-Inland Forest. Although the population is small, the trees have been measured every fall and analyzed for QTLs. Surprisingly strong QTLs for diameter have been identified. This could have important implications if this relationship can be verified in a larger population.

The Institute of Forest Genetics at Placerville is continu-

HARDWOOD TREE IMPROVEMENT PROGRAM

Highlights

- The Louisiana Department of Agriculture and Forestry grew seedlings from 52 families of Nuttall oak for the fifth series of progeny tests. This is the last series of tests that will be grown to establish the genetic base for this species.

- The Texas Forest Service continued grafting Nuttall oak selections. A total of 101 out of 220 selections have been preserved. The Mississippi Forestry Commission and the Texas Forest Service are establishing scion banks for this species.

- Thinning did not stimulate growth in green ash progeny tests between the ages of 10 and 15 years.

Introduction

In 1998, the members of the Hardwood Tree Improvement Cooperative measured 23 progeny tests. Most of these tests were older than 15 years and included selections of green ash, sycamore, sweetgum, and cherrybark oak. The results of these tests confirmed earlier findings: most of the selected families at ages 5 or 10 years continued to perform very well at later ages. First-year survival was also collected on four Nuttall oak progeny tests. All of the tests had excellent survival and will provide data for determining which selections should be used in seed orchards. None of the cooperative's natural stand management studies were measured in 1998.

Six new Nuttall oak tests were established, and the Louisiana Department of Agriculture and Forestry grew seedlings to establish the fifth series of tests for this species. This is the last series of tests that will be established for Nuttall oak. Temple-Inland Forest established a second-generation sycamore progeny test. This was the first test established in cooperation with the N. C. State University — Industry Cooperative Hardwood Research Program. A project to evaluate intensive management for hardwood fiber production was also established by Temple-Inland Forest. This project will evaluate the potential of different species, when grown under irrigation with intensive management, for hardwood fiber production.

The members maintained a total of 46 progeny tests (Table 9). In addition, the members maintained natural-regeneration studies, thinning studies, and a sweetgum coppice study.

Table 9. Active progeny tests in the Hardwood Tree Improvement Program.

Species	Number of Tests
Cherrybark oak	16
Green ash	1
Nuttall oak	18
Sweetgum	2
Sycamore	6
Water/Willow oak	3

During the 1998/99 measurement season, the members will collect data from 21 progeny tests. Potlatch Corporation will collect 15-year data on their hardwood natural regeneration study. Also, the first second-generation sweetgum progeny tests will be produced.

[4] Submitted by J.P. van Buijtenen

Tree Improvement

Progeny Tests

First-year survival was collected in 1997/98 from four Nuttall oak progeny tests planted by the Arkansas Forestry Commission, Louisiana Department of Agriculture and Forestry, Mississippi Forestry Commission, and Potlatch Corporation. Survival in these tests ranged from 94 to 100 percent. The Arkansas Forestry Commission grew seedlings from 43 families of Nuttall oak in 1997, and the members established six new progeny tests for this species during the 1997/98 planting season. The severe drought in 1998 destroyed a portion of these tests. A final evaluation of the damage will be made during the 1998/99 measurement season. In the fall of 1997, the members collected acorns from an additional 52 Nuttall oak selections. The Louisiana Department of Agriculture and Forestry grew the seedlings from these selections to establish the fifth series of Nuttall oak progeny tests in 1998/99 (Figure 19). This will be the last series of Nuttall oak progeny tests that will be established. After these tests are planted, the members will have established a total of 220 families in 22 progeny tests.

Figure 19. Nuttall oak seedlings grown by the Louisiana Department of Agriculture and Forestry for the last series of progeny tests.

Progeny test data have not indicated a meaningful genotype by environment interaction for hardwood species planted in the southern coastal plain. Therefore, to increase the size of the breeding population and expand the testing area throughout the South, scion from a number of the sycamore and sweetgum second-generation selections were shared with the North Carolina — Industry Cooperative Hardwood Research Program. Selections from both programs were grafted into common scion banks. Open-pollinated seed collected from these scion banks will be established in progeny tests located throughout the coastal plain.

In 1998, the first of these second-generation progeny tests were established for sycamore. These tests will be grown under an intensive silvicultural regime that will include irrigation and fertilization. Temple-Inland Forest established 40 families in their progeny test (Figure 20). In 1999, the Arkansas Forestry Commission and Temple-Inland Forest will grow the first second-generation sweetgum progeny tests from these scion banks in the Western Gulf Region.

Figure 20. The second-generation sycamore progeny test during the first growing season.

Temple-Inland Forest has initiated a project that includes irrigation and fertilization to evaluate the potential of intensively managing selected hardwood species for fiber production. Several species (cottonwood, green ash, sweetgum, and sycamore) were established in a replicated design using large block plots in Jasper County, TX. Each row in a species block plot was a different family or clone. A block plot was also planted that contained several species including loblolly pine, willow, tallow, cherrybark oak, and Nuttall oak. During the first year, the cottonwood and sycamore grew very well (Figure 21). Full season irrigation and an intensive fertilization program will be maintained for the duration of the study.

Figure 21. Cottonwood during the first growing season in the hardwood intensive management project established by Temple-Inland Forest.

Table 10 presents the 20-year-data summary for five cherrybark oak progeny tests measured during the 1997/98 measurement season. Significant differences among families were detected for growth traits in most of these tests. The best growth occurred at the Tyler County, TX, location maintained by Temple-Inland Forest. This test had an average height of 20 m, and the families varied from 15 m to 21 m in mean height. Families that contained second-generation selections at earlier ages averaged 24 percent more volume than the plantation mean. These are typical results for most of the oak species that we have studied: the best growing families can be identified by age 10. These tests have been released to the cooperators and will not be remeasured.

Table 10. Cherrybark oak twenty-year progeny test data summary.

Location	Plantation Average				
Co./Par., State	Sur. (%)	Height (m)	Diameter (cm)	Volume (dm^3)	Pct. Vol. Imp.[1]
Angelina, TX	72	14.7	18	97.6	14.4
Calhoun, AR	79	6.1	9	14.0	-[2]
Natchitoches, LA	72	14.0	15	71.1	14.6
St. Landry, LA	70	15.2	16	89.8	36.5
Tyler, TX	81	19.0	20	180.0	29.8

1 Percent volume improvement is the mean of the selected open-pollinated families compared to the test mean.
2 Non-significant differences for volume growth.

The Texas Forest Service collected 20-year data from green ash (one), sweetgum (two), and sycamore (two) progeny tests (Figure 22). Families from which second-generation selections were made at ages five and ten years generally continued to perform very well at age 20. The sweetgum families produced 26 percent more volume than the plantation average, and the green ash families produced 67 percent more volume. Sycamore decline seriously impacted survival in both sycamore tests: average survival was only 40 percent. Survival varied among families with a range from 11 to 67 percent. Even though second-generation selections had been made only in families with little or no disease infection at earlier ages, some of these families were severely infected by age 20. Some families were so severely infected that survival was reduced to 17 percent. Selections made from these families will not be used for seed collection.

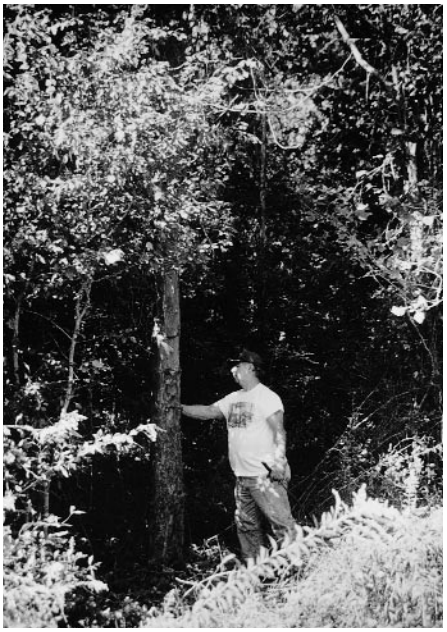

Figure 22. A twenty-year old sycamore progeny test maintained by the Texas Forest Service.

Data were collected from four thinning studies during the 1997/98 measurement season. Two green ash progeny tests were thinned after the ten-year data were collected, and one green ash test was thinned after the 15-year data were collected (Figure 23). All of the tests were planted using a randomized-complete-block design with four-tree-row plots. Either four or six replications were planted at each site. Two replications at each site were left unthinned as a control. Either one tree per plot (25 percent) or two trees per plot (50 percent) was thinned in the remaining replications. Five growing seasons after thinning, there were no significant differences for survival or any measured growth traits among the thinning treatments in any of the tests. Green ash did not respond to thinning under the conditions of these studies.

Figure 23. A Texas Forest Service green ash progeny test five years after thinning.

Twenty-five-year data were collected from a sycamore test that was thinned after the 15-year data were collected. The same thinning treatments were used in this study as previously described. In this study, neither thinning treatment (25 or 50 percent) had any significant effect upon tree growth. When this progeny test was thinned, the live-crown ratio of the trees had already been reduced to less than 30 percent. Sycamore did not respond to thinning under these conditions.

Selections and Seed Orchards

No new second-generation selections were made during the past year. The members of the cooperative have made 329 second-generation hardwood selections (Table 11). Grafting has preserved all but three cherrybark oak and one yellow poplar second-generation selections. The state agencies continued grafting efforts to establish seed orchards for their selected species. The Mississippi Forestry Commission yellow-poplar seed orchard is 86 percent completed. The severe drought in 1998 caused some mortality in the seed orchards; however, the Texas Forest Service orchards remained over 90 percent completed (Figure 24). Seed was collected from the sycamore, sweetgum, and green ash seed orchards for use in the nursery (Figure 25). Grafting efforts will continue in 1999 to complete orchard establishment and preserve new selections of cherrybark oak and water/willow oak.

Table 11. Number of second-generation selections in the Hardwood Tree Improvement Program.

Species	Number of Selections
Cherrybark oak	62
Green ash	61
Sweetgum	84
Sycamore	70
Water/Willow oak	40
Yellow poplar	12

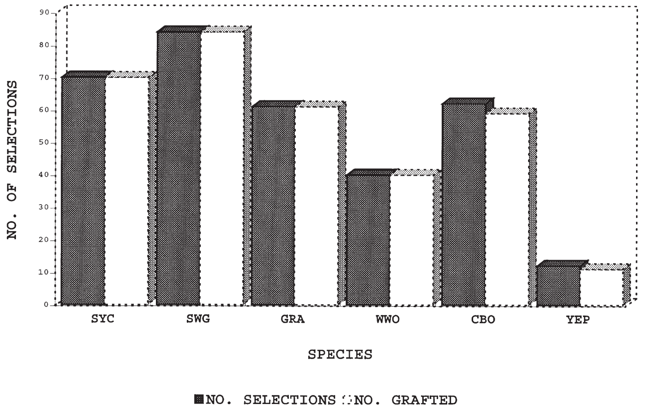

Figure 24. The number of second-generation selections and the number established in seed orchards in the Western Gulf Forest Tree Improvement Program (SYC = sycamore, SWG = sweetgum, GRA = green ash, WWO = water/willow oak, CBO = cherrybark oak, YEP = yellow poplar).

Figure 25. Sweetgum seed in the Texas Forest Service seed orchard.

The Texas Forest Service continued grafting efforts to preserve all of the first-generation Nuttall oak selections (Figure 26). In 1998, 81 percent of the Nuttall oak grafts were successful. A total of 101 Nuttall oak selections is currently preserved. The Mississippi Forestry Commission and the Texas Forest Service are establishing these grafts in scion banks for preservation. The Mississippi Forestry Commission currently has 90 Nuttall oak selections planted in their scion bank. Additional rootstock is being grown to continue grafting efforts with this species in 1999.

Figure 26. A Nuttall oak graft to be transplanted in the Texas Forest Service scion bank.

PERSONNEL

Debra Carraway, who had served as the secretary and office manager for the cooperative since 1995, transferred to another position within the Texas A&M University System. Mary Trejo filled this position in September and is rapidly learning her new duties. C. R. Chandler, formally stationed at the Texas Forest Service-Arthur Temple Research Area, transferred to a silviculture research position within the agency. Gerald Lively has ably taken on the responsibility for the operation of the Arthur Temple Research Center.

The staff now includes the following:

W. J. Lowe	WGFTIP Geneticist
T. D. Byram	Assistant WGFTIP Geneticist
G. D. Gooding	Assistant WGFTIP Geneticist
M. H. Trejo	Secretary
J. G. Hernandez	Research Specialist
J. H. McLemore	Aide to Specialist
G. R. Lively	Research Specialist
I. N. Brown	Research Specialist
D. M. Travis, Jr.	Aide to Specialist
G. F. Fountain	Aide to Specialist

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

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

Hardwood Program

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

Urban Tree Improvement Program

Membership in the Urban Tree Improvement Program includes the following municipalities and nurseries: Aldridge Nurseries (Von Ormy), Altex Nurseries (Alvin), Baytown, Burleson, Carrollton, Dallas, Dallas Nurseries (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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