TWENTY-FIFTH ANNUAL REPORT

N. C. State University-Industry Cooperative
Tree Improvement Program

School of Forest Resources
North Carolina State University
Raleigh

June, 1981
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EXECUTIVE SUMMARY

1. The Cooperative has completed a six year project to broaden the genetic resource base.

   a. A total of 3045 new plantation selections have been graded under this program. The effort represents a 1.3 million dollar investment in genetic improvement for the future.

   b. Analysis of mature wood specific gravity indicates that for comparison purposes the Cooperatives working area can be divided into four large regions. Geographic subdivisions to characterize yield or quality of forest products from juvenile wood are not concluded to be worthwhile.

   c. A total of 2014 second generation selections have been graded in progeny tests of Cooperative members.

2. First generation and good general combiner breeding programs are concluded, field testing will soon be finished.

   a. Cooperative members have established 1147 progeny tests on 4225 acres.

   b. Advanced generation breeding has begun in earnest with 16 diallels of second generation selections started. An additional 10 diallels have been initiated with plantation selections.

   c. Field test designs for the advanced generation program have been finalized.

3. The combined influence of heat, drought, insects and a relatively poor flower crop reduced cone and seed yields for the Cooperative in 1980.

   a. 7.9 tons of genetically improved seed were harvested in 1980. This represents a 69% reduction compared to the previous three year average.

b. Pounds of seed per bushel yields were the third lowest on record for loblolly pine orchards. In contrast, slash pine yields were excellent.

c. Seed orchard management research initiatives were begun in 7 new areas in the last year.

4. A total of fourteen graduate students are working directly with the Cooperative on M.S. and Ph.D. programs.

5. The Cooperative has developed an electrophoresis lab facility in the last year. This new capability will allow pine genotypes to be "fingerprinted" and as a result will expand research capabilities.

INTRODUCTION

The North Carolina State University-Industry Cooperative Tree Improvement Program has completed its 25th year of operation. Today, more than ever, it is evident that the vision of those few industrial leaders that provided the initial impetus and support for this program was accurate. The period has been one of great change and progress for the Southern forestry enterprise. Major changes through these 25 years include: phenomenal growth of the forest products industry; increased emphasis on forest land management and the production of raw materials which serve as the "lifeblood" of the industry; plantation establishment and culture has become commonplace; the contribution of tree improvement technology to value production per acre per year has been transformed from an idea to practice. The Cooperative has been an active force working to help formulate useful changes and all that are and have been associated with the program are rightfully proud of the accomplishments.

The Cooperative was formed with the University and eleven industrial charter members joining in a commitment to develop a promising idea into workable technology. Eight of the original eleven members have experienced name changes as a result of corporate merger or reorganization, yet all continue to support the pioneering effort they organized twenty-five years ago. An additional sixteen organizations have joined the Cooperative for a current total of 27 members. Since several members have forest land management activities in more than one geographic area, the total number of working units of the Cooperative is 36.

More than 55 functional tree improvement programs have been developed for loblolly pine and over 30 additional seed orchard programs are underway for other conifer species. Loblolly pine seed orchards of Cooperative members have produced over the years a total of 118 tons of genetically improved seed. The seed produced would be sufficient to regenerate 3.5 million acres of land with genetically improved seedlings. As a result of genetic improvement, it is estimated that 236 million dollars in net present value has been added to these regenerated acres of forest land.

Cooperation and continuous commitment has resulted in substantial success for the tree improvement program. However, in terms of developing the genetic potential we have "only just begun." The Cooperative has developed a solid genetic base on which future generations of improvement will be built. At each step the organizational implementation of resource development efforts is being agressively pursued. The research needed to guide these developmental and implementation efforts is gaining additional momentum. While the environment within which this established technology is practiced includes greater accountability for each investment alternative, the future is bright. Research projections indicate that the genetic improvement obtained in future generations will be greater than the benefits realized to date. However, the technology that is now accepted practice can and must be refined and improved if maximum returns are to be obtained in the future. It is to this challenge of the future that the Cooperative rededicates its efforts.

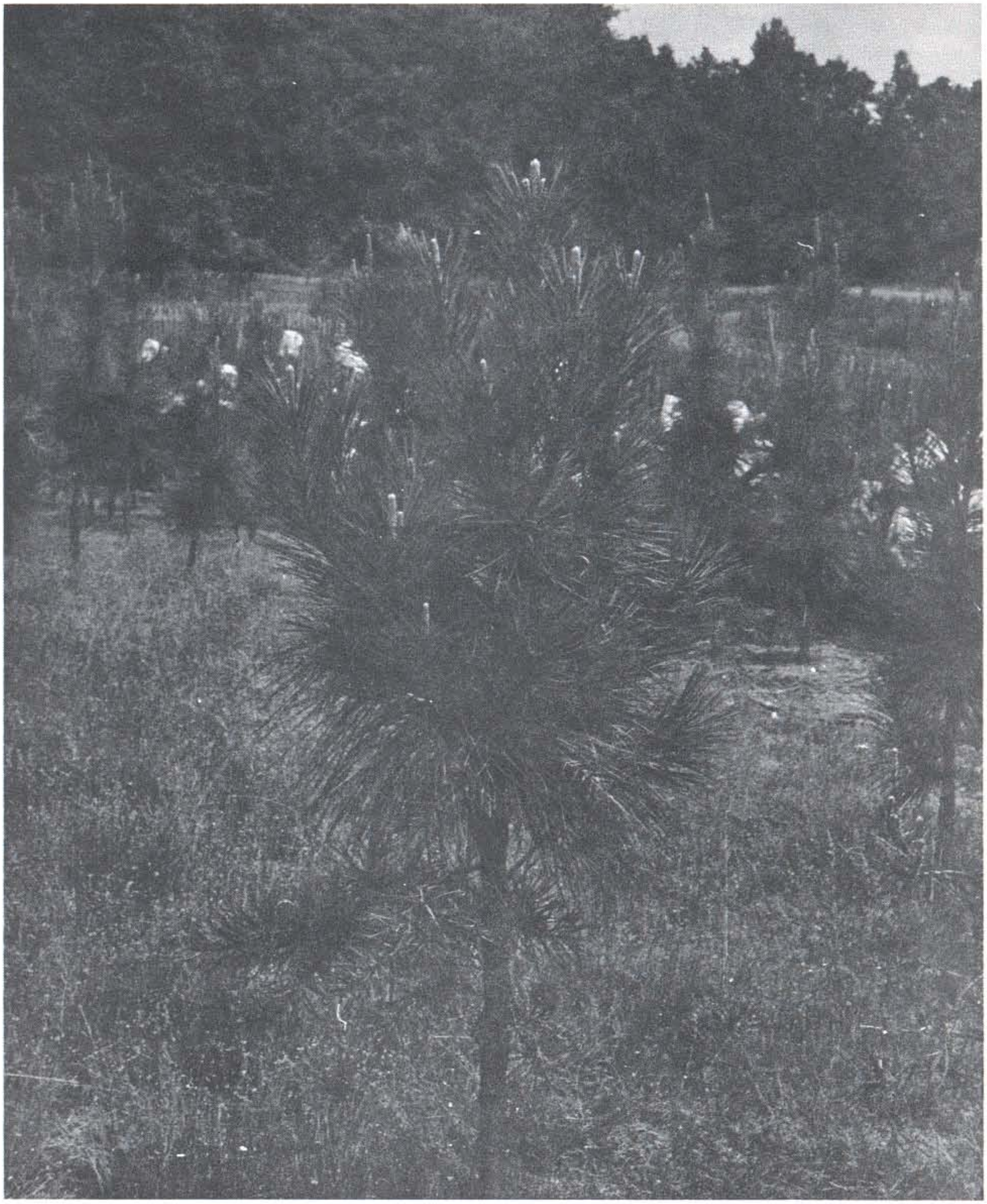
SELECTION

Plantation Selection

A monumental effort to broaden the genetic base of the Cooperative began six years ago, July 1,1975. The challenge to each member was to locate and have graded by the Cooperative staff 100 phenotypically superior loblolly pines growing in plantations. In reality each member was to find 100 new plantation selections for each orchard/breeding program that is to be carried into advanced generations of improvement. As a result several members who work with both Piedmont and Coastal programs were targeted for 200 new selections. It is a delight to report that this project is complete.

As of April 15, 1981, a grand total of 3045 phenotypically superior trees were graded under the plantation select tree program. An intensive effort the last year resulted in the addition of 685 new selections. The average superiority of all plantation selections over the check trees (5 next best crop trees in the stand) is estimated to be nearly 18% for volume. It is clear that these trees have tremendous potential to contribute to the increased productivity of future forest stands. Each of these selections will be bred and their progeny field tested. Selections from these tests will be used to broaden the genetic base for third generation seed orchard and breeding programs.

The commitment by members of the Cooperative to this program has been nothing short of phenomenal. Seventeen of the 27 Cooperative members met their plantation selection goals. In addition, seven members located in



The Virginia Division of Forestry has used scions from small mutant trees as grafting interstocks. The result has been an apparent dwarfing. Without the interstock the graft of the same clone shown above was nearly double in size.

excess of 75% of the plantation selections set as their goal. Three members missed their goal by a substantial number of trees as a result of limited acreage of loblolly pine plantations in their operating area. Based on selection costs of $400 per tree and grading costs of $30 per tree it was determined that the investment by members of the Cooperative in this program has exceeded $1,300,000---a significant sum indeed! It is an investment that will pay dividends for many generations. These selections will form the major portion of the genetic base for the third and future generations of improvement.

Regional Specific Gravity Values for Plantation Selections

Plantation trees were selected on the basis of growth and form criteria. Wood characteristics were not emphasized in the selection process. However, the recognition that specific gravity is important in product yield and value led us to categorize specific gravity for each tree in order to form a data base useful in future breeding work. The specific gravity information has already allowed the determination of regional specific gravity values for plantation selections throughout the Cooperative's operating region. Previous studies have shown that wood specific gravity is uncorrelated with either growth or form characteristics of loblolly pine, so specific gravity values obtained from plantation selections should be representative of those found in unselected trees.

As part of the plantation selection grading process, 12mm increment cores were taken at breast height from each select tree to determine Juvenile and mature wood specific gravities. The cores taken extended completely through each select tree giving a "bark to bark" sample. Each core was visually separated into juvenile and mature components. Visual separation of the juvenile and mature wood normally will average nine to ten rings from the pith. The juvenile and mature wood specific gravity for each tree was obtained by averaging the values of the respective components for each side of the tree.

For purpose of the analysis, the geographic operating area of the Cooperative was divided into seven regions, based largely on physiographic and environmental factors. Regions are quite similar to the breeding regions used by the Cooperative, within which selected genetic material is exchanged freely. The regions are as follows:

I. Virginia and the Eastern Shore of Maryland.

II. North Carolina and South Carolina Coastal Plain.

III. North Carolina and South Carolina Piedmont and Mountains.

IV. Georgia and Florida Coastal Plain.

V. Lower Gulf Coastal Plain of Mississippi, Alabama, and northern Florida.

VI. Mountains and Piedmont of Georgia, Alabama, and Eastern Tennessee.

VII. Upper Gulf Coastal Plain in Mississippi (arbitrarily designated north of Interstate 20), West Tennessee and Kentucky.

Average age and juvenile and mature specific gravity values are shown for each region in Table 1. Specific gravities generally decrease from South to North and from the coast inland to the Piedmont which generally agrees with results obtained in natural stands of loblolly pine. An exception to this trend is that plantation trees in the North and South Carolina Coastal Plain have significantly higher ($P = .05$) juvenile and mature gravities than any area covered by the study.

Table 1. Variation patterns in loblolly pine wood specific gravity in the southeastern United States[1]

Region	Ave. Age	Juvenile Wood[2] No. Trees	Juvenile Wood[2] Mean	Juvenile Wood[2] Std. Dev.	Mature Wood[2] No. trees	Mature Wood[2] Mean	Mature Wood[2] Std. Dev.
II (N.C.-S.C. Coastal)	20	354	.423a	.032	358	.541d	.039
V (Lower Gulf)	22	294	.416b	.035	408	.524e	.037
IV (Ga.-Fla. Coastal)	20	204	.412bc	.033	212	.524e	.050
VI (Ga.-Ala. Tenn. Piedmont)	21	451	.410c	.029	442	.513f	.040
III (N.C.-S.C. Piedmont)	22	430	.409c	.032	438	.509fg	.038
I (Va.)	26	313	.407c	.029	327	.504g	.036
VII (Upper Gulf Coastal)	22	124	.407c	.031	135	.501g	.036

[1]/Values are based on trees selected as of August, 1980.

[2]/Mean values not followed by a common letter are significantly different from each other at p = .05 through use of Duncan's New Multiple Range Test.

In view of previous studies the expected trend would be for the specific gravity of the Georgia-Florida Coastal Plain region to be higher than the North Carolina-South Carolina Coastal Plain. For example, studies have shown loblolly pine trees grown in northern Florida to have high gravities, averaging approximately .56 for mature wood. Only 8 trees in our sample, however, came from northern Florida since large acreages of plantations sufficiently old for selection work are virtually non-existant in the area. These trees had an average mature wood specific gravity of .57, higher than the .52 value reported for the region as a whole, and more in line with previously reported estimates.

For any given tree, specific gravity determinations are accurate to no more than two decimal places. This fact, combined with results of Duncan's New Multiple Range Test (Table 1) indicates that the South can be divided into more broadly defined regions than were used in this analysis. These regions will be useful for tree breeders who wish to compare specific gravities of individual trees with the regional average.

For mature wood gravity, the Southeast can be divided into four regions:

1) The North Carolina-South Carolina Coastal Plain, a region of high gravity with an average mature wood gravity of .54.

2) The Lower Gulf and Georgia-Florida Coastal Plain, where average mature wood gravity is .52.

3) Virginia and Upper Gulf Coastal trees of Mississippi, Tennessee, and Kentucky, with an average mature wood value of .50. Many loblolly pine plantations in this area are outside the natural range of the species.

4) North Carolina-South Carolina Piedmont and Mountains and Georgia-Alabama-eastern Tennessee Piedmont and Mountain regions with an average mature wood specific gravity of .51 when rounded to two decimal places.

Further consolidation of regions for mature wood specific gravity would not appear to be prudent. First, even small differences in specific gravity can have a major impact on yield and quality of the end-product from harvested material. For example, the range of average mature wood gravities across all regions is only .04, but this small range represents an 8% difference in dry weight per cubic foot of mature wood delivered at the mill. Second, given the small amount of variation associated with any regional specific gravity value, small errors in comparing individual tree values to regional averages could have a major effect on success resulting from tree improvement efforts with specific gravity.

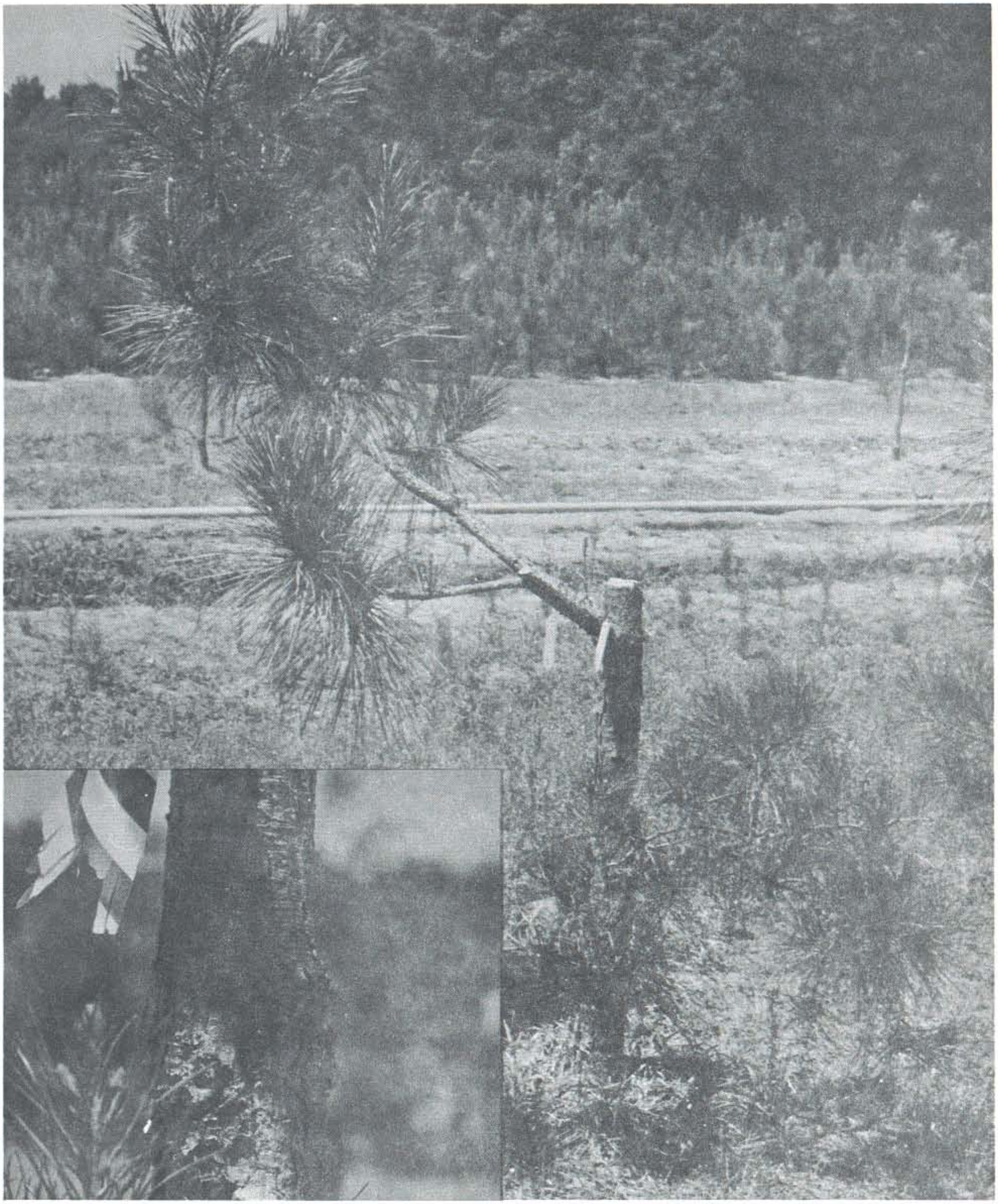
The range in regional specific gravity values for juvenile wood is less than it is for mature wood, and geographic trends are not evident. Two areas of slightly higher juvenile wood specific gravity (.42) occur in the North Carolina-South Carolina Coastal Plain and Lower Gulf regions. Other regions have juvenile wood specific gravities of .41. Geographic subdivisions used to characterize yield or quality of forest products obtained from juvenile wood would not be worthwhile.

For tree improvement activities, recognizing small regional differences in juvenile wood specific gravity, where they exist, would result in increased efficiency and gain. Trees harvested on short rotations have a large proportion of low gravity wood and even modest increases in juvenile wood specific gravity would be of tremendous benefit to the forest products industry. In addition, in advanced-generations of tree breeding, selections are often made in progeny tests at young ages before information on mature wood specific gravity becomes available. In those cases selection for wood specific gravity will be necessarily restricted to juvenile values. Due to statistically significant (p = .05) correlations for individual tree juvenile and mature wood values within regions (r = .5 to .7), selection based on juvenile wood specific gravity would also result in gains for mature wood specific gravity.

Differences among regions in specific gravity should not be interpreted as being genetic in origin. First, other studies have shown seed source effects to have small influences on specific gravity at any given location. Second, the origin of seed used to establish most of the plantations now reaching maturity is unknown. State nurseries were responsible for growing many of the seedlings, so many plantations were probably established with seed collected within each state, but this was not always the case. Much movement took place across provinces within states. In the case of plantations established north of loblolly pine's natural range seed came from a variety of sources. The high heritability of wood specific gravity would indicate that much of the variation within regions can be attributed to genetic factors.

Second Generation Selection

Control pollinated progeny tests are measured after the fourth, eighth, and twelfth year of growth in the field. During the year following measurement the test data are summarized to determine which are the best trees in the best families. A small list is composed of those trees (10 to 20) having superiority in many, if not all, the following traits: height, diameter, volume, rust resistance, crown and straightness. Each Cooperator screens the list of candidates for selection to eliminate the trees that are obviously below selection standards. Each of the select tree candidates surviving this initial screening process is subsequently graded by a member of



The search for a universally compatible rootstock goes on. Known highly incompatible clones were grafted on hundreds of rootstocks by the Virginia Division of Forestry. A small percentage grew normally, note the graft union in the inset photo. Rootstock branches were pruned severely until it was determined that the graft was successful, then the graft was "decapitated" at the graft union. Shown is the subsequent development of the rootstock foliage that will be vegetatively propagated through rooted cuttings for further tests.

the Cooperative staff. It is common for no more than six or eight trees in a test of two to three thousand to be finally graded as a second generation selection. These selections are periodically reviewed and current status recorded. Each time a test is remeasured (age 8 and 12) the process is repeated, new selections are screened and previous selections are reviewed to verify this continued superiority. The grade sheet for Continental Forest Industries second generation selection number 5-1079 is shown on page 15. This is typical of the permanent record developed and maintained for more than 2000 second generation selections identified for the Cooperative.

The availability of family information, both within a test and across tests is of key importance to the tree grading and selection process. The grader takes to the field all the information shown on the bottom half of the grade sheet. As shown in the example (page 15), the grader can use in his acceptance or rejection decision the within test individual performances and specific cross (full-sib family) performance as well as the performance level data for full and half-sib families across tests. Such information is essential to properly identify the superiority of families and the best trees in those families. This process results in the selection of trees having a truly outstanding pedigree.

The pedigree of Continental Forest Industries selection number 5-1079 is excellent (see page 15). Growth superiority of the individual over members of the full-sib family and the test average is great. At age 13 a height advantage over the test mean of more than 12 feet is indeed exceptional. In addition the performance level values (100 is best, 0 is worst) for the full and half-sib families across all tests are excellent. The strength of

SECOND GENERATION SELECT TREE GRADE SHEET
N. C. STATE COOPERATIVE TREE IMPROVEMENT PROGRAM

SELECTION	05-1079	REPLICATION NUMBER	2
TEST IDENTIFICATION	0514236780130	TREE NUMBER	8
TEST LOCATION	FLANDERS TRACT	SELECTION AGE	13
CROSS DESIGNATION	01-Q64 x 05-033	ASSESSMENT AGE	14
SPECIFIC GRAVITY	.47	PRIORITY STATUS	1

COMMENTS: GOOD HEIGHT & DIAMETER. FORM ACCEPTABLE.
1967 PIEDMONT LOBLOLLY SUPPLEMENTAL TEST #51

FROM SPECIFIC TEST	DBH	HEIGHT	VOLUME	CRON.SCORE	%INF.	CROWN	STRAIGHTNESS
INDIVIDUAL PERFORMANCE	7.5	47.0	5.219	1.00		3.00	2.00
FAMILY AVERAGES	6.8	39.2	3.760	2.86	65.0	2.82	2.60
FAMILY PERFORMANCE		89	91	78	81	56	58
TEST AVERAGES	6.1	34.9	2.800	3.44	79.0	2.90	2.73

ACROSS TEST	HEIGHT	VOLUME	CRON.SCORE	%INF.	CROWN	STRAIGHTNESS
SPECIFIC CROSS PERFORMANCE	78	71	71	69	68	65
FEMALE PARENT PERFORMANCE	62	63	54	52	60	64
MALE PARENT PERFORMANCE	61	60	52	51	54	59

the selection and its solid pedigree is demonstrated superiority in each and every trait both within and across tests.

A listing by member organization of the number of graded second generation selections is given in Table 2. A total of 2014 selections have been graded to date. Many of the older programs are maturing to the point where the majority of the second generation selections to be identified have been graded. We project that about 100 to 125 selections will be graded for each orchard/breeding program. These will be further culled so that approximately half of the selections for any single program will be included in the next breeding cycle.

Table 2. A listing of second-generation selections of loblolly pine in the Cooperative.

	Number of Selections
Hiwassee	158
Catawba	80
Union Camp (Va.)	111
Champion--Western Carolina Division	68
Chesapeake	98
Continental Forest Industries (Ga.)	91
Champion--Eastern Carolina Division	120
International Paper	104
Weyerhaeuser (N. C.)	221
Weyerhaeuser (Miss.-Ala.)	40
Federal	109
Union Camp (Ga.)--Loblolly Only	59
Westvaco	140
Kimberly-Clark	135
Continental Forest Industries (Va.)	100
Georgia Kraft	82
N. C. Forest Service	10
American Can	43
S. C. Commission of Forestry	52
Tennessee River	74
Virginia Division of Forestry	95
Georgia-Pacific	7
Masonite	7
Container	4
Brunswick	5
MacMillan-Bloedel	1
Total	2014

BREEDING AND TESTING

First Generation Progeny Testing

This tremendous undertaking spanning nearly 20 years is virtually complete. The controlled pollination work has been finished for all but a very few special cases. Final field plantings will be established in 1982 and 1983. It is clear that this task could not have been completed in anything close to a reasonable schedule had the effort not been truly cooperative in all respects. A summary of the number of tests established to date and the acreage involved is shown in Table 3.

Table 3. Acreages planted and number of progeny tests by species and type test in the N. C. State Cooperative as of May 1, 1981.

Species or Type Test	Acreage	Number of Tests
Coastal Loblolly	1592	452
Piedmont Loblolly	973	288
Slash Pine	573	113
Virginia Pine	256	83
Shortleaf Pine	33	4
Pond Pine	42	14
Other (Mountain, Longleaf, Hybrids, etc.)	194	58
Good General Combiner (Open-pollinated)	360	80
Disease Diallel	113	28
Good General Combiner (Control-pollinated)	89	22
Total	4225	1142

Recently, a tally of the number of seedlots planted in each of the last 10 years was completed. Members of the Cooperative have established over 15,000 control-pollinated seedlots in progeny tests, averaging over 1500 seedlots per year (Table 4). Data from these tests, collected annually, are being used for roguing seed orchards and identification of second generation selections.

Table 4. Seedlots planted per year by members of the Cooperative in conjunction with the progeny testing program 1972-1981.

Year Planted	Number of Seedlots
1972	1068
1973	1511
1974	1666
1975	1578
1976	2454
1977	1208
1978	1182
1979	1483
1980	1603
1981	1950
Total	15703

Progeny Test measurement has become a considerable undertaking for members of the Cooperative. The program currently collects data from approximately 300 progeny tests and related studies each year. In 1980, measurements were taken on over 750,000 individual trees. The current measurement status of loblolly pine progeny tests is shown in Table 5. It is evident that a tremendous amount of information remains to be obtained from first generation tests. With current measurement schedules, the final age 12 assessments will be made in 1995. It is expected that second generation and plantation selection testing programs will be well underway as the first generation program finally concludes.

Table 5. Measurement status of Coastal and Piedmont loblolly tests as of May 1, 1981.

	Number of Tests	
	Piedmont	Coastal
Not measured to-date	48	91
Fourth-year measurements only	94	152
Eighth-year measurements completed	146	209
Total	288	452

Good General Combiner Breeding and Testing

Good general combiners are first-generation parent trees that have consistently produced outstanding offspring as determined from progeny testing. In a typical orchard of 25 to 35 clones, as many as three to five good general combiners have been identified. In 1975 the Cooperative embarked upon a program to interbreed the good general combiners in the Program. The purpose of breeding good general combiners with each other was to develop a base population in which the parents on both the male and female side of the pedigree were intensively selected on the basis of outstanding combining ability. These parents had been previously bred in the 4-tester mating scheme used routinely in first generation progeny testing. However, under the tester scheme outstanding parents were often mated to genetically average or below average testers. It was the intent of the good general combiner breeding effort to breed the "best with the best". The base population developed from this breeding effort will form a rich genetic resource pool from which new selections can be drawn and improved second generation orchard acreage can be developed. A recent assessment of progress in the good general combiner breeding and testing program resulted in a decision that crossing be terminated. The decision to curtail crossing was based on the number of crosses now in the field, seed available in storage, and the 1980 conelet inventory for crosses already made. It was concluded that controlled cross seedlots generated to date are sufficient to fulfill the project objective. A total of ten progeny tests of these crosses were planted in 1980, twelve tests were planted in early 1981 and four more are planned for 1982. It is anticipated that the final year of test establishment will be 1983.

A summary of the good general combiner crosses planted to date and scheduled for 1982 field planting is given by region in Table 6. This has been a significant development project undertaken by members of the Cooperative and it has been well done in a timely fashion.

Table 6. Number of crosses established in various breeding regions in each of three years for Good General Combiner test program.

	1980	1981	1982	Total
North Atlantic Coastal Region	26	31	-	57
Mid-Atlantic Coastal Region	40	-	37	77
South Atlantic and Gulf Coastal Region	40	91	-	131
Upper Coastal and Western Piedmont Region	-	36	-	36
High Piedmont and Eastern Piedmont Region	72	66	43	181

Advanced Generation Breeding Underway

Although completion of first generation breeding and test establishment is now within sight, significant progress has already been made in breeding for the next cycle of improvement. Three years ago the Cooperative adopted a plan to breed both second generation selections and plantation selections using a scheme involving six parent disconnected half diallels[1]. As of this spring six members of the Cooperative have begun breeding work on 16 diallels of second generation selections. The members with work already underway are

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[1]/Talbert, J. T. 1979. An advanced-generation breeding plan for the N. C. State University-Industry pine tree Improvement Cooperative. Silvae Genetica 28:72-75.

Catawba Timber Company, Continental Forest Industries, International Paper Company, Union Camp Corporation, Westvaco, and Weyerhaeuser Company. In addition three members, Catawba Timber Company, Hammermill Paper Company, and Weyerhaeuser Company have initiated breeding work on a total of ten plantation selection diallels. With this advanced-generation breeding effort the Cooperative is embarking on a long and arduous program of genetic resource development. All associated with this vital project are eagerly anticipating the progress and benefits in the years ahead.

Accelerated Breeding

The rate at which generations can be cycled has a marked influence on the long-term profitability of a Tree Improvement program. In view of this scientists in various parts of the program, country and, in fact, the world, have concentrated efforts on two areas having major impact on the rate of generation cycling. These areas are a) how to identify superior trees at a relatively young age and b) how to make young trees or their grafted propagules flower rapidly.

Research to stimulate flowering in young trees has in the last year met with outstanding success. Of particular note is the work of Dr. Michael S. Greenwood of Weyerhaeuser Company which has resulted in U. S. Patent No. 4,199,897 entitled "Methods for Inducing Flowering on Young Forest Trees." In August the Director of the Cooperative received a letter from R. M. Wolff, Vice President, Land and Timber for Weyerhaeuser Company in which the Company granted to the North Carolina State Cooperative Tree Improvement Program, and to its members in good standing during the period between January 1, 1976 and

April 29, 1980, a paid-up, royalty-free, nonexclusive and irrevocable right and license to practice the methods covered by the patent of Dr. Greenwood's methods. The methods developed by Dr. Greenwood work well for breeding purposes and provide a key to shortening the breeding cycle and turning generations over rapidly. The process can ultimately be of great benefit to the program. Greatest benefits will accrue to all members if these or similar methods are widely used by the Cooperative membership.

Subsequent research by others has suggested that early flowering can be promoted with alternative yet similar methods. Rapid establishment and intensive management of recommended breeding orchards followed by an agressive program of control pollination will reduce the breeding cycle substantially over the Cooperatives first generation experience. Several flower stimulation treatments can be applied to field grafts with successful results. It is apparent that several procedures will accomplish the same result, i.e. shortening the breeding cycle. The Cooperative's Advisory Committee will focus attention in the near future on a decision regarding a reasonable generation interval for the breeding program. Once such a decision is made the members and staff will employ the most efficient techniques available to meet the goal.

Advanced Generation Field Test Design

With advanced generation breeding underway, it is expected that the initial second generation genetic tests will be established by 1984. Genetic tests can serve several functions, including a progeny testing role for parents in seed orchards, and as a base population from which selection for the next generation of improvement will occur. In the first generation, major

Growth depression from related matings is the subject of the research shown above. Grafts of certain Piedmont source second generation selections are being subjected to flower stimulation treatments in the greenhouse. This work is being carried on by several Cooperative members, and the Cooperative staff. Support for this project is derived from a U.S.F.S. grant.

emphasis was on the progeny testing function, which facilitated eventual roguing of poor parents from seed orchards. The tester mating design used allowed the control-pollinated tests to serve as a base population in which second generation selections could be made. In second generation and plantation selection breeding and testing, there will be greater emphasis in the role of genetic tests as base populations for selection. The change in objectives led to the adoption of six-parent disconnected half diallels as the mating design to be used in second generation and plantation selection breeding. The change in mating designs and the increased emphasis in the role of genetic tests as a source of selection also led us to examine first-generation experimental designs to determine if improvements could be made for the next generation.

The first generation experimental design called for planting each cross in two separate locations in each of three years. A randomized complete block design was used with six blocks planted in one location (a "main test") and three blocks planted in the second location (a "supplemental test"). Ten seedlings from each full-sib cross were planted in each plot of a block. The number of full-sib crosses planted in a single test varied, but was rarely less than 25. More than 700 first generation loblolly pine genetic tests have been established by Cooperators according to this design. These tests, along with open-pollinated good general combiner tests established by Cooperators in 1975, were used to optimize experimental design for second generation and plantation selection genetic tests.

As analyses were undertaken, several assumptions were made. First, it was decided that a randomized complete block design would be used as in the first generation, and that families would be represented in each replication by multiple tree plots. Experience with first-generation progeny tests indicated that 30 to 50 families represents an ideal test size so a decision was made that each test would contain crosses resulting from two or three six-parent disconnected half diallels (30 or 45 families). Finally, it was necessary to decide which trait and measurement age should be used to determine the optimum number of trees per plot, replications per test, and number of test sites. First generation test data showed that tests designed to precisely estimate family differences in height or volume at age four would also provide acceptable precision for other traits of interest. Furthermore, test variation was greatest at age four and declined with older ages, so design criteria for age four tests would also be acceptable to estimate family differences at later ages. A consideration of whether to design tests around height or volume showed that approximately the same size test would suffice for either trait. Therefore, it was decided to design second generation and plantation selections around height at age four.

The most efficient number of test locations depends upon the magnitude of family by location interactions. The presence of strong family by location interaction would indicate that families perform differently, relative to one another, when planted on different sites. If the interaction is large and families are tested on only one site type, their performance would not meet expectations when planted on a variety of site types. Enough test locations must be used to get a precise estimate of family performance over a variety of site types; but costs of testing rise rapidly as more locations are required. An efficient number of test locations was determined by plotting a measure of the precision with which family means could be estimated over numbers of locations at which each family could be planted. Precision was greatly improved when a second, third and fourth location were added, but the improvement was marginal for adding the fifth location. Thus, every family is to be tested in four test plantations. Families are to be tested in two environments in each of two years.

The most efficient number of blocks per location and trees per plot were determined in the same manner as the number of locations. Six blocks per test and six trees per plot were found to be an efficient design for each test planting. This means that each full-sib family will be represented by 144 seedlings distributed among four test plantations, each containing six blocks of six-tree row plots.

Two check types will be included in each second generation and plantation selection test. One lot will be a check of pooled unimproved seed from each Cooperative member in a breeding region. A second check lot will consist of a pooled check of bulked seed from each first generation seed orchard in the region. At the time the second check is composed, first generation orchards will have been subjected to varying degrees of roguing, so the check will not actually represent unrogued or fully rogued orchard stock, but something intermediate in nature. It will allow general comparisons of second generation or plantation selection progeny and first generation seed orchard stock.

An additional change involving check lots in second generation and plantation selection genetic tests is that two plots of each check will be included in each replication of the test. Comparisons of families in a test to a check lot are always more precise as the number of check lot plots are increased. Inclusion of two plots of each check will allow more efficient comparisons than was obtained in first generation tests where only one plot

Longleaf pine is receiving increased emphasis in several Tree Improvement programs. Shown is an outstanding four-year-old longleaf seedling in a North Carolina Forest Service progeny test and a new graft destined for the expanding seed orchard.

was used. Efficiencies would increase further if more plots were used but the improvement in precision declines dramatically as the number of plots are increased beyond two. Calculations of relative efficiencies have shown that two plots are much more efficient than one, but that three plots are only slightly more efficient than two.

Livingston Parish Test Results

In 1975 a number of Cooperators established operational plantings of the Livingston Parish, La. provenance of loblolly pine. For each of the plantings, a planting of bulk local provenance loblolly pine identical to the Livingston Parish planting in age, site index and site preparation was located. To maximize the probability that the same strain of rust inoculum was received, the planting of local provenance loblolly was selected as close as possible to the Livingston Parish planting. Five measurement plots of twenty-five planted trees were established in each of the Livingston Parish plantings. For each of the measurement plots established in a Livingston Parish planting, a comparable plot (same site gradients, etc.) was selected in the local provenance loblolly pine planting.

The first measurement of these plantings was made in the winter of 1980. The results are shown in Table 7. Of the nine Livingston Parish plantings assessed, eight showed Livingston Parish better than the commercial source in height. In rust infection, Livingston Parish averaged about one-half the infection percent of the commercial source. This was not suprising since all of the plantings assessed are in the same latitudinal range as the Livingston Parish provenance occurs naturally. The more northerly plantings have not been analyzed, however based on the performance of Livingston Parish in the good general combiner tests, it is expected that the performance of Livingston Parish in the northerly plantings will be poorer.

Table 7. A Comparison of Commercial Source and Livingston Parish Loblolly at age 5.

Planting Location	Total Height (Ft.)		Rust Infection (%)	
	CC	LP	CC	LP
Lauderdale Co., MS	8.92	9.93	20.9	18.2
Wilcox Co., AL	7.99	9.91	9.4	0.0
Wilcox Co., AL	13.58	15.08	34.4	13.4
Wilcox Co., AL	7.58	9.33	17.3	8.6
Covington Co., AL	11.14	12.30	33.0	17.7
Crenshaw Co., AL	5.98	6.40	33.6	17.4
Monroe Co., AL	11.21	14.07	56.3	15.2
Monroe Co., AL	12.33	11.87	13.5	6.2
Talbot Co., GA	6.46	8.82	36.6	17.8
Overall Average	9.47	12.21	31.9	14.3

SEED ORCHARD PRODUCTION

Cone and Seed Yields

The 1980 cone crop was small. Members of the Cooperative collected the fewest cones since 1976. As reported in last year's Annual Report, the cone harvests for years 1977 through 1979 set new records each year. In fact, the production in each of those years was more than double any previous production level. However, through this period of abundant production we repeatedly warned members of the Cooperative to be wary - the lean year(s) would occur. The 1980 crop was truly a lean harvest. We are fortunate that poor production has occurred but once in the last four years and that inventories of genetically improved seed were sufficient in many cases to supply regeneration needs.

An indication of how drastic the fall off in cone and seed production was can be seen in Table 8. The loblolly pine orchards of the Cooperative produced an average of 36,274 bushels per year for the three year period, 1977 through 1979. An average of 25.3 tons per year of loblolly improved seed were extracted from the harvests of this period. The statistics for 1980 show a

Table 8. A comparison of total cone and seed yields for all conifers and loblolly pine in the Cooperative's three best production years and 1980.

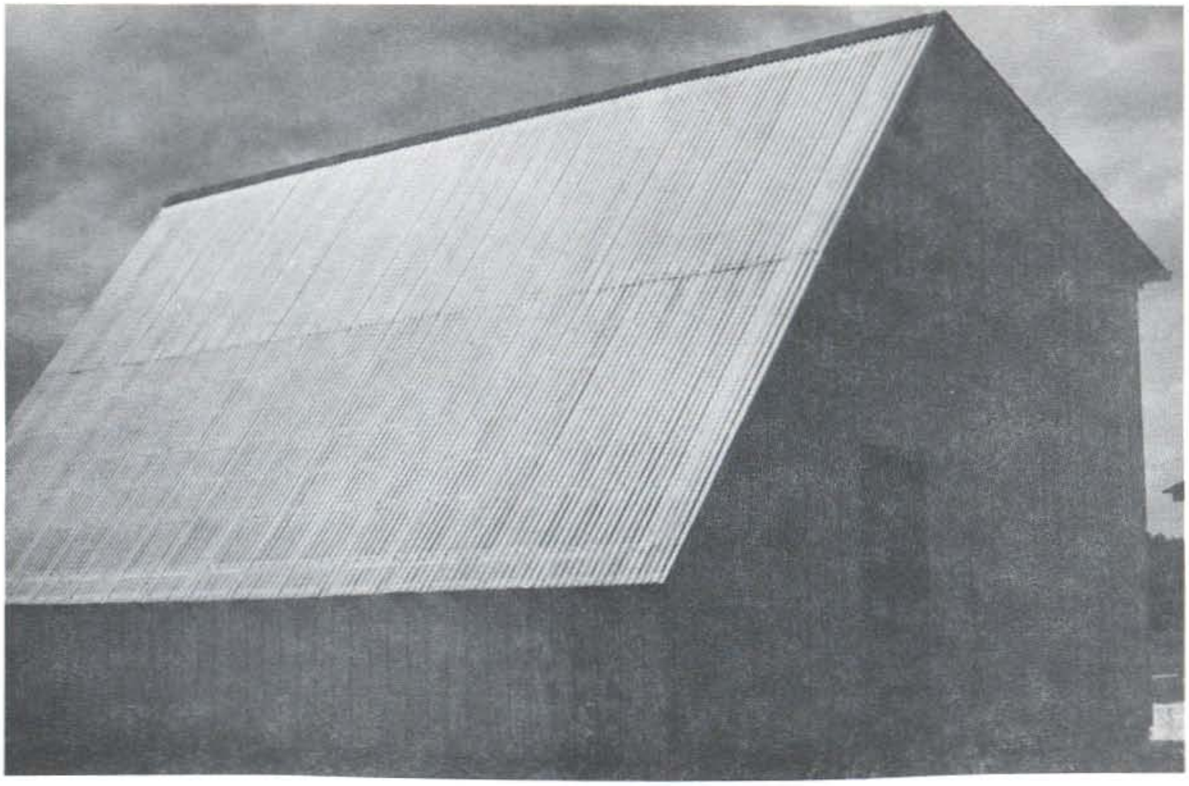
	All Conifers		Loblolly Pine	
Harvest Year	Bushels of Cones	Tons of Seed	Bushels of Cones	Tons of Seed
1977	46,041	32.8	32,152	24.8
1978	46,258	25.6	37,977	23.5
1979	49,415	31.6	38,693	27.7
1980	20,465	10.4	15,296	7.9

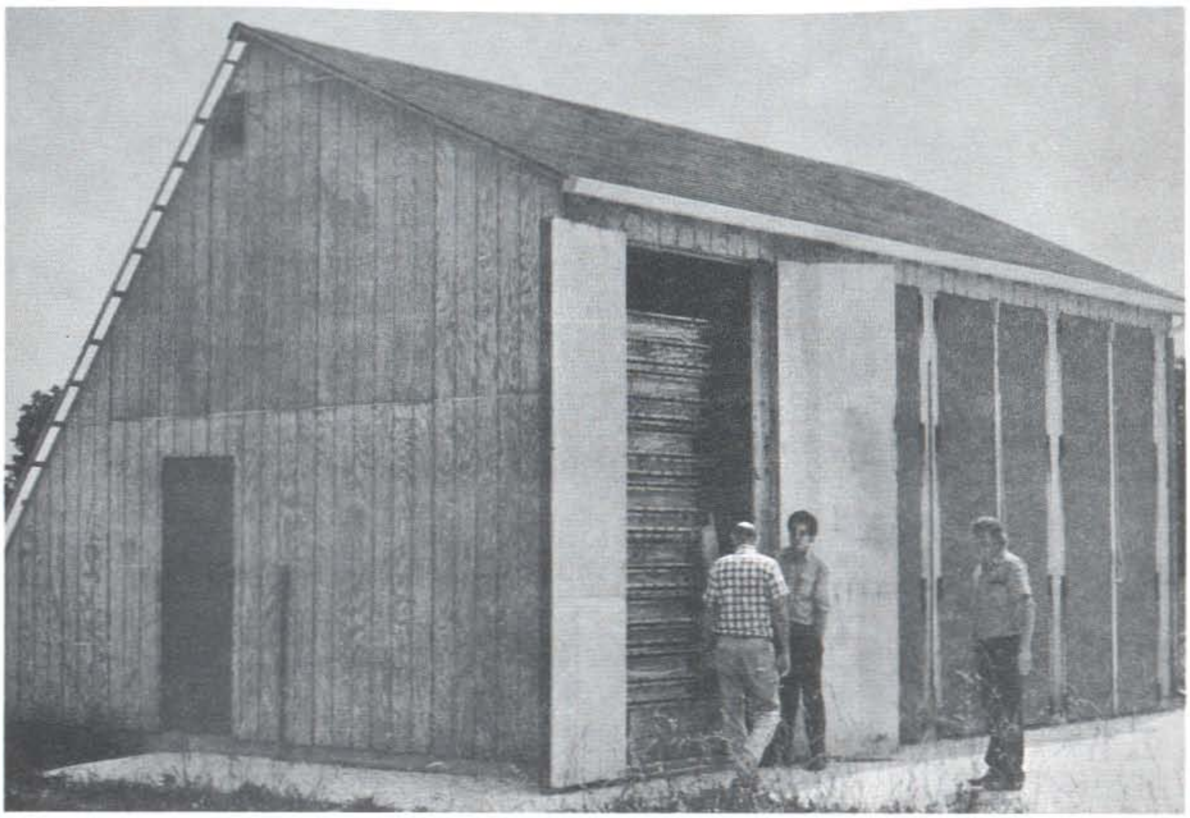
cone harvest of only 15,296 bushels and a resultant seed yield of 7.9 tons of improved seed. This represents a 58% drop in cones harvested and a 69% reduction in tons of seed produced when compared to the average for the previous three years.

It has been frequently observed that small cone crops are associated with poor yields measured in pounds of seed produced per bushel of cones. This association was certainly evident for loblolly pine in 1980. Only 1.04 pounds of seed were extracted per bushel in 1980 (Table 9). In only two of the last 12 years have the pounds of seed per bushel yields been lower for members of the Cooperative . The drop in yields was greatest for Coastal source loblolly pine. The reasons for the poor pounds per bushel yield are not certain but several factors are suspected.

Table 9. Cone and seed yields of the Cooperative orchards for the last eleven years.

	Loblolly Pine		Slash Pine	
Year	Bushels Cones	Lbs. Seed/ Bushel	Bushels of Cones	Lbs. Seed/ Bushel
1969	1769	1.10	317	0.42
1970	5146	1.36	1744	0.88
1071	6478	1.14	3795	0.80
1972	6807	0.98	1684	0.60
1973	11853	1.09	2779	0.58
1974	8816	0.99	4088	0.74
1975	16348	1.31	5516	0.93
1976	14656	1.21	5233	0.79
1977	32152	1.54	12880	1.17
1978	37977	1.24	4789	0.54
1979	38693	1.43	7460	0.62
1980	15296	1.04	4418	1.06





High energy costs have led to useful ways of doing business. Shown are the front and back views of a Solar drier designed and constructed by the Virginia Division of Forestry.

The 1980 growing season was one of the hottest and driest years in recent history. The combination of heat and drought can adversely affect cone and seed development in several ways. First, the cones and extracted seed that develop in dry years are always smaller. With small seeds and cones, fewer pounds of seed are extracted per bushel, however, since the seeds are smaller the number of seeds per pound may be greater than normal. Several orchard managers observed as many as 2000 to 3000 more seeds per pound in 1980 over their normal count. This phenomena is one reason why a better statistic to measure production levels would be thousands of plantable seedlings per bushel of cones, or even better, the number of plantable seedlings per acre of orchard.

A more serious consequence of the heat and drought of 1980 was the direct damage to cones. In many orchards a significant portion of the 1980 crop showed signs of "sun scald". Cones suffering from sun scald are brown and dessicated on one side (the exposed top side) for the entire length of the cone. Cones damaged in this manner will seldom open properly in the extractory due to partial case hardening. The seeds produced in the portion of the cone which prematurely dries and turns brown will most often be empty. The degree to which the 1980 crop was damaged by heat and drought was a factor in the reduced yields.

The flower crop that produced the 1980 cone harvest was small and this followed a very large crop in 1979. When the sequence occurs --large followed by small --it is often observed that insect population sizes increase in association with the plentiful food supply of the large crop and subsequently the small crop is "clobbered" by the large insect population carryover. This phenomena occurred in 1980 in the case of one insect, the Dioryctria disculsa. It is also true that insect control with the systemic insecticide Furadan® was marginally effective because of the dry weather. Soil moisture must be available for the soil applied systemic insecticide to remain in solution and be transported effectively within the tree. The 1980 drought no doubt limited Furadan® activity and this, coupled with the disproportionately large insect population, adversely affected seed yields per bushel of cones and to some extent the bushels of cones produced.

In sharp contrast to the dismal yields of loblolly pine seed in 1980, the slash pine seed orchards of the Cooperative realized the second highest pounds per bushel yields in the last 12 years. The size of the collection (4418 bushels) was rather modest for slash pine since many orchards were not collected or only partially collected as a result of substantial surpluses in genetically improved seed of this species. For each bushel harvested the average yield was 1.06 pounds of seed. It is not readily apparent why in a year that loblolly orchards produced very poorly that the slash orchards of the Cooperative had excellent yields. However the seed surplus for slash may have allowed a more selective harvest with respect to cone quality.

Major emphasis by members of the N. C. State Cooperative Tree Improvement program has always been directed toward improving loblolly pine. Slash pine has been an important but clearly a secondary species for the Cooperative. Seed production statistics for all conifer species (Table 10) reflect these trends. The combined loblolly and slash pine production represented 95% and 97% of the total conifer seed production of the Cooperative for the 1979 and 1980 years respectively. It is interesting to note in Table 10 that the 1980 seed production in comparison with 1979 showed a significant reduction for all conifer species, the one exception was slash pine. An extremely sharp drop in production is noted for both longleaf and white pine seed orchards. Year to year fluctuations in production from longleaf orchards continue to be erratic.

Table 10. Comparison of cone and seed yields for 1979 and 1980.

	Bushels of Cones		Pounds of Seeds		Pounds of Seed/ Bushel of Cones	
	1979	1980	1979	1980	1979	1980
Loblolly Pine Coastal Source	26186	10381	35982	9944	1.22	0.96
Loblolly Pine Piedmont & Mountain Source	12507	4915	19529	5913	1.26	1.20
Slash Pine	7460	4171	4608	4418	0.54	1.06
White Pine	1341	547	850	195	0.35	0.36
Virginia Pine	562	352	412	259	0.62	0.74
Shortleaf Pine	74	37	57	32	0.76	0.86
Fraser Fir	59	33	134	78	2.36	2.36
Longleaf Pine	1226	13	1694	2	0.56	0.12
Sand Pine	0	10	0	4	0	0.40
Pond Pine	0	6	0	2	0	0.33
Total	49415	20465	63266	20847		

Once again members of the Cooperative were surveyed to determine how much genetically improved seed was being planted in their nurseries and how many millions of seedlings were produced. These statistics are shown in Table 11. In 1980 a total of 21303 pounds of loblolly pine seed were sown in nurseries. This represents only 38 percent of the 55400 pounds of seed harvested in Cooperative member orchards the previous fall. Clearly substantial quantities of seed were stored in inventory for lean years, and in some cases members sold considerable quantities of seed on the open market. The 1980 nursery crop of genetically improved seedlings grown by members of the N. C. State

Cooperative totaled 194.78 million. This represents 58% of the annual loblolly pine regeneration by member organizations.

Table 11. Production of genetically improved loblolly pine seedlings in 1980 by members of the Cooperative.

Source	Pounds of Seed Planted	Seedling Production (Millions)	Seedlings Per Pound
Coastal Plain	16147	145.98	9041
Piedmont	5156	48.80	9464
Total	21303	194.78	9143

Seed orchard seed is normally larger than wild, unimproved seed collected in forest stands. The increased size of orchard seed is a result of the intensive seed orchard management efforts. However, it follows that with large seed there are fewer per pound and fewer plantable seedlings are produced per pound of seed orchard seed. It has been common to expect approximately 8000 plantable seedlings per pound of orchard seed. The 1980 survey indicates that members of the Cooperative are averaging slightly more than 9000 plantable seedlings per pound. In a year when extreme drought and excessive heat took a toll on nursery production it is a delight to realize seed to seedling production rates higher than anticipated.

Seed Orchard Management Research

Economic studies of tree improvement investments have commonly shown that profitability is directly linked to seed orchard production levels. With this understanding the Cooperative members have intensified their interest in research directed toward increasing seed orchard production and toward understanding how to efficiently and effectively apply management practices. The efforts to refine and improve understanding of orchard management practices have resulted in the implementation of a number of research projects. So much energy has been directed toward this effort in the last year that it has become known as "the year of the seed orchard management workplan". A brief description of each of the new research projects follows:

Subsoiling and Soil Management Regimes --Although subsoiling has been a standard management practice for years in Cooperative seed orchards, much remains unknown about the effects of subsoiling on tree physiology and on soil physical properties. Additionally, diagnostic procedures for determining the need to subsoil are essentially lacking. To date, determining when to subsoil has been a matter of intuition and general observations regarding orchard appearance and apparent vigor.

In the last year plans have been developed for a series of research projects to answer the following questions:

1. How frequently and with what intensity should seed orchards be subsoiled?
2. Can the effects of subsoiling be prolonged or enhanced by the application of organic matter and fertilizers to the subsoil trench?
3. Are there useful diagnostic procedures that can determine the need for subsoiling?

Understanding how to utilize irrigation and fertilization effectively is the purpose of the research study shown. The study is in Weyerhaeuser's second generation seed orchard, Lyons, Georgia.

Turf Management through Alteration of Species Composition --Historically many seed orchard managers in the Cooperative have relied on natural seeding and spread of native grasses and plants to provide seed orchard "turf" or ground cover. Very frequently, many of these native plants are little more than weeds which often require rigorous mowing programs to keep them in check. However, as mowing and management costs have spiralled upward, seed orchard managers have expressed interest in alternate turf management strategies; particularly reduced frequency of mowing. A study plan has been prepared with the objective to evaluate cultural methods for altering species composition to a species requiring less intensive mowing and means of supressing growth of existing species. The study will examine the effects of selective herbicides alone and in conjunction with overseeding and growth retardants. The first installation of this study is in Weyerhaeuser's first generation orchard in eastern North Carolina.

Turf Management through Initial Cultivation and Subsequent Seeding of Desired Grass Species --The relationship between competing vegetation and tree development has been well established in forest practice. Additionally, seed orchard managers have recognized the importance of controlling vegetation, particularly during the first years of an orchard's life. Most often mowing and spot cultivation or use of herbicides immediately around the grafts have been the common practices to control competition. There is some thinking but little documented evidence that clean cultivation of the orchard may enhance early development in comparison to conventional practice. Under this approach the orchard would be cultivated for the first two to three years followed by establishment of a desired grass species.

A workplan has been developed for a two phase study. The first phase of the study will evaluate the effects of cultivation on orchard development. The second phase will establish different species of grass and evaluate their suitability for seed orchard use. To date the study is being planned for installation in Boise Cascade Corporation's second generation orchard in South Carolina.

The Impact of Irrigation Timing on Flower Production--Research by members of the Cooperative has previously shown irrigation to be beneficial in some years on a number of site types. The frequency and degree of response has been a function of local weather conditions and to some extent the inherent moisture holding characteristics of the orchard soil. However in these studies, the irrigation treatments examined were basically water added, no water added. The response from varied irrigation treatments during the growing season is largely undefined. A study plan has been developed to test adding and withholding irrigation water in the early and late portions of the growing seasons. These treatments are being compared to add or withhold water throughout the growing season. An installation of this study is planned for Champion's orchard in Alabama. It is hoped that this and other hoped for installations of the study will compliment similar research initiated by graduate student Dave Harcharik in Catawba's Piedmont orchard in South Carolina.

The Impact of Irrigation and Supplemental Nitrogen Fertilization on Seed Orchard Development --In addition to the routinely sought flowering responses, some proponents of seed orchard irrigation believe that irrigation of young, nonflowering seed orchards would prove worthwhile because of enhanced tree growth. This argument appears to have merit since a bigger tree should have a larger crown which in turn would provide a greater opportunity for increased flower crops.

A study plan was developed in the second generation seed orchard belonging to Weyerhaeuser Company at Lyons, Georgia. Results after one growing season indicate that irrigation significantly increased tree height and vigor. In fact, only those treatments involving irrigation produced a response that was significantly greater than the control. These results were reasonable considering the extremely dry weather during the 1980 growing season.

Supplemental Mass Pollination Research --This work is directed toward understanding the application of large quantities of pollen to unprotected female flowers. This technique has the potential to increase realized genetic gains from existing seed orchards by increasing the numbers of seeds produced by a few, selected male parents. Supplemental pollination may be particularly effective, perhaps even necessary, in seed orchards where very intensive roguing down to 4-10 clones is done. Until an effective method of vegetative propagation becomes available, supplemental mass pollination is probably the only way to economically produce large numbers of hybrids, e.g. pitch x loblolly pine.

The success of supplemental mass pollination depends upon applying large quantities of highly viable pollen to receptive strobili on a schedule that permits it to compete with background pollen in seed orchards. Studies to determine the best schedule for applying supplemental pollen were installed in 1980 and 1981. Results from the first study, one that employed dyed pollen, will be available by Fall, 1981. It is hoped these results will guide us in

Graduate Students Steve McKeand and Mike Harbin are shown weeding "pots" in a portion of Dave Harcharik's irrigation research. This student project was designed to better understand the role of water management in flower production.

planning other studies to refine techniques of application. The final results from a second study using pollen that carries a gene marker will be available after seeds are collected in Fall, 1981 and 1982, and are processed in the electrophoresis laboratory at N. C. State University. This work is being coordinated by Dr. Floyd Bridgwater of the U.S.F.S. and is underway in a Weyerhaeuser Seed Orchard in eastern North Carolina.

Utility of First Generation Pollen Parents in Young Second Generation Seed Orchards --The design of second generation orchards calls for the inclusion of selected first generation clones (approximately 16% of the orchard ramets) to serve as pollen parents during the early years of seed production in the orchard. It was anticipated that first generation grafts of sexually mature trees would provide pollen in greater quantities at an earlier age than the sexually immature second generation grafts. Several of the older second generation orchards are beginning to produce male and female flowers. There are some indications that the "pollen parent" concept has limited utility in that there may be little, if any, difference between the onset of pollen production in first and second generation plant material. If first generation material can be eliminated from second generation orchards there will be an improvement in genetic quality of seed produced in young orchards and a reduction in orchard establishment costs.

A study plan was developed to evaluate pollen production in second generation orchards. The study was established in three second generation orchards during the autumn of 1979 and one orchard during the autumn of 1980. In the spring of 1981 three of these orchards produced significant quantities of flowers. Analyses of this spring's data are not complete, but preliminary indications are that second generation grafts produced at least as much pollen as first generation pollen parents.

Seed Orchard Establishment

Members of the N. C. State Cooperative completed establishment of first generation seed orchards over ten years ago. Specialty orchards for disease resistance and improved first generation orchards known as 1.5 generation orchards were widely established during the 1970's. The combined acreage for these orchards totals 3248 for all conifer species. Of the total acres established 93% is loblolly pine.

Virtually all orchard acres being established now and in the near future will be of the second generation type. To date members have established over 500 acres of second generation orchards. There are 27 members in the Cooperative and 22 of them have begun the establishment of second generation seed orchards. Only a few members have completed this vital activity. In fact we have purposefully recommended a deliberate pace for second generation orchard development. It is desirable to have the orchards developed in concert with the maturation of the progeny tests in a region and the availability of second generation selections from these tests. With this strategy of deliberate development, each new orchard block contains the best of currently available select trees. The availability of selections is enhanced each year as new tests are measured and screened for select trees. We anticipate most second generation orchards will be completed by the mid to late 1980's.

Graduate Student Al Garlo's research demonstrates that mature Frazer Fir can be successfully grafted. Air layers on seed producing orchard trees have also been successful. These results will aid seed orchard expansion efforts for a species currently having an extreme shortage of seed.

ASSOCIATED ACTIVITIES

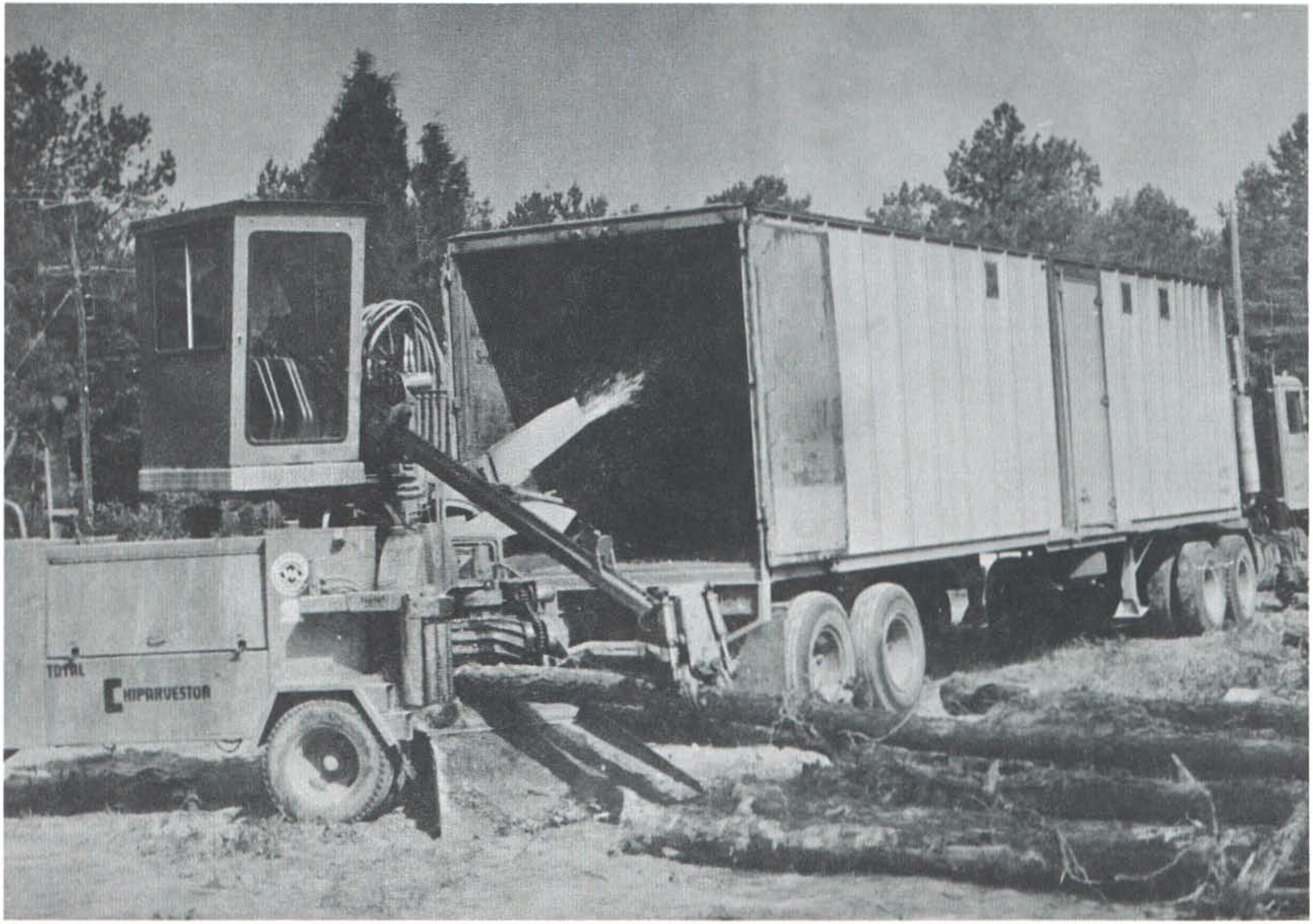
Graduate Student Research & Education

The education of graduate students and the research they conduct in conjunction with their degree program is a vital activity of the Cooperative. During the last year 14 students have been working toward advanced degrees in association with the Tree Improvement Cooperative, five are working on Masters degrees and nine are involved in the Ph.D. program. In addition, John Talbert and J. B. Jett have worked with two students on senior honors research projects.

In addition to the work with students on their respective research programs, Cooperative staff members were invited to lecture many times in the past year in a variety of graduate and undergraduate courses. J. B. Jett and Bruce Zobel were jointly responsible for teaching a Tree Improvement Methods Course. Numerous seminars on aspects of tree improvement were conducted by members of the staff in the last year.

The graduate students working with the Cooperative, the degree to which they aspire and the title of their research project are listed on the following page. It is evident that the student research projects encompass a wide range of subject matter but in each case the work is supportive of overall program research goals. Financial support for students comes from a variety of sources--The Tree Improvement Program, The School of Forest Resources, The N. C. State University Agricultural Research Service, The U. S. Forest Service, and industry-sponsored fellowships.

Student	Degree	Research Project
Robin Arnold	Masters	An economic analysis of rust resistance alternatives with loblolly, shortleaf and loblolly x shortleaf hybrids
Cheryl Busby	Ph.D.	Developing a multi-trait selection index for loblolly pine
Mike Carson	Ph.D.	Genetic variation in rust symptom types with loblolly pine
Bruce Emery	Ph.D.	Intensive roguing of seed orchards
John Frampton	Ph.D.	Microscopic and biochemical analysis of rust symptom types in loblolly pine
Albert Garlo	Masters	Vegetative propagation of Fraser Fir
Mike Harbin	Masters	Seed source studies involving Florida source loblolly pine
Dave Harcharik	Ph.D. (complete)	Seed orchard irrigation
James Hodges	Masters	Genotype-fertilizer interaction studies of slash pine
Susan Hubbard	Ph.D.	Geographic variation in host-pathogen interactions with fusiform rust on loblolly pine
Steve McKeand	Ph.D.	Electrophoretic studies of inbreeding levels in natural loblolly pine stands
Richard Sniezko	Ph.D.	Hybrid vigor resulting from outcrossing S_1 loblolly pines.
Joe Weber	Ph.D.	Geographic variation in natural stands of Fraser Fir
Claire Williams	Masters (complete)	Wet site loblolly pine source differences



Sawlog production from loblolly pine is becoming increasingly important to members of the Cooperative. With this shift in land management objectives, effective systems for intermediate cuts are a concern.

Program Staff

Faculty-level staff are well-known to Cooperators because of their nearly constant travel to work with Cooperative members in the field. Laboratory, secretarial and data processing staff are in most cases not nearly so visible, yet their work is of equal importance and they contribute vitally to the smooth and effective operation of the Cooperative. Program staff members are currently as follows:

Faculty-Level Staff

Bob Weir - Director
J. B. Jett - Associate Director
Jerry Sprague - Liaison Geneticist
John Talbert - Liaison Geneticist
1/Bob Towe - Tree Selection Specialist

Support Staff

Alice Hatcher - Coordinator
Data Processing & Secretarial
Donna Miller
*Vernedia Hunter
Judy Stallings
Jackie Evans

Associated Appointments

Floyd Bridgwater - U. S. Forest Service
Steve McKeand - Tissue Culture
Bruce Zobel - Professor Emeritus

*Vernon Johnson - Coordinator
Laboratory & Field Technician
*Addie Byrd
*Steve Russell
*Rob Wilson

1/Bob Towe completed his 19 month appointment to grade plantation selections on March 31, 1981.

*Individuals' time and financial support shared by Tree Improvement and one or more other Cooperative programs.

March 31, 1981 brought to the Cooperative an equal amount of delight and regret. All were delighted with the successful completion of the six-year long project of grading over 3000 plantation selections. Regret was also apparent because Bob Towe, the program's tree grading specialist, completed his term appointment with the Cooperative. Bob served the program with distinction in a demanding and often very difficult role. The benefits derived from his contribution will be a part of the program for many years to come.

For the first time in this report associated appointments have been noted. Dr. Floyd Bridgwater is employed by the U. S. Forest Service Southeastern Experiment Station and assigned to the Forestry Department at N. C. State University. Floyd's research program has been developed in close coordination with the Cooperative and the joint research initiatives are expected to be mutually beneficial to both organizations. Steve McKeand is a research assistant with the industry supported special project on Tissue Culture which is being largely conducted in the Department of Botany. Steve is responsible for the design and establishment of the greenhouse and field trials of tissue culture plantlets. Results of these trials will have a direct impact on opportunities for increasing genetic gain in future generations. Bruce Zobel continues to work half-time with the Forestry Department concentrating mostly on teaching and graduate student programs.

Electrophoresis Laboratory

The Cooperative has maintained a laboratory facility to support research and development projects since the initial year of operation. Laboratory work has, over the years, included seed quality evaluation, extraction, cleaning and storage of control pollinated seed and seed for special research studies, pollen germination tests, tests of pollen storage methods, maintenance of a pollen bank for Cooperative breeding work, soil sample preparation, micro-pulping studies and a variety of wood property analyses. Substantial laboratory space has been dedicated to wood properties work. In fact, the primary focus of the laboratory has been on projects involving analysis of wood specific gravity, moisture content, fiber length, cell wall thickness and lumen diameter. As an example, one laboratory technician, Steve Russell, has worked virtually full-time over the recent several years determining specific gravity for the more than 3000 plantation selections. It has been determined, however, that demand for wood property studies will decline over the next several years. The capability for such work will remain but it is also apparent that an opportunity exists to expand the laboratory capability to accommodate other research needs. The decision has been made to convert a significant portion of the laboratory activity to the development of an operational electrophoresis facility.

Electrophoresis work has been called "fingerprinting genotypes" of complex higher organisms. It is a type of chromatography using an electrical current through a starch gel to separate distinct enzymes which are in turn stained for identification. Most enzymes carry an electrical charge. It is this charge plus other characteristics of an enzyme that cause different ones to migrate through a starch gel at different rates in the presence of an electrical current. Since a single gene is known to code for a specific enzyme, then differences in migration rates of enzymes can be interpreted as gene differences. At this time research has been done to allow separation and identification of nearly 30 enzymes or genes in loblolly pine using these techniques. It is of most interest to study some of these 30 genes or gene positions (loci) for tree to tree differences at the same gene positions. When this is done, the result is a characterization of a tree genotype at a sample of gene positions.

Once the genotype of a tree or group of trees can be determined, a number of research and related activities become possible. Electrophoretic analysis could be used to spotcheck for contamination of control pollinated seedlots in the Cooperative breeding program. Mislabeled seedlots could be found and in some cases the correct labeling could be ascertained. Misidentified grafts of select trees in the orchard could in many cases be properly identified using these methods. Research applications are even more exciting. Research to determine the amount of selfing in seed orchard seed has already been done using these techniques. We anticipate applying these same methods to determine how much selfing increases, if at all, when seed orchards are rogued intensively to very few clones and few trees per acre. The degree to which random mating occurs among select trees in an orchard can be studied with these techniques. Plans are already underway to study the effectiveness of supplemental mass pollination with these methods. Effective mass pollination techniques might allow greater genetic gain through application of highly selected pollen. Effective mass pollination could greatly increase the cost effectiveness of hybridzation programs.

The staff of the Cooperative are eagerly anticipating results of the first electrophoresis project from our lab which was initiated on May 1, 1981, after over 6 months of laboratory conversion and startup activity. The first project is Steve McKeand's Ph.D. research studying the inbreeding levels in a natural stand of loblolly pine. The laboratory is being jointly developed by the Cooperative and Dr. Gene Namkoong's research program. Dr. Namkoong directs a U. S. Forest Service pioneering research project studying the population genetics of tree species. The laboratory is at this time rather modest in scope. It is expected that the electrophoresis facility will be able to accommodate no more than 3 to 4 major projects per year.

MEMBERSHIP OF TREE IMPROVEMENT COOPERATIVE

Organization	States Where Operating
American Can Company	Ala., Miss.
Brunswick Pulp Land Company	S.C., Ga., Tenn.
Bowaters	Catawba Timber Co.--S.C.,N.C., Va.,Ga. Hiwassee Land Co.--Tenn., Ga., Ala., N.C.
Boise Cascade Corporation	S.C., N.C.
Champion International	Alabama Region--Ala., Tenn., Miss. East Carolina Region--N.C., Va. West Carolina Region--S.C., N.C., Ga.
Chesapeake Corporation of Virginia	Va., Md., N.C.
Container Corporation of America	Ala., Fla.
Continental Forest Industries	Savannah Div.--S.C., Ga. Hopewell Div.--N.C., Va.
Federal Paper Board Co., Inc.	N.C., S.C.
Georgia Kraft Company	Ga., Ala.
Georgia-Pacific Corporation	Northern Region--Va., N.C. Southern Region--S.C., Ga.
Great Southern Paper Company	Ga., Ala., Fla.
Hammermill Paper Company	Ala.
International Paper Company	Atlantic Region--N.C., S.C., Ga. Gulf Region--Miss., Ala.
Kimberly-Clark Corporation	Ala.
MacMillan-Bloedel Corporation	Ala., Miss.
Masonite Corporation	Ala., Miss.
North Carolina Forest Service	N.C.

MEMBERSHIP OF TREE IMPROVEMENT COOPERATIVE (CON'T)

Organization	States Where Operating
Rayonier, Inc.	Fla., Ga., S.C.
Scott paper Company	Ala., Fla., Miss.
South Carolina State Commission of Forestry	S.C.
St. Regis Paper Company	Ala., Miss., Fla., Ga.
Tennessee River Pulp and Paper Co.	Tenn., Ala., Miss.
Union Camp Corporation	Savannah Div.--Ga., S.C., Ala. Franklin Div.--N.C., Va.
Virginia Division of Forestry	Va.
Westvaco Corporation	South--S.C. North--Va., W.Va.
Weyerhaeuser Company	N.C. Region--N.C., Va. Miss. Region--Miss., Ala.

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