TWENTY-EIGHTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

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EXECUTIVE SUMMARY

1. Results of a recent survey indicate Cooperative members manage 20 million acres of forest land.

   a. Forest industry members of the Cooperative plant 710,000 acres per year.

   b. 82% of the current annual planting on industry lands is with genetically improved seedlings.

   c. A total of 450 million genetically improved seedlings are grown annually by Cooperative members.

2. Cooperative members have established 1150 progeny tests in 20 years. Analyses of data collected from these tests are revealing important information.

   a. Parental performance level values for height at age 4 correlate well with age 12 values ($r = .75$).

   b. Parental performance level values for rust resistance at age 4 are highly correlated with age 12 values ($r = .94$).

   c. A total of 2347 second generation selections have been identified from the best families in the Cooperative's extensive progeny test program.

   d. The check seedlot system for use in the advanced generation testing program has been developed and is described.

   e. The accelerated breeding and testing program is gaining momentum.

3. The 1983 seed orchard cone harvest for all conifer species was the largest in Cooperative Program history - 86,000 bushels.

   a. Members of the Cooperative produced 49.0 tons of genetically improved loblolly pine seed -- enough seed to regenerate 1.3 million acres of forest land.

   b. Second generation loblolly seed orchards produced 1966 pounds of seed in 1983.

   c. The Cooperative members have enjoyed large cone and seed crops in six of the last seven years.

4. Cooperative program research initiatives are providing supportive information from a wide array of studies.

   a. Rain is concluded to be an important pollination agent for loblolly pine.

   b. From a study in progress, it is estimated that supplemental mass pollination may increase rust resistance by as much as 18% over rogued seed orchard seed.

   c. A mill study to determine relative economic weights concluded that an increase of one cubic foot of volume is worth 0.4 times as much as improving straightness score one unit, when the desired product is lumber.

   d. Percent rust infection is highly correlated with c-score, a severity index (r = .91).

   e. A new laboratory screening method for rust resistance explained between 86% and 98% of the variation among families for rust resistance in field trials.

   f. No family by region interactions were found in analyses of piedmont and mountain tests planted in north Georgia.

   g. A book entitled Applied Forest Tree Improvement authored by Bruce J. Zobel and John T. Talbert has been published.

5. A total of 16 graduate students are working in association with the Cooperative on M.S., Ph.D. and special studies programs.

6. A total of 29 members operate 40 working units in the Cooperative program.

An outstanding second generation selection in a Virginia Division of Forestry progeny test.

INTRODUCTION

The North Carolina State University-Industry Cooperative Tree Improvement Program has successfully completed its 28^{th} year of operation. It has been a productive year with activities conducted in an environment of cautious optimism. The long awaited economic recovery is well underway. However, most tree improvement operations and research programs continue to operate at an increased level of accountability for expenditures. Despite this, tree improvement programs in the Cooperative are being supported at effective levels and good progress is evident.

Cone and seed production levels for 1983 were once again at very high levels. More bushels of loblolly pine cones were harvested this year than any year in the Cooperative's history. Large cone and seed crops in six out of the last seven years have contributed to well stocked seed inventories and, in some cases, to substantial surpluses that have been sold or traded. Seed sales have for several members generated income that has eased recent budget pressures on tree improvement operations.

The very large progeny test data base is now being carefully and thoroughly analyzed by Cooperative staff members. We are learning from our past efforts how to manage the genetic testing program of the future as efficiently as possible. With increased accountability for tree improvement, improved efficiency is mandatory for the decade of the 80's. Tree improvement is an important and valuable technology for increasing forest productivity. After tax rate of return estimates exceed 18% for most tree improvement investments in loblolly pine. Tree improvement has greatest benefit when used as a part of a sound intensive management program that is widely practiced. It is concluded from a recent survey of Cooperative members' land management, regeneration and tree improvement activities that both are being practiced on a wide scale (Table 1). The summary statistics in Table 1 show increases in every category when compared to the previous survey conducted in 1980. New members and working units have joined the Cooperative since 1980, however, some members have expanded their forestry activities as well.

The following determinations were made from the statistics in Table 1. They tell a remarkable story of forestry and tree improvement in action:

a. Cooperative members own or lease 20 million acres of forest land.

b. 15.8 million acres of this forest land are judged suitable for pine management.

c. 60% of the pine management acres are now in plantations.

d. Forest industry members of the Cooperative plant 710,000 acres a year including landowner assistance programs.

e. 30.5% of the plantations have been established with genetically improved seedlings.

f. 82% of the current annual planting on industry lands is with genetically improved seedlings.

g. Currently 35% of the landowner assistance program planting is with improved seedlings.

h. 60% of the seedlings now grown in state nurseries are genetically improved.

i. A total of 450 million genetically improved seedlings are grown annually by Cooperative members.

Table 1. Summary statistics for land management, regeneration and tree improvement activities of the Cooperative members.

General For The Industries	
Acres of forest land operated	20 million
Percentage of holdings suitable for pine regeneration	79 percent
Pine Regeneration	
Acres of plantations established to date	9.5 million
Acres planted annually - fee/lease land	630 thousand
Numbers of acres planted annually - landowner assistance	80 thousand
Number of seedlings grown annually in nurseries	432 million
Three State Forestry Organizations	
Number of seedlings produced annually in nurseries	160 million
Combined Tree Improvement Activities	
Acres planted to date with improved seedlings	2.8 million
Acres planted annually with improved seedlings - fee/lease land	515 thousand
Acres planted annually with improved seedlings - landowner assistance	28 thousand
Number of improved seedlings annually - industry	354 million
Number of improved seedlings grown annually - states	96 million

SELECTION, BREEDING AND TESTING

Stable Family Performance Over Time

As reported in last year's annual report, Cooperative members completed the establishment of first generation progeny tests in the spring of 1983. Establishment of first generation progeny tests had been a major activity of Cooperative members since 1964 when the first six control pollinated progeny tests were planted. Through this period, Cooperative members established over 1150 progeny tests. Of this number, 306 were piedmont loblolly and 486 were coastal loblolly. The remainder were tests of slash pine, Virginia pine, shortleaf pine, pond pine and other species, plus special test series like the good general combiner and rust diallel plantings.

The progeny test data base continues to grow rapidly with each set of annual measurements. For many years, an expanding data base meant an increase in the number of testing programs or the number of parents within a given testing program for which information was available. More recently, data base expansion has meant an increase in the average age of the test measurements available. With completion of the 1984 measurements, 70% of the first generation piedmont and coastal loblolly tests have undergone age 8 assessments (Table 2). Twelfth year measurements are available on 35% of the tests and an additional 17% have age 4 assessments complete. Only 13% of the first generation piedmont and coastal loblolly tests have yet to receive their first assessment.

The information obtained from these tests has been used for two major purposes.

1) The determination of breeding values or genetic worth of parent trees in the first generation orchards.

2) The creation of a base population from which second generation selections can be drawn.

Table 2. Measurement status of first generation coastal and piedmont loblolly progeny tests.

	Number of Tests	
	Piedmont	Coastal
Not Measured	30	73
Fourth Year Measurements	53	84
Eight Year Measurements	223	329
Total	306	486

One of the primary uses of the breeding values has been the roguing of first generation seed orchards. In too many instances, the breeding value information lagged behind the need for seed orchard roguing. Thus, many of the initial seed orchard roguings became thinnings rather than true roguings. As the need for subsequent roguings became evident, available breeding value information was based predominately on age four progeny test data. The availability of this information presented a dilemma. Only time would prove or disprove the reliability of age 4 data in predicting more mature performance. So, a decision had to be made on whether the orchards would be "rogued" based on information from four year-old tests or whether they would merely be "thinned" essentially ignoring the age four information. In a majority of the cases, the decision was to rogue. With information now available on a significant number of tests at ages 4, 8, and 12, we know that our earlier decisions were sound. This is indeed good news.

The standard method of comparing the relative worth of parents in a first generation seed orchard is through the use of performance level values. After each measurement season, performance level values are

Intensive management of genetic tests in the early years (top) produces a well developed test on Weyerhaeuser's land by age four (right).

generated for the parents in each orchard based on the oldest information available from each progeny test. Thus in recent years, the evaluations have been based on a mixture of 4, 8, and 12 year data. This gives the best assessment of parental value currently available, but does not provide any indication of parental value stability from age to age since the number of tests contributing to the analyses vary annually. To assess the reliability of performance level values from age to age, separate evaluations by age based on the same set of progeny tests are required. Sufficient information is now available for a number of testing programs to obtain meaningful age to age comparisons.

Performance level values were computed for height, and where applicable for rust resistance, for each of seven programs at ages 4, 8, and 12. The same tests were used for the evaluations at each age. Tables 3 and 4 are typical of the results obtained. Visual assessment of the performance level values suggests that decisions based on age four data would be essentially the same as those based on age 8 or age 12 data. As to be expected, there is some shifting in clonal positions, particularly among the average performers, but basically the good remain good and the poor remain poor over time. The correlation coefficients verified the subjective assessment. The correlation coefficients for height in Table 3 were .86 for ages 4 and 8 and .84 for ages 4 and 12. The age 8 to age 12 correlation was .96. For rust resistance (Table 4), the age to age correlations were even more impressive. The correlation of performance levels for rust resistance between age 4 and 12 was .97.

As stated previously, the results obtained from the evaluation of Continental's (Georgia) piedmont loblolly program are representative of the results obtained from the seven programs assessed. The average age to age

Table 3. Performance levels for height at ages 4, 8 and 12 for Continental Forest Industries' (Georgia) Piedmont loblolly program.

Half-Sib Families**	No. of Crosses	Performance Levels* Age 4	Age 8	Age 12
CC		28	32	29
5-15	4	37	39	41
5-52	10	45	50	50
5-41	15	46	41	43
1-14	4	46	53	57
5-19	4	49	45	40
7-77	4	53	57	57
1-11	4	56	57	58
1-64	4	56	64	62
5-21	4	57	62	61
5-12	4	58	51	56
3-21	3	58	60	62
5-33	16	61	62	63
1-516	3	65	63	65
5-5	15	66	68	65
1-523	3	70	64	64

*Performance levels are based on eight progeny tests.
**Half-Sib families composed of less than 3 crosses were deleted from the analysis.

Age to Age Correlations: $r_{4,8} = .86$
$r_{4,12} = .84$
$r_{8,12} = .96$

Table 4. Performance levels for rust resistance at ages 4, 8, and 12 for Continental Forest Industries' (Georgia) Piedmont loblolly program.

Half-Sib Families**	No. of Crosses	Performance Levels* Age 4	Age 8	Age 12
1-516	3	24	27	25
5-41	15	30	29	29
5-12	4	33	30	29
1-523	3	42	42	51
7-77	4	43	38	36
CC		52	44	45
1-11	4	53	56	55
3-21	3	53	54	56
5-33	16	55	56	55
5-5	15	55	54	54
5-15	4	58	55	57
5-52	10	59	63	61
5-21	4	61	64	61
1-14	4	65	68	67
1-64	4	67	69	67
5-19	4	71	77	74

*Performance levels are based on eight progeny tests.
**Half-Sib families composed of less than 3 crosses were deleted from the analysis.

Age to Age Correlations: $r_{4,8} = .98$
$r_{4,12} = .97$
$r_{8,12} = .98$

correlation coefficients for height and rust performance levels for the seven programs analyzed are given in Table 5. Overall, the correlation from age 4 to age 12 for height was .75 and age 4 to age 12 for rust resistance was .94. Correlations of this magnitude between age 4 and later assessments are extremely gratifying. With these results, a great deal more confidence can be placed on past decisions based on information from age four progeny tests.

Further evaluations are currently underway to assess performance over time. If these evaluations are comparable to the ones reported above, adjustments in current measurement schedules will be considered.

Table 5. Average correlation coefficients for height and rust performance levels at ages 4, 8, and 12.

	Height	
	Age 8	Age 12
Age 4	0.84	0.75
Age 8		0.93
	n = 7 companies	

	Rust	
	Age 8	Age 12
Age 4	0.96	0.94
Age 8		0.97
	n = 5 companies	

-Evaluations were for the same tests at each age.
-Only evaluations based on 3 or more crosses were used in the analyses.
-Height correlations were from: Champion, SC; Chesapeake; Continental Forest Industries, GA; International Paper Co.; Weyerhaeuser Co., NC; Federal Paper Board; Kimberly-Clark.
-Chesapeake and Weyerhaeuser were not included in the rust analyses.

Second Generation Selection Program

A listing of second generation selections for each Cooperative member is given in Table 6. A total of 2347 selections have been graded to date. In the past couple of years, the identification of second generation selections has slowed significantly, particularly in the more mature first

Table 6. A listing of second generation selections of loblolly pine in the Cooperative.

	Number of Selections
Hiwassee	169
Catawba	95
Union Camp (VA)	123
Champion (WCD)	79
Chesapeake	109
Continental Forest Industries (GA)	99
Champion (ECD)	127
International Paper (SC)	129
International Paper (MISS-ALA)	10
Weyerhaeuser (NC)	229
Weyerhaeuser (MISS-ALA)	78
Federal	111
Union Camp (GA)	59
Westvaco (SC)	155
Kimberly Clark	146
Continental Forest Industries (VA)	104
Georgia Kraft	100
N. C. Forest Service	16
American Can	64
S. C. Commission of Forestry	54
Tennessee River	86
Virginia Division of Forestry	147
Hammermill	6
Georgia Pacific	8
Leaf River	15
Container	4
St. Regis	5
Rayonier	5
Brunswick	10
MacMillan-Bloedel	5
Great Southern	1
Total	2347

generation programs. This is at least partially due to an increasing awareness that additional selections from these programs have limited utility.

Table 7 lists by first generation breeding program the number of full-sib families and half-sib families represented in the second generation selections from that program. A typical first generation breeding program consisted of approximately 25 clones. The first generation breeding program utilized a tester mating scheme whereby 4 or 5 tester clones were mated to all other first generation parents. Using this mating scheme, a four tester system would result in 84 full-sib families and a five tester system would generate 100 full-sib families in a 25 clone breeding program. A review of Table 7 shows that, based on a typical breeding program, approximately 30% of the full-sib families are represented in the second generation selections. More important though than full-sib family representation is the representation of half-sib families in the second generation population. Using 25 clones as a typical orchard size, the 40 breeding programs represented in Table 6 involved the breeding and testing of approximately 1000 first generation parents. Of the approximately 1000 first generation parents tested, 649 are currently represented in the second generation population.

Table 8 shows the occurrence of second generation selections for International Paper Company's South Coastal loblolly breeding program. Twenty-three first generation parents were bred using a five tester mating scheme. The breeding program resulted in the testing of 100 full-sib families of which 37 are represented in second generation selections. Of the twenty-three first generation parents tested, 20 are represented in second generation selections. All five testers are well represented.

Table 7. Family representation in second generation loblolly pine selections.

	Number of Full-Sib Families	Number of Half-Sib Families
Hiwassee - Piedmont & Mountain	52	28
Catawba - Piedmont	49	30
Union Camp (VA) - Coastal	60	37
Champion (WCD) - Piedmont	41	30
Chesapeake - Coastal	30	17
Continental Forest Industries (GA) - Piedmont	28	18
Continental Forest Industries (GA) - Coastal	12	10
Champion (ECD) - Piedmont	33	18
Champion (ECD) - Coastal	11	10
International Paper - South Coastal	37	20
International Paper - North Coastal	13	10
International Paper - Piedmont	4	5
International Paper (MISS-ALA) - Coastal	10	11
Weyerhaeuser (NC) - South Coastal	54	27
Weyerhaeuser (NC) - South Coastal Low Density	5	6
Weyerhaeuser (NC) - North Coastal	49	24
Weyerhaeuser (NC) - Piedmont	18	13
Weyerhaeuser (MISS-ALA) - Upper Coastal	38	28
Federal - Coastal	17	10
Federal - Piedmont	33	15
Union Camp (GA) - Lower Coastal	29	15
Union Camp (GA) - Upper Coastal	8	8
Westvaco - S. C. Coastal	40	19
Westvaco - N. C. Coastal	10	8
Kimberly Clark - Piedmont	54	22
Continental Forest Industries (VA) - Coastal	39	21
Continental Forest Industries (VA) - Piedmont	13	12
Georgia Kraft - Piedmont	36	22
Georgia Kraft - Mountain	8	12
N. C. Forest Service - Piedmont	10	10
American Can - Coastal	41	22
S. C. Comm. of Forestry - Coastal	13	14
S. C. Comm. of Forestry - Piedmont	27	16
Tennessee River - Piedmont	44	22
Va. Div. of Forestry - Coastal	31	19
Va. Div. of Forestry - Piedmont	33	17
Hammermill - Coastal	3	4
Georgia Pacific - Florida	1	2
Leaf River - Coastal	11	11
St. Regis - Coastal	4	6
Totals	1049	649

Table 8. The number of second generation selections chosen from International Paper's South Coastal Loblolly First Generation Program. Shown are the number of selections from each half-sib family (females and male testers) and from the specific full-sib family combination.

			Male	7-2	7-22	7-51	7-33	7-29	
			Ht. P.L.	70	47	45	45	44	Selection
			Rust P.L.	58	61	50	50	34	Totals
Female	Height P.L.	Rust P.L.							
7-56	72	73		2	4	2	6	8	22
7-17	64	22							
11-16	63	56		4	3		2		9
7-34	59	64						1	1
7-107	58	64		3	1			2	6
7-52	57	43		4	1			1	6
7-4	54	53							
7-105	53	69		6		1	4		11
7-71	52	34		3	1				4
11-19	50	64		1					1
7-106	49	31							
11-23	48	27							
7-58	48	43		1					1
7-18	48	22					1		1
7-14	45	35							
7-54	44	66		3					3
7-10	40	73						1	1
11-20	39	72		2					2
7-2	70	58							
7-22	47	61		6					6
7-51	45	50		4	1				5
7-33	45	50			1	1			2
7-29	44	34		2					2
			Totals	41	12	4	14	13	84

Note: Crosses outside the tester mating scheme accounts for second generation selections from an additional 5 full-sib families and 2 additional half-sib families.

Clone 7-2, the best of the testers, is the male parent in 41 of the second generation selections. The remaining four testers, 7-22, 7-51, 7-33 and 7-29 are represented in 18, 9, 16 and 15 selections respectively. The best of the females, clone 7-56, is a parent in 22 of the selections. Another of the better parents, clone 11-16, is represented in 9 selections. Selections with clone 7-56 are available with all five testers, clone 11-16 occurs in combination with three of the testers. Generally, poor performing clones, like 7-14, are not represented in the second generation population. Occasionally, a selection will occur from a poor performer like 7-18 which is represented by a single second generation selection. These selections obviously will not be a part of the second generation breeding effort. Table 8 reflects the fact that the large majority of selections are from the better first generation parents.

The above discussion and the figures in Table 8 illustrate the high degree of co-ancestry which resulted from use of the tester mating scheme in the first generation breeding program. This level of co-ancestry limits the utility of additional selections from many first generation breeding programs. From Table 8, it is obvious that each of the five testers and the best of the female parents are all well represented in second generation selections. Selecting additional trees from a program like this would accomplish little.

The status of second generation selection work is currently being assessed for each of the first generation breeding programs. Recommendations based on this assessment will be forthcoming at the Advisory Committee meeting in June.

Check Seedlots for Advanced Generation Testing

Over the past year, considerable effort has been directed toward development of the check seedlot system for use in the second generation and plantation selection testing programs. It was previously decided to use two check types in each advanced generation progeny test. One check type would be a seedlot of pooled unimproved seed from each Cooperative member in a testing area. The second type would consist of a pooled check of bulked seed from the first generation seed orchards in the region. The first check type, generally referred to as a Commercial Check, would be used for two purposes. The first and most important use is as a basis for comparison of families between test series. The secondary use is to provide a rough estimate of gain. The second check type, commonly referred to as a seed orchard mix, will provide a general comparison of advanced generation material to first generation seed orchard stock.

Advanced generation progeny tests have been designed primarily to serve as a base for selection. Since the commercial check seedlots will be the mechanism whereby families are compared over test series for the purposes of selection, it is essential that common checklots be employed. The first step in developing the common checklots was to define distinct testing areas. Figure 1 shows the delineation of the eight testing areas for which common checklots have been developed. The unimproved lots and first generation seed orchard collections were bulked from each of the eight areas to obtain a common commercial check seedlot and a common seed orchard mix seedlot for each area.

In the process of composing the checklots for each testing area, it became readily apparent that checklots for a single testing area could not

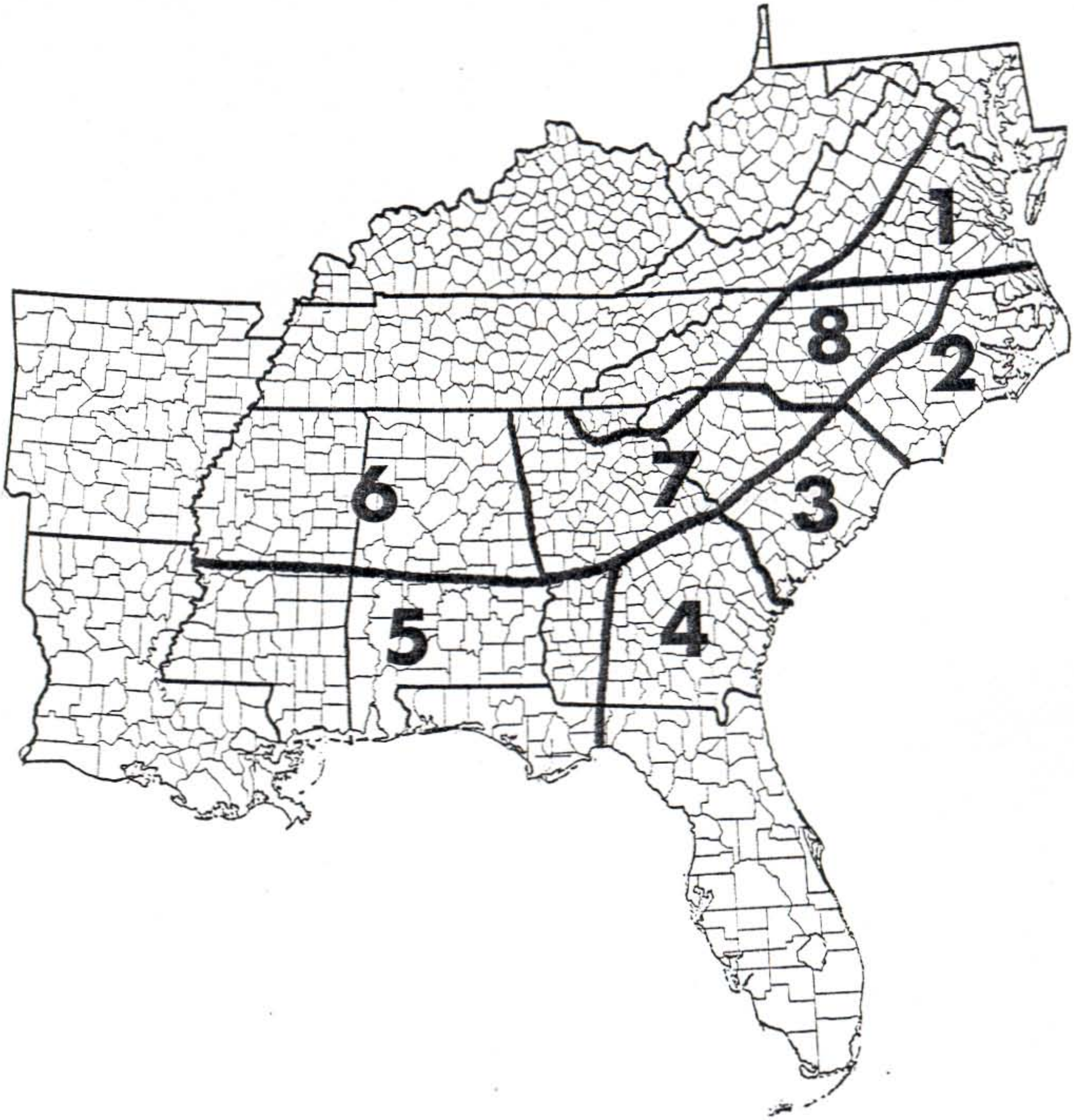


Figure 1. Testing Areas for Advanced Generation Genetic Tests.

1. Virginia Coastal Plain and Piedmont
2. North Carolina Coastal Plain
3. South Carolina Coastal Plain
4. Georgia-Florida Coastal Plain
5. Lower Gulf
6. Upper Gulf
7. Georgia & South Carolina Piedmont
8. North Carolina Piedmont

provide the range of comparisons necessary for proper selection for the third generation program. Many Cooperators have lands which overlap two or more testing areas. The third generation production orchards and breeding programs for most Cooperators could thus be comprised of selections from two or three testing areas. For example, a Cooperator in the southern extreme of area 3 could well use selections from the northern portions of area 4. Likewise, a Cooperator in the middle of area 3 could potentially utilize selections from the northern extreme of area 4 and the southern extreme of area 2, as well as those from area 3. Because of such overlap of selection use from area to area, a method to compare the performance of selections in adjacent areas was needed.

To facilitate the comparison of selections across testing areas, the following check system has been adopted for second generation and plantation progeny tests:

1) Each test series will contain one seed orchard mix checklot. This checklot will be the composite SOM seedlot from the test area from which the test series was derived and planted.
2) Each test series will contain three commercial check (CC) seedlots. One of the commercial check seedlots will be the composite CC seedlot from the test region from which the test series was derived and planted. The remaining two CC seedlots will be from the two most adjacent areas. In determining adjacent areas, the border between the Piedmont and Atlantic coastal areas will not be crossed. Examples: A test series in region 3 will contain the CC seedlots from regions 2, 3 and 4. A test series in region 7 will contain CC seedlots from 6, 7 and 8. A test series in region 1 will contain CC seedlots from regions 8, 1 and 2.

This system will yield four distinct check seedlots for each test series. Each of the four seedlots will be represented in each block of each test by 2 plots for a total of 8 check plots per block. On the surface, this may appear to be a significant increase over the number of checklots used in the first generation program. In reality, the number of check plots in each block of the first generation tests was the same as the number adopted for the advanced generation program. In the first generation program, each block contained a CC seedlot, an SOM seedlot and 6 genetic check seedlots. The basis of comparison in the advanced generation testing program has simply been shifted from the use of genetic checks to the use of commercial checks. The check system described should provide a much improved system for comparison of selections between testing programs and regions.

Advanced Generation Breeding Progress

In the fall of 1981 in a special Advisory Meeting, the Cooperative members adopted an accelerated breeding and testing schedule for advanced generation improvement. The adoption of this accelerated schedule resulted from the recognition of the increased economic return possible from a shortened generation interval. Since that time, there has been a steadily increasing commitment of resources by Cooperative members toward meeting the goals adopted.

Full scale accelerated breeding greenhouse facilities have now been constructed by five member organizations. Since several organizations building these facilities operate two or more working units in the program, the benefits will be realized in 10 of the 40 cooperative working units. Investments in containerized outdoor breeding facilities have been made by

Female "flower" buds produced in response to GA $4/7$ treatments in Champion's breeding orchard, Tillery, N. C..

Outdoor containerized breeding orchards are being used successfully to accelerate the advanced generation breeding.

at least 10 other organizations. Many Cooperators have used wire girdles to promote pollen production and application of GA $_{4/7}$ to stimulate flowering in field breeding orchards. All of these efforts have paid dividends. Breeding progress increased several fold in the spring of 1984 as compared to that reported in 1983. Successful pollen production on branches of young loblolly grafts (2 to 4 years from grafting) prompted one Cooperator to comment, "I have so much pollen for next year, I may not have enough female flowers to use it all." "Problems" such as this were unheard of a generation ago. All associated with the program are delighted with the excellent progress being made.

Additional investments have been made by over half the Cooperative members to build new greenhouses or upgrade existing greenhouses. These investments in small greenhouse facilities are largely directed toward growing containerized seedlings for genetic tests. Container grown genetic test seedlings can save one year between cone harvest and test establishment in the field. In addition, container grown tests result in much higher seed to seedling ratios which in turn lowers the number of expensive, hard to produce control pollinated seed required from the breeding activity.

We are pleased with the progress to date. The accelerated breeding and testing program is gaining momemtum. We believe we are moving into the next generation of improvement on or ahead of schedule. It is an exciting and rewarding period in our Cooperative Program.

The small greenhouse shown above was constructed by the Cheaspeake Corporation of Virginia in order to grow containerized genetic test seedlings.

SEED ORCHARD PRODUCTION

Cone and Seed Yields

Another year of excellent cone and seed production was enjoyed by members of the Cooperative. In fact, the 1983 cone harvest for all conifer species was the largest in Cooperative history. The 1983 cone harvest fell 12 bushels short of 86,000. A total of 56.6 tons of genetically improved seeds were extracted from this record cone crop. The total seed yield surpassed the previous record (1981) by 2.1 tons. Cones harvested from loblolly pine orchards comprised 80% of the conifer collection with slash pine accounting for an additional 15% of the total harvest (Table 9).

Table 9. Comparison of cone and seed yields for 1982 and 1983.

Species	Bushels of Cones 1983	Bushels of Cones 1982	Pounds of Seeds 1983	Pounds of Seeds 1982	Pounds of Seed/ Bushels of Cones 1983	Pounds of Seed/ Bushels of Cones 1982
Loblolly Pine:						
Coastal 1st gen.	51063	28718	73927	39000	1.45	1.36
Coastal 2nd gen.	1518	692	1848	763	1.22	1.10
Piedmont 1st gen.	15779	15351	22147	21292	1.40	1.38
Piedmont 2nd gen.	93	--	118	--	1.27	--
Slash Pine	12716	6955	12396	6405	0.97	0.92
Longleaf Pine	1001	742	980	730	0.98	0.98
White Pine	2957	0	1015	0	0.34	0
Virginia Pine	663	223	411	211	0.62	0.95
Pond Pine	66	32	19	48	0.29	1.50
Shortleaf Pine	31	22	18	18	0.58	0.82
Sand Pine	0	38	0	10	0	0.26
Total All Conifers	85,988	52,827	113,165	68,643	--	--
Fraser Fir	101	54	286	166	2.83	3.07

The remaining 5% of the conifer harvest was distributed among seven species with the largest producer being white pine. Table 9 compares the 1983 harvest with the 1982 harvest for all conifer orchards. The Cooperative has enjoyed two very good production years in a row.

We are particularly pleased to note in Table 9 the first separate reporting of cone and seed yields from second generation loblolly pine orchards. The 1983 combined production from Coastal and Piedmont second generation orchards was 1611 bushels of cones and 1966 pounds of seed (1.22 lbs./bu.). This production level in second generation orchards is equivalent to that achieved from first generation orchards in 1969. The "future" of loblolly pine tree improvement is indeed upon us.

Fifteen years of cone harvest and seed yield information is summarized in Table 10 for loblolly and slash pine, the Cooperative's two most

Table 10. Cone and seed yields of the loblolly and slash orchards in the Cooperative for the last fifteen years.

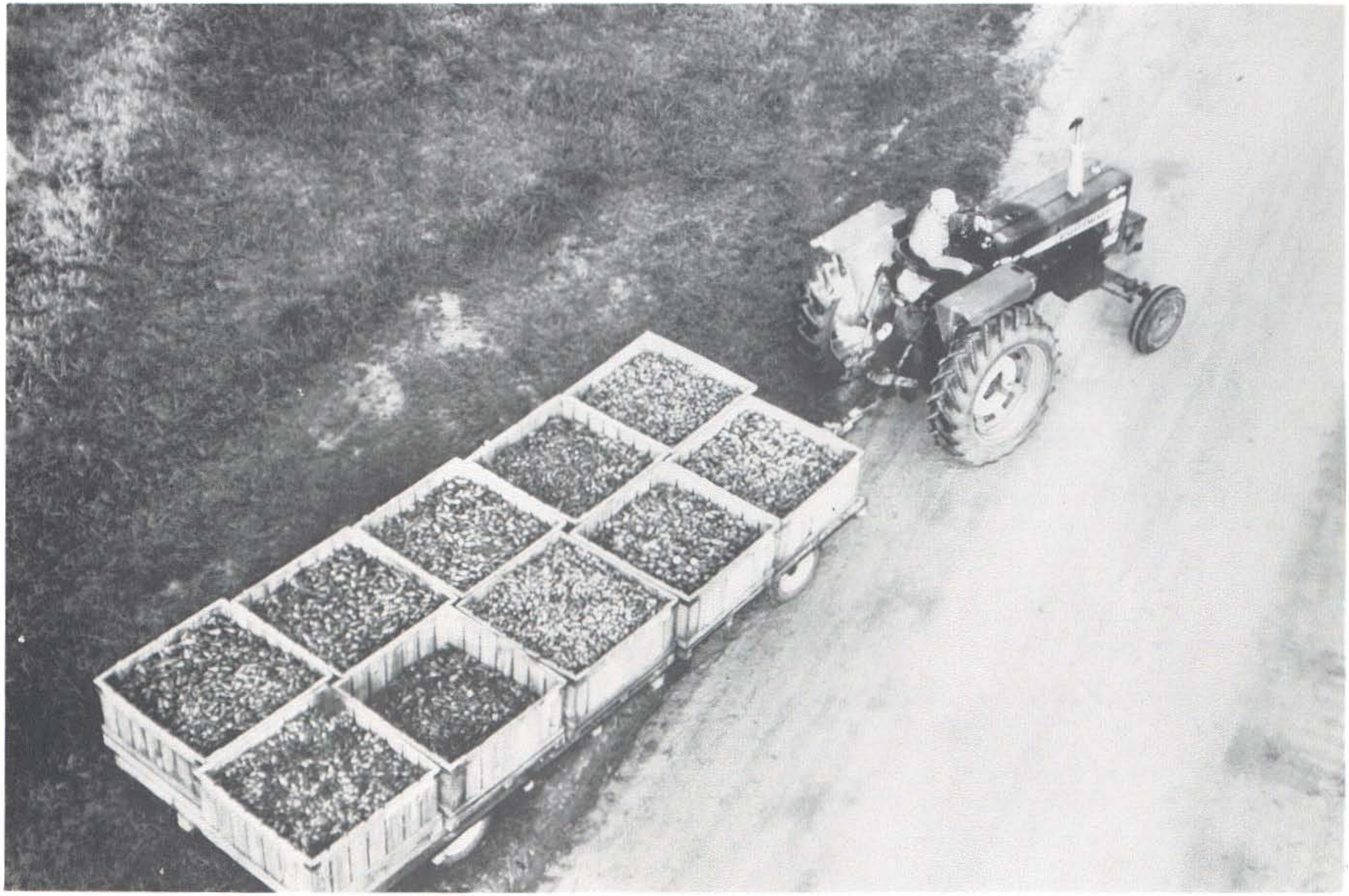
	Loblolly Pine		Slash Pine	
Year	Bushels of Cones	Lbs. Seed/ Bushel	Bushels of Cones	Lbs. Seed/ Bushel
1969	1769	1.10	317	0.42
1970	5146	1.36	1744	0.88
1971	6478	1.14	3895	0.80
1972	6807	0.98	1684	0.60
1973	11853	1.09	2779	0.58
1974	8816	0.99	4088	0.74
1975	16348	1.31	5516	0.93
1976	14656	1.21	5233	0.79
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
1981	64145	1.58	4880	0.96
1982	44761	1.36	6955	0.92
1983	68453	1.43	12716	0.97

important species. More loblolly cones were harvested in 1983 than in any previous year. The slash pine cone harvest was also outstanding, falling just under the record setting crop of 1977. Seed yield (lbs./bu.) were also good last year but not a record for the Cooperative. This no doubt reflects the "in growth" or beginning years of production for a large number of quite young seed orchards (7 to 9 years). Seed yields per bushel of cones harvested are always lower in young seed orchards.

It is evident from Table 10 that "full" production for the Cooperative orchards was not realized until 1977. Since that time, members have enjoyed six excellent production years and only one poor production year (1980). It is clear that with proper management, loblolly pine seed orchards can produce large crops almost annually (Table 10). Since the fall of 1972, loblolly orchards managed by Cooperative members have produced nearly 214 tons of genetically improved seed (Table 11). This is enough seed to grow 3.4 billion seedlings which would in turn regenerate 5.72 million acres of land. Loblolly pine improvement programs are having a major impact on forest growth and productivity.

Table 11. Production of cones, seed and seedlings from Cooperative members' loblolly pine seed orchards over the last 7 years including an estimate of acres regenerated with improved seedlings.

Harvest Year	Bushels of Cones	Tons Of Seeds	Millions Of Seedlings	Millions of Acres Regenerated
1977	32,152	24.8	396	0.66
1978	37,977	23.5	376	0.63
1979	38,693	27.7	443	0.74
1980	15,296	7.9	127	0.22
1981	64,811	50.5	808	1.35
1982	44,761	30.5	488	0.81
1983	68,447	49.0	784	1.31
Totals	302,137	213.9	3,422	5.72



Approximately 190 bushels of harvested loblolly cones on the way to the seed extractor. These cones produced by the Virginia Division of Forestry are expected to yield seed with an estimated present net value of $85,000.

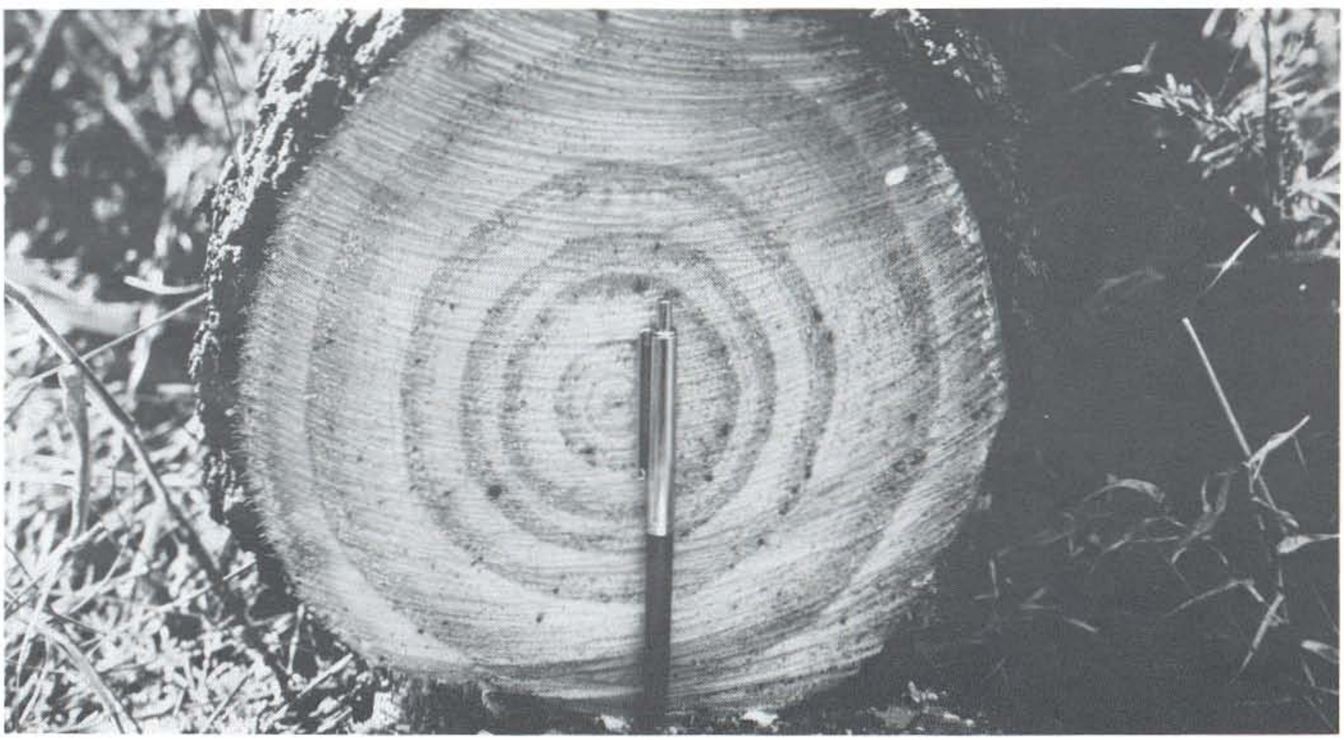
Production Leaders

Summarizing seed orchard production and yield statistics each year often reveals some peculiar happenings--this year was no exception. Surprisingly, the heaviest production in 1983 occurred at the far extremes of the Cooperative working territory.

Production statistics for Leaf River, American Can, Tennessee River, Chesapeake and the Virginia Division of Forestry are noted in Table 12. For all five organizations, these represent record setting production levels. These organizations have through the years seen one good flower crop after another destroyed by late freezes, droughts, hurricanes, and other catastrophes perpetrated by "Mother Nature." It is extremely graftifying to see record production levels from these areas of the Cooperative.

Table 12. Outstanding cone and seed production from five Cooperative members located at the fringe of the operating region.

Organization	Bushels of Cones	Pounds of Seeds
Leaf River	3813	4957
American Can	5340	6864
Tennessee River	4670	8172
Chesapeake	2604	4803
Virginia Division of Forestry	4025	6725

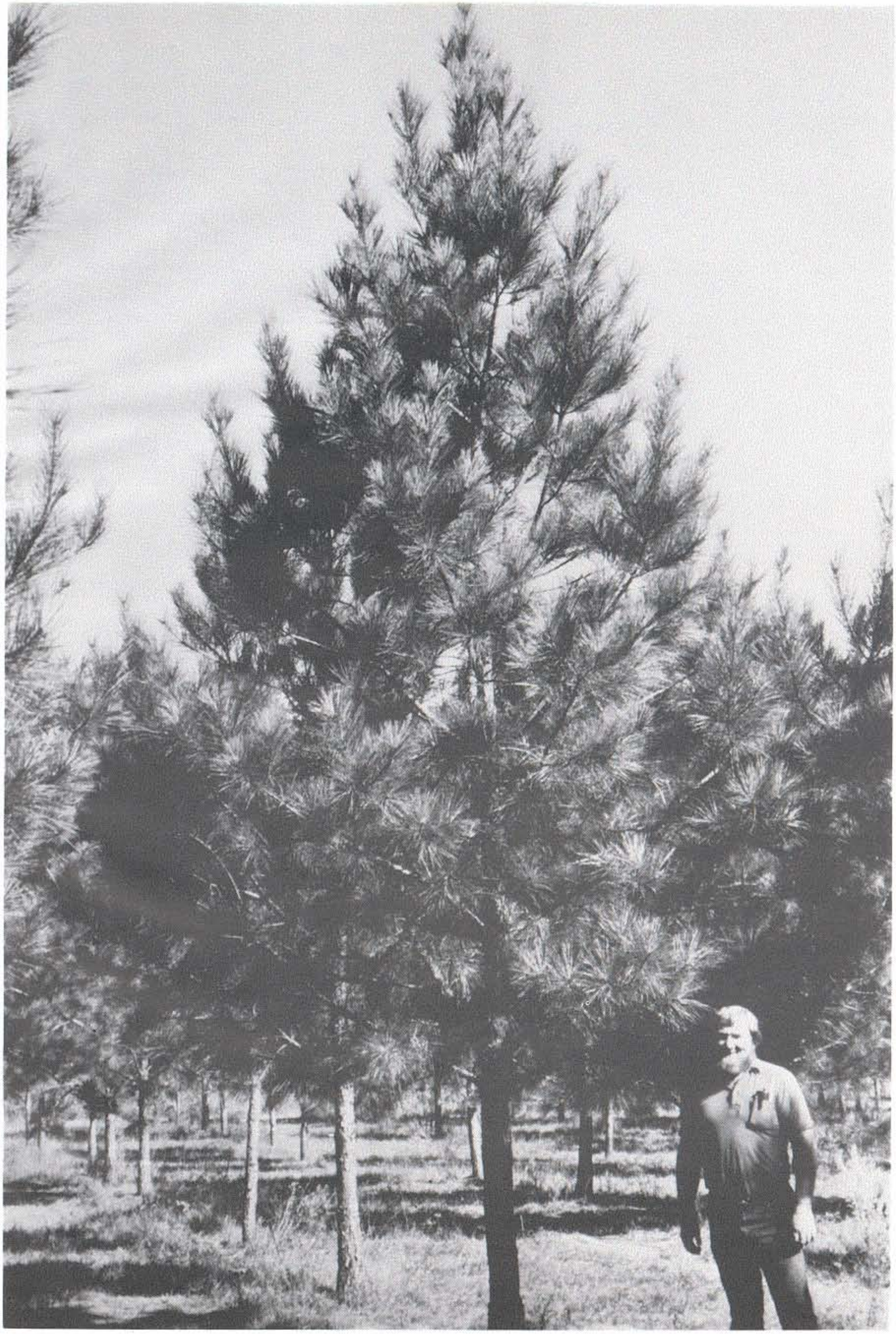


Brunswick Pulp and Land Company's second generation orchard (top) was recently rogued. The growth in this orchard has been phenomenal (bottom).

The record 1983 loblolly cone harvest was the result of moderate to good production from many orchards across the Cooperative. Few outstanding production levels were noted, however, nearly everyone enjoyed harvests in the range of 35 to 60 bushels per acre. One delightful and notable exception was the 1983 record for most bushels per acre and pounds of seed per acre achieved by American Can Company. American Can's Bellamy Orchard located near Butler, Alabama produced 145 bushels of loblolly cones per acre and 178 pounds of seed per acre. This 19.6 acre orchard which is 17 years old is under the capable management of Mike Williford. For a job well done, Mike and the American Can organization are to be congratulated.

South Carolina Commission of Forestry's Coastal Orchard near Wedgefield, S. C. set the 1983 standard for seed yields per bushel. A 31 acre block of orchard managed by "Big Booth" Chilcutt produced 611 bushels of cones yielding 1293 pounds of sound seed or 2.12 lbs./bu.. Yields in excess of 2.00 lbs./bu. can only be achieved with top quality orchard management, especially successful insect control.

Honorable mention this year goes to Mike Harbin and Chesapeake Corporation for a 2.00 lbs./bu. yield from 1270 bushels gathered off 22 acres of coastal orchard near West Point, Virginia. Mike's harvest year was not without problems, however. He reported 395 bushels harvested from his eastern shore loblolly orchard with a footnote that said, "Actual cone crop was approximately 500 bushels--squirrels got the difference." It is evident that good seed yields and fat squirrels are both part of Chesapeake's tree improvement program. Happy Hunting!



Orchard Manager Randall Driggers proudly shows off Rayonier's well developed second generation orchard.

RESEARCH RESULTS AND ASSOCIATED ACTIVITIES

Pollination Mechanisms in Loblolly Pine

Graduate research assistant Ms. Sheryl Brown conducted pollination studies over the last two years to determine the process and actual mechanisms responsible for moving pollen into contact with the ovules in loblolly pine. Repeated observations were made on pollination droplets and strobili on trees in Weyerhaeuser's 26 year-old loblolly seed orchard near Washington, N. C..

The work Sheryl conducted was tedious but exciting. She spent many long nights in a bucket truck adapted with a special microscope platform and power source observing pine "flowers". The information she obtained will be useful in developing effective supplemental mass pollination methods. It can also aid the accelerated breeding program through improvement of control pollination techniques. The following is a list of conclusions from her thesis:

1. Rain can effectively act as a pollination agent in strobili as early as stage 4.

2. Pollination droplets begin to emerge on unpollinated ovules as they progress from stage 5 to 5 late. Droplets emerge in the evening or early morning.

3. The two major factors effecting droplet emergence and withdrawal on an ovule are the stage of strobilus development and the environmental conditions. High relative humidity is conducive to droplet emergence.

4. Pollination droplets with pollen on them recede more rapidly than droplets with no pollen. However, even these can take over four hours to recede.

5. Once ovules have been pollinated via pollination droplets or rain, the pollination droplets will not emerge.

6. Pollination droplet emergence and withdrawal on an ovule is independent of other ovules elsewhere in the strobilus.

7. The importance of rain as a pollen carrier indicates that artificial pollination might be enhanced by a subsequent heavy water spray. This method was not tested.

8. The rain-pollination mechanism offers an explanation for the function of wings on pollen grains in the Pinaceae. It is hypothesized that the wings enable the pollen grain to float to the ovule surface.

Supplemental Mass Pollination - Work in Progress

The potential benefits from being able to produce large numbers of seeds economically by applying selected pollen have been realized for some time. Seeds from each clone in a seed orchard are essentially a collection of random matings (full-sib crosses) with the other clones in the seed orchard. In fact, half-sib (or clonal) evaluations are based on the average performance in genetic tests of a clone that has been crossed with several other genotypes. Some of these full-sib crosses perform better than the average and some poorer. If we could make only those specific crosses that were better than average in seed orchards, genetic gains would be increased. Producing enough seeds for operational plantation establishment by bagging and controlled pollinations would be prohibitively expensive. Supplemental mass pollination is an attempt to produce as many seeds of the desired pollen parent as possible without bagging female strobili, i.e. in competition with wind-borne seed orchard pollen.

Supplemental mass pollination was shown to be feasible only recently (results were reported at the 17^{th} SFTIC, 1983). Properly-timed applications of large amounts of supplemental pollen resulted in 86% of selected pollen grains in ovules. Encouraged by these experimental results, Georgia Kraft Company installed a supplemental mass pollination trial in their Briarpatch Seed Orchard in cooperation with the U.S.F.S. and N. C. State University.

Georgia Kraft regenerates a significant number of acres each year in high fusiform rust risk areas. The basic objective of the study was to increase rust resistance from the seed orchard using supplemental mass pollination.

Calculations based on performance level information provided by the N. C. State Cooperative staff showed that there were several ways to improve rust resistance from the Piedmont seed orchard (Table 13). Roguing the seed orchard (done this spring just before pollen flight) improved the

Table 13. Expected % rust-free trees from seedlots in the Georgia Kraft Supplemental Mass Pollination Trial.

Seedlot	% Rust-Free	Improvement Over Rogued Seed Orchard Bulk
6 Controlled Crosses	90%	27%
SMP with 70% Success	81%	18%
7 Clone Bulk	72%	9%
Rogued Seed Orchard Bulk	63%	

expected rust resistance 4% over unrogued seed orchard seed. Collecting seeds by clone from the seven best clones in the seed orchard is expected to increase rust resistance another 9% over rogued seed orchard seeds. The best six controlled crosses (full-sib families in genetic tests) are expected to average 27% more rust-free trees than rogued seed orchard seeds. The success of supplemental mass pollination will not be known until seeds are harvested in the fall of 1985 and tested. However, if only 70% of seeds from supplementally mass pollinated ramets is of the desired male parent, rust resistance is expected to average 18% over rogued seed orchard seeds. All of the male and female parents receiving supplemental pollen were selected for good growth as well as for rust resistance. Therefore, growth is expected to improve as well as resistance to fusiform rust.

In addition, a shortleaf pine pollen mix was applied to a ramet of each of the same female clones used in the intraspecific supplemental mass pollination trial. Expected performance of those shortleaf x loblolly pine hybrids cannot be estimated. However, we expect that they will be more rust resistant than any of the intraspecfic crosses and will grow less well than most of the loblolly parents. If sufficient levels of rust resistance cannot be realized using SMP to make specific crosses, producing hybrids with SMP may be a promising alternative.

Supplemental mass pollination must be economical or it will never become an accepted operational practice. An economic analysis was not done in conjunction with this study. However, some useful information that will help estimate costs was gained from the study.

Ramets pollinated were approximately 40-50 feet tall. The number of clusters of female strobili ranged from 93 to 238 per ramet and averaged 163 clusters per ramet. Each ramet required about 20 minutes to pollinate including set-up time for the bucket truck.

Approximately one milliliter of pollen was applied to each cluster in two one-half milliliter bursts. Pollen was applied using a pole duster purchased for approximately $35 from Antles Pollen Supplies, Inc. of Wenatchee, Washington. The duster is a 6' long section of aluminum tubing with a pollen bottle installed in-line. A 6" diameter funnel serves as a wind screen when placed over a cluster of strobili. Compressed air controlled by a thumb release drives the pollen from the bottle into the wind screen and onto the strobili.

Some quick calculations were made assuming 1) each ramet of the size described will yield 1.5 bushels of cones at harvest, 2) each bushel will yield 1.5 lbs. of seed, 3) each lb. of seed will yield 10,000 plantable seedlings, 4) 600 trees per acre will be planted, 5) each ramet requires 30 minutes for SMP.

Using these figures, one would expect that two people pollinating for eight working hours could produce:

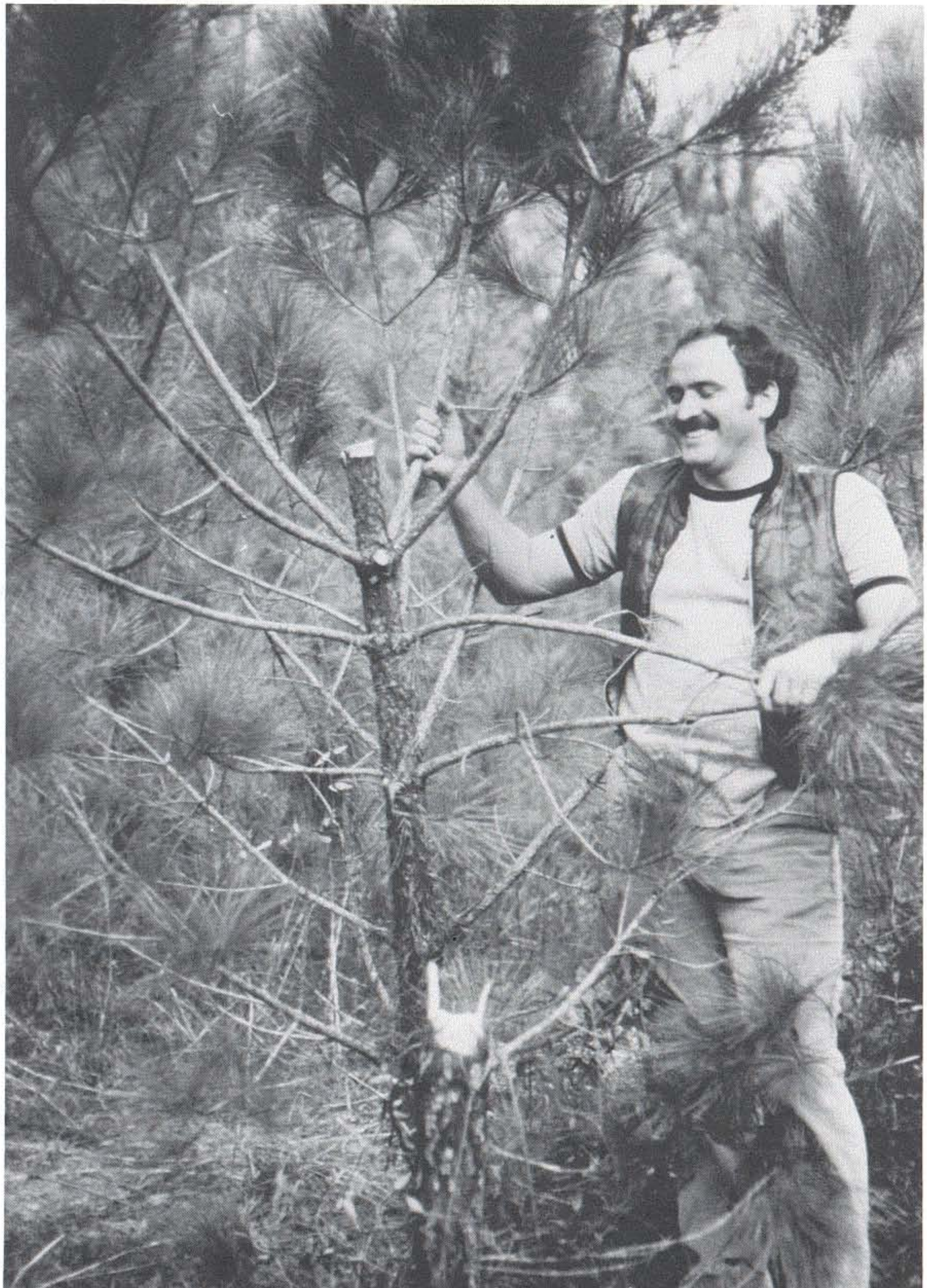
1) 24 bushels of SMP cones,

2) 36 lbs. of SMP seeds,

3) 360,000 SMP seedlings, and

4) regeneration of 600 acres.

If SMP were only 70% successful, all of these acres could be expected to have 18-20% more rust-free trees than rogued seed orchard seeds.



"Christmas Tree Rustlers" decapitated progeny test trees in a Brunswick test. James Hodges decided it was better to smile than cry!

Index Selection

Selection indexes can be constructed using multiple regression techniques to combine the information on several traits and/or relatives to determine the best trees for breeding or for use in seed orchards.

All the information on traits and family is currently used by the Cooperative in selection. However, the weight given to each trait and the relative weight given to family and individual performance is subjective. That is, it is not quantified as it must be in constructing a selection index.

The fact that the relative weights for each kind of information used in selection are not known, means that we have been unable, thus far, to accurately forecast future genetic gains. Most gain forecasts have been based on calculations assuming that we select for each trait individually without consideration for the others. Thus, estimates of gain may be too large since gains for each trait will be less when other traits are considered. For example, it is not always possible to choose only the largest trees in a genetic test when straightness is also considered. Some slightly smaller trees must often be selected which are straighter than the largest trees. Selection has been done in this manner since the program began without knowing how much growth should be sacrificed to get desired gains in straightness and thus optimize the gain from selection.

The relative weight given to each trait in a selection index, called the relative economic weight, quantifies the economic value of changing each trait during selection. For example, previous work has shown that for small logs (6" to 11" d.b.h.) to be processed in a chip-n-saw mill, we should assign three times as much importance to increasing volume by one cubic foot as to improving tree straightness score by one unit. This does not mean that straightness is not important. These weights must be interpreted with care. A one-cubic foot increase in volume in a small tree is substantial on a percentage basis and might not be easily achieved through selection. However, these relative weights do give us a better idea of how much importance we should give to volume and straightness in selection.

These relative economic values have not been estimated before since they are not easy to obtain. The data from the chip-n-saw study summarized was based on mill studies done by Weyerhaeuser Company. (These results were reported in the Proceedings of the 15th SFTIC, 1979). Since relative economic weights may differ for different products, straightness may be relatively more or less important if plywood or lumber were the desired product. A mill study is required for each product option.

Dr. Cheryl Busby Talbert analyzed the data from two such studies during 1983 as part of her Ph.D. dissertation study at N. C. State University. She estimated relative economic values for tree heights, diameters, volumes, and straightness scores when plywood and lumber were the desired products. The plywood data were kindly supplied by Doug Phillips of the U. S. Forest Service, and the sawmill data were from a study conducted jointly by Hammermill Paper Company and the N. C. State Cooperative. Cheryl estimated the relative economic weights below.

Table 14. Relative Economic Weights for Volume and Straightness Score for Lumber and Plywood.

	Lumber	Plywood
Volume	0.4	0.7
Straightness Score	1.0	1.0

The relative economic weights shown in Table 14 mean that an increase of one cubic foot of volume is worth 0.4 times as much as improving straightness score by one unit when the desired product is lumber. Increasing volume is relatively more important than improving straightness when plywood is the desired product. Conversely, this means that improving straightness is relatively more important for lumber producers. This is reasonable when one realizes that sweep or crook can be more easily merchandized out when 8.6' plywood bolts are produced than when 8' to 20' logs are used to produce sawn lumber.

Future research will be aimed at synthesizing the data from pulp, chip-n-saw, lumber, and veneer studies to determine how we might improve the selection process to increase genetic gains.

Measuring Fusiform Rust Infection

An intensive analysis of first generation progeny test data has been initiated to determine what should be measured and when it should be measured in the next generation of genetic testing. Although work is not complete, one interesting result has surfaced in the analysis to date.

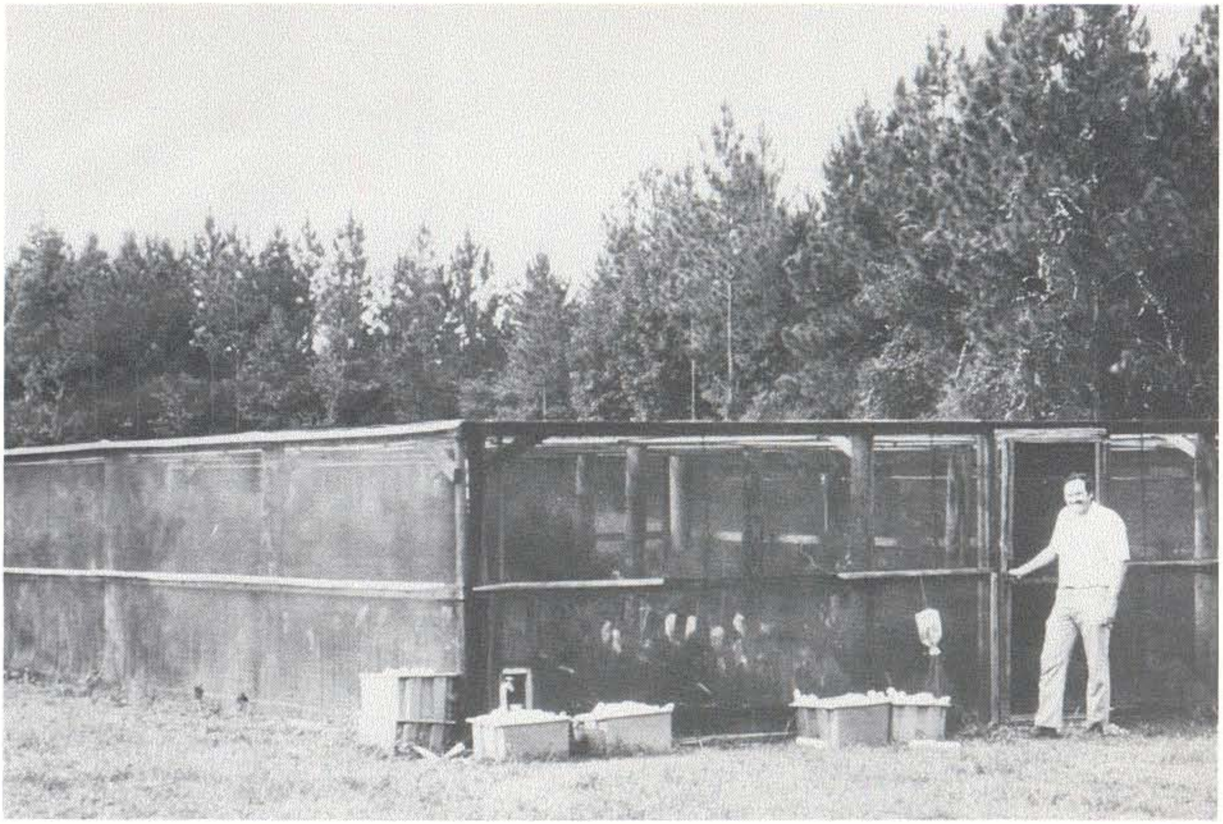
Rust assessment in first generation progeny tests consists of two component parts: 1) percent infection and 2) cronartium score (c-score), a five point severity index. Analyses summarized in Table 15 show conclusively that ratings based on c-score and percent infection are so closely correlated that they give the same answer. Simply put, the same winners and losers will be chosen regardless of which rating system is used. It is remarkable that over a rather wide range of test infection levels (21% to 92%), the average correlation between c-score and percent infection was equal to 0.91.

Table 15. Correlation of % rust infection with cronartium score for 16 Cooperative Program Progeny tests measured at age 8.

Cooperator	Test	Test % Rust	Correlation* Coefficient
Champion, S. C.	1966 Piedmont Main	92	0.66
	1970 Piedmont Main	89	0.88
International Paper Co.	1971 Coastal Main	56	0.96
Federal	1967 Piedmont Main	61	0.94
Georgia Kraft	1972 Piedmont Main	60	0.95
	1972 Piedmont Supp.	49	0.94
	1973 Piedmont Main	56	0.95
	1973 Piedmont Supp.	66	0.91
	1974 Piedmont Main	66	0.96
	1974 Piedmont Supp.	29	0.84
Weyerhaeuser	1966 Coastal Main	21	0.90
	1967 Coastal Main	30	0.89
	1969 Coastal Main	39	0.94
Kimberly Clark	1966 Piedmont Main	50	0.93
	1967 Piedmont Main	42	0.91
	1968 Piedmont Main	24	0.97
	Average Correlation Coefficient r = 0.91		

*All correlations are statistically significant with probability of greater r equal to or less than .001.

Considerable research must still be done before we know how to best handle rust assessment in the future. Such questions as when to measure rust infection, and how important is rust associated mortality when determining genetic resistance, remain unanswered. We are also seeking to determine how best to utilize field testing in combination with artificial screening for rust in the U. S. Forest Service Resistance Screening Center. However, the above results indicate that assessment of fusiform rust in field tests can be simplied.



Shown is Brunswick Pulp and Land Company's shade house and the succulent tissue-summer grafting work conducted in this facility.

In Vitro Studies of Fusiform Rust Resistance

Graduate research assistant John Frampton (now Assistant Professor with the Tissue Culture Project) recently completed his Ph.D. Thesis involving *In vitro* studies of fusiform rust resistance. *In vitro* means in the "test tube" or a laboratory study as opposed to *in vivo* which would indicate the more normal greenhouse or field trials. John's work revealed potentially promising resistance screening techniques that are summarized below.

To complement the field testing of progeny from select trees for fusiform rust resistance, a greenhouse method of assessing resistance using artificial innoculations has been developed and is currently used by the U. S. Forest Service Resistance Screening Center. Select trees are rated on the basis of the percent of their half- or full-sib progeny that become galled after innoculation. This measurement alone generally accounts for little of the variation in family field resistance for loblolly pine (r-square = 0.24 for one study). However, additional symptom types have recently been considered, which used in conjunction with percent seedlings galled, account for considerably more of the family field resistance (r-square = 0.60 for one study).

Experiments utilizing *in vitro* innoculation techniques offer many potential benefits over greenhouse and field studies. Through the use of *in vitro* techniques, environmental factors can more precisely and easily be controlled allowing for greater expression of genetic differences in resistance as well as better assessment of environmental factors on resistance expression and disease development. *In vitro* studies involving cloned pathogen and/or cloned host material are feasible and could enhance genetic studies of host-pathogen relationships. But perhaps the most important aspect of in vitro technology is the potential to develop methods of reliably screening seedlots for resistance. Such technology would undoubtedly be more rapid and less expensive than traditional screening methods and offer the potential to better understand and catalogue resistance mechanisms existing in the host populations.

Twelve loblolly pine embryos from each of 24 full-sib families (arranged in a 3 x 8 factorial mating design) were innoculated in vitro with basidiospores of the fusiform rust pathogen. Histological assessment of two types of responses, rapid incompatible necrosis and the appearance of a red staining substance at the innoculation point, were made. From this work and also from the work done by others, these two responses were regarded as the expression of effective resistance reactions. The first response, rapid necrosis was characterized by the rapid death of host tissue and often resulted in fungus necrosis. This response showed significant family differences and family rankings corresponding to field resistance. The second, presence of a red staining substance, appeared to barricade the fungus from entering the cell. Combinations of these traits explained much of the variation in family field resistance ratings at age four. Four and five variable regression equations were developed with R-square values ranging between 0.86 and 0.98. Some of these traits showed moderate to high family heritability estimates which suggests that development of a rapid in vitro resistance screening technique is very promising.

The work summarized above utilized the tedious and time consuming work of histology (microscope slide preparation). An additional study indicated the possibility of avoiding this tedium by developing a set of easily assessed macroscopic symptoms that might be useful for screening purposes.

Further, it may be possible to develop a biochemical assay to detect the presence and degree of rapid necrosis which appears to be associated with compounds that are most likely of phenolic origin. Biochemical assays for the presence and degree of the red staining substance may also be possible. Thus, the tedium and time involved in histological preparation and assessment could be bypassed. Another potential enhancement would be the development of techniques to successfully infect and assess callus of loblolly pine. Select trees could be directly screened rather than their progeny. Unfortunately, attempts to date to innoculate callus *in vitro* have proven unsuccessful.

In conclusion, the future of developing an *in vitro* method of screening loblolly pine for resistance to fusiform rust is promising. Coupled with the developing tissue culture technology such a method may provide the tree breeder with an effective and rapid method of obtaining substantial genetic gains in fusiform rust resistance.

Genotype by Environment Interactions for Piedmont and Mountain Sources

Past studies have shown little difference between Piedmont and Mountain sources in average performance, but the possibility of a significant amount of family by environment interaction is a concern. If the Piedmont and Mountain families perform differently in different test environments, erroneous conclusions could be made. For example, if families that performed well in Piedmont test locations did not perform well in the Mountains or vice versa, an important genotype by environment interaction would exist. Existence of such a genotype by environment interaction could require separate breeding and testing programs as well as production seed orchards. If, however, Piedmont families perform the same relative to each other in both Piedmont and Mountain locations, and if Mountain families perform the same in the Piedmont and Mountains, significant savings in breeding, testing and orchard establishment would result. No genotype by environment interaction would imply that performance in either location (Piedmont or Mountain) is a reliable indicator of performance in both locations.

Starting in the early 1970's, Georgia-Kraft planted at least one of its Piedmont source supplemental progeny tests in the mountains of north Georgia. The main Piedmont tests were planted in the Piedmont. Likewise, in the late 1970's, at least one of the Mountain source supplemental tests was planted in the Piedmont with the main Mountain tests established on a Mountain site. These tests provided a comparison of the same crosses planted in both Piedmont and Mountain locations.

Several tests were selected for analyses based on the following criteria:

1. Survival greater than 75%.
2. A reasonable level of precision in the test (i.e. not a great deal of within replication environmental variation as measured by the coefficient of variation).
3. An adequate number of common crosses (usually 25-30).

A summary of the tests analyzed is shown in Table 16. Rust infection was high in most tests. Rust levels between 30% and 70% are ideal for discriminating among families. In the tests where rust was above 20%, family differences were very large. In the tests where rust was under 10% (1977 Mountain Main, 1979 Mountain Main and Supp. #1), the differences among families were small and not significant.

Table 16. Test Means for Traits Analyzed in Georgia-Kraft's G x E Study.

Georgia-Kraft Tests	Trait Means						
	% Survival	Height (ft.)	DBH (in.)	C-Score	% Rust	Crown	Straightness
1972 Piedmont (Age 8)							
Main-Putnam Co., GA (Pied.)	87.9%	23.7	4.3	2.3	59.8%	3.9	3.7
Supp.#1-Dawson Co., GA (Lower Mtn.)	89.6%	22.1	4.3	1.9	49.3%	3.9	3.9
Supp.#2-Crawford Co., GA (Pied.)	81.6%	16.2	2.9	1.5	31.4%	4.0	3.8
Supp.#3-Putnam Co., GA (Pied.)	84.9%	20.9	3.7	2.4	59.5%	3.7	3.6
1973 Piedmont (Age 8)							
Main-Hancock Co., GA (Pied.)	94.7%	20.5	3.8	2.1	55.7%	3.6	3.4
Supp.#1-Cherokee Co., GA (Lower Mtn.)	92.0%	20.3	3.8	2.6	65.7%	3.8	3.9
Supp.#3-Floyd Co., GA (Mtn.)	83.3%	20.4	4.5	1.2	14.9%	4.2	3.9
1974 Piedmont (Age 8)							
Main-Hancock Co., GA (Pied.)	81.1%	17.0	3.1	3.0	66.1%	3.9	3.9
Supp.#2 Floyd Co., GA (Mtn.)	79.4%	22.3	4.5	1.6	28.8%	3.7	3.5
1975 Piedmont (Ages 4 & 5)							
Main-Hancock Co., GA (Pied.)	89.6%	7.7	-	1.8	24.5%	4.0	3.9
Supp.#1-Crawford Co., GA (Pied.)	93.8%	8.0	-	1.8	24.9%	4.1	4.1
Supp.#2-Floyd Co., GA (Mtn.)	90.2%	10.7	-	1.7	20.3%	4.1	3.9
1977 Mountain (Ages 5 & 6)							
Main-Murray Co., GA (Mtn.)	75.8%	9.5	-	1.0	0.5%	3.9	3.6
Supp.-Greene Co., GA (Pied.)	86.2%	9.1	-	1.8	29.1%	3.8	3.5
1979 Mountain (Age 4)							
Main-Chattooga Co., GA (Mtn.)	94.4%	9.5	-	1.1	7.3%	3.9	3.8
Supp.#1-Jasper Co., GA (Pied.)	95.0%	7.8	-	1.1	4.3%	3.9	3.5

Table 17 summarizes with correlation analyses the relative performance of families tested in the Piedmont with the same families tested in the Mountains. Most of the correlations are moderate to high. Any one correlation is not terribly important, but the average correlations are most revealing:

Height	$\overline{r}$ = .57
DBH	$\overline{r}$ = .40
C-Score	$\overline{r}$ = .65
% Rust	$\overline{r}$ = .64
Crown	$\overline{r}$ = .46
Straighteness	$\overline{r}$ = .61

The correlation of rust resistance across the tests was reasonably high (excludes the 1977 and 1979 Mountain tests) which indicates we are doing a good job of identifying resistant crosses in tests where the rust levels are sufficient for identifving family differences. As expected, height was more highly correlated across tests than DBH. Height is under more genetic control than diameter and, thus, has a higher correlation.

Crown scores were not as repeatable across tests as straightness scores. Several reasons for this can be proposed. Crown is extremely difficult to score on young trees and is highly subjective. Crown score is not as strongly inherited as stem straightness.

When evaluating these correlations of family performance in Piedmont and Mountain locations, it is worth considering whether these correlations are similar to what would result if Piedmont tests were compared to Piedmont tests, or if Mountain tests were compared to Mountain tests. To address these concerns, analyses were done, the results of which are

Table 17. Correlation of Family Means on Piedmont Sites with Family Means on Mountain Sites.

Georgia-Kraft Tests Being Compared	Correlation Coefficients of Cross Means for Piedmont and Mountain Tests for Traits: % Survival[1/]	Height	DBH	C-Score	% Rust	Crown	Straightness
1972 Piedmont Tests (Age 8) Main-Putnam Co., GA (Pied.) with Supp.#1-Dawson Co., GA (Lower Mtn.)	-0.03^{NS}	0.69^{***}	0.60^{***}	0.81^{***}	0.82^{***}	0.64^{***}	0.69^{***}
1973 Piedmont Tests (Age 8) Main-Hancock Co., GA (Pied.) with Supp.#1-Cherokee Co., GA (Lower Mtn.)	0.10^{NS}	0.55^{***}	0.31^{*}	0.91^{***}	0.87^{***}	0.46^{***}	0.60^{***}
1974 Piedmont Tests (Age 8) Main-Hancock Co., GA (Pied.) with Supp.#2 Floyd Co., GA (Mtn.)	0.55^{***}	0.44^{*}	0.29^{NS}	0.21^{NS}	0.23^{NS}	NA	0.51^{***}
1975 Piedmont Tests (Age 5) Main-Greene Co., GA (Pied.) with Supp.#2-Gilmer Co., GA (Mtn.)	0.22^{NS}	0.41^{*}	-	0.66^{**}	0.66^{***}	0.30^{NS}	0.64^{***}
1977 Mountain Tests (Ages 5 & 6) Main-Murray Co., GA (Mtn.) with Supp-Greene Co., GA (Pied.)	0.22^{NS}	0.78^{***}	-	NA	NA	0.52^{**}	0.63^{***}
1979 Mountain Tests (Age 4) Main-Chattooga Co., GA (Mtn.) with Supp.#1-Jasper Co., GA (Pied.)	0.18^{NS}	0.55^{***}	-	NA	NA	0.37^{**}	0.56^{***}
Average Correlation	0.22	0.57	0.40	0.65	0.64	0.46	0.61

[1/] Correlation for % survival is usually low since there is little variation in survival (i.e. survival > 80%).

NS = not significant at p = .05, * = significant at p = .05, ** = significant at p = .01, *** = significant at p = .001

NA = not applicable, no significant cross difference exist in one or more tests being compared.

presented in Table 18. The correlations were moderate to high depending on the trait. The average correlations between sites within regions were essentially the same as those for sites between regions.

The only traits with meaningfully different correlations appear to be DBH and Crown score. DBH correlations are suspect because of the small number of tests used in the analyses. Crown score is probably higher when only the Piedmont locations are compared since these are mainly 8 year-old tests. The Piedmont-Mountain comparisons include 4, 5, and 6 year-old tests. At young ages, crown score is imprecise.

A final comparison was made to see how families in Main tests compared to each other in different years. This gave another indication of the average correlation of Piedmont tests with Piedmont tests and Mountain

Table 18. Comparison of average correlation coefficients of family means from sites in different regions and from sites within regions.

	Average Correlation Coefficients	
Trait	(Pied. with Mtn.)[1/]	(Pied. with Pied.) (Mtn. with Mtn.)
Height	$\bar{r}$ = .57	$\bar{r}$ = .54
DBH	$\bar{r}$ = .40	$\bar{r}$ = .58
C-Score	$\bar{r}$ = .65	$\bar{r}$ = .69
% Rust	$\bar{r}$ = .64	$\bar{r}$ = .71
Crown	$\bar{r}$ = .46	$\bar{r}$ = .64
Straightness	$\bar{r}$ = .61	$\bar{r}$ = .65

[1/] From Table 17.

tests with Mountain tests. Average correlations from the three sets of analyses are shown in Table 19. The results from the final analyses were quite comparable to those previously obtained. Growth, rust resistance, and form can be reliably predicted for a family whether grown on a Piedmont site or on a Mountain site. One qualification exists for a meaningful rust evaluation. The tests must be established in an area with sufficient rust infection (30-70%) to obtain a meaningful evaluation of families.

Table 19. Comparison of average correlations of family means between regions and within regions. Within region correlations are shown between locations only, and between locations and years combined.

	Average Correlation Coefficients		
Trait	(Pied. with Mtn.)[1]	Locations Only[2] (Pied. with Pied.) (Mtn. with Mtn.)	Locations and Years (Pied. with Pied.) (Mtn. with Mtn.)
Height	$\bar{r}$ = .57	$\bar{r}$ = .54	$\bar{r}$ = .52
DBH	$\bar{r}$ = .40	$\bar{r}$ = .58	$\bar{r}$ = .51
C-Score	$\bar{r}$ = .65	$\bar{r}$ = .69	$\bar{r}$ = .73
% Rust	$\bar{r}$ = .64	$\bar{r}$ = .71	$\bar{r}$ = .74
Crown	$\bar{r}$ = .46	$\bar{r}$ = .64	$\bar{r}$ = .65
Straightness	$\bar{r}$ = .61	$\bar{r}$ = .65	$\bar{r}$ = .76

[1]From Table 17.

[2]From Table 18.

Forest Tree Improvement Book

We are delighted to announce that the long awaited book entitled Applied Forest Tree Improvement authored by Bruce J. Zobel and John T. Talbert has been recently published by John Wiley and Sons Publishing Company. As most of you know, Bruce Zobel has over 30 years experience in tree improvement in the southern U.S. as well as around the world. Bruce was the Director of the N. C. State Tree Improvement Cooperative for the first 21 years. John Talbert, coauthor of the book, served as liaison geneticist with the Cooperative for nearly six years.

As Bruce and John wrote in the preface "The objective of our book is to consolidate and summarize the concepts that are necessary for useful and efficient operational tree improvement programs." The book concentrated on the practical, rather than on the more theoretical and statistical aspects. Much of the information presented comes from experience obtained from the cooperative tree improvement programs in the southeastern United States, and many examples used in the book involve pines. The book has been written for three distinct audiences: 1) students, 2) personnel of tree improvement programs, and 3) forest management personnel. We believe this book to be a useful and informative addition to many libraries. We commend Bruce and John for a very difficult task well done.

Graduate Student Research and Education

The education of graduate students and the research they conduct in conjunction with their degree program is an important activity of the Cooperative. During the past year, 16 students have been involved in graduate studies in close association with the Tree Improvement Cooperative. Five have been pursuing Masters degrees and eight were involved in Ph.D. programs. Of special note is the completion of degree programs by six students in the last year. In addition, we had the pleasure this past year of working with two students on one year special projects. Steve Lee, from Scotland, will return to manage the progeny testing program for the United Kingdom Forestry Commission. Guy San Fratello will upon completion of his year of special study return to manage aspects of the South Carolina Commission of Forestry Tree Improvement Program.

In addition to the work with students on their respective research programs, Cooperative staff members were invited to lecture in a variety of graduate and undergraduate courses during the year. Numerous seminars on aspects of tree improvement were conducted by members of the staff.

The graduate students working in association with the Cooperative, the degree to which each aspires and the subject of their research project are listed on the following page. The student research projects encompass a wide range of subject matter, but in each case, the work is supportive of the 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, industry-sponsored fellowships, and foreign governments.

Student	Degree	Research Project
Robin Arnold	Masters	An economic analysis of rust resistance alternatives with loblolly, shortleaf and loblolly x shortleaf hybrids
Sheryl Brown	Masters	A detailed study of the pollination mechanism of loblolly pine (completed)
Cheryl Busby	Ph.D.	Developing a multi-trait selection index for loblolly pine (completed)
Bruce Emery	Ph.D.	Intensive roguing of seed orchards
John Frampton	Ph.D.	In vitro studies of Disease resistance in loblolly pine (completed)
Mike Harbin	Masters	Seed source studies involving Florida source loblolly pine (completed)
Gary Hodge	Ph.D.	Cold tolerant loblolly pine
James Hodges	Masters	Genotype-fertilizer interaction studies of slash pine
Randy Johnson	Ph.D.	Genetic variation in nitrogen uptake and utilization in loblolly pine (joint student with Fertilizer Coop)
Steve Lee	None	Special one year study in genetics with emphasis on progeny testing
Bialian Li	Masters	Geographic variation of Fraser fir
Guy San Fratello	None	Special one year study in genetics with emphasis on seed orchard establishment and management
Richard Sniezko	Ph.D.	Hybrid vigor resulting from outcrossing S_1 loblolly pines (completed)
Jarbas Shimizu	Ph.D.	Genotypic competitive effects in loblolly
Claire Williams	Ph.D.	Early selection in loblolly pine
Lisa Wisniewski	Masters	Discriminate analysis used to classify rust resistance classes (completed)
Lisa Wisniewski	Ph.D.	Physiological studies of rejuvenation in loblolly pine

Program Staff

Listed below are Cooperative program staff members. The program is fortunate to have such a dedicated and capable group working as a team. The faculty level staff and those listed under support staff work full time on Cooperative activities except where noted otherwise by an asterisk. These laboratory and field technicians have joint appointments with Tree Improvement and one other cooperative program.

Faculty-Level Staff

Bob Weir - Director
J. B. Jett - Associate Director
Steve McKeand - Geneticist
Jerry Sprague - Liaison Geneticist

Associated Appointments

Floyd Bridgwater - U. S. Forest Service
John Frampton - Tissue Culture
Bruce Zobel - Professor Emeritus

Support Staff

Alice Hatcher - Coordinator
Data Processing & Secretarial
Rosina Rubes
Judy Stallings
Jackie Evans

*Vernon Johnson - Coordinator
Laboratory & Field Technicians
*Addie Byrd
*Greg Ferguson

In the last year, two changes occurred in the ranks of the faculty level positions associated with the Cooperative. Liaison Geneticist, John Talbert resigned to pursue an M.B.A. at the University of Washington. John's position was filled by Dr. Steve McKeand who is now serving as Geneticist and Assistant Professor on the Cooperative staff. Steve is no stranger to the Cooperative having spent nearly four years with the Special Project on Tissue Culture, a joint research program between the Departments of Forestry and Botany. The second change occurred when Dr. John Frampton was hired to replace Steve. John is responsible for the design and establishment of greenhouse and field studies of vegetative propagules developed in the Tissue Culture laboratories. Results of this work will have a major impact on opportunities for increasing genetic gain in future generations. We also note two additional associated appointments that make important contributions to the program. Dr. Floyd Bridgwater is employed by the U. S. Forest Service's Southeastern Forest Experiment Station and is 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 mutually beneficial to both organizations. Floyd is also working with several graduate students. The second associated appointment is Dr. Bruce Zobel who continues to work half-time with the Forestry Department concentrating mostly on teaching and graduate student programs.

MEMBERSHIP OF THE 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.
Buckeye Cellulose Corp.	Ga.
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	Brewton--Ala., Fla. Fernandian Beach--Fla., Ga.
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 Forest Seed Company	Miss., Ala., Fla., Ga., S.C.
International Paper Company	Atlantic Region--N.C., S.C., Ga. Gulf Region--Miss., Ala.
Kimberly-Clark Corporation	Ala.
Leaf River Forest Products Co.	Ala., Miss.
MacMillan-Bloedel Corporation	Ala., Miss.
North Carolina Forest Service	N.C.

MEMBERSHIP OF THE 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., Franklin Div.--N.C., Va. Alabama Div.--Ala.
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.

During the past year, Leaf River Forest Products Company acquired the seed orchard and a significant portion of the land base formerly owned by Masonite Corporation. Membership in the Tree Improvement Cooperative was assumed by Leaf River. A smooth transition has been assured by the fact that Jerry Breland and Tommy Sims, advisory committee member and contactman respectively for Masonite, have assumed the same responsibilities for Leaf River Forest Products. We welcome Leaf River working out of New Augusta, Miss. to the Cooperative Program. Additional working units have been added to the Cooperative in the last year by Union Camp and Container Corporation. Union Camp added their Alabama Division to the Cooperative, and Container joined with their Fernandina Beach, Florida program (lands are in south Georgia and Florida).

Effective July 1, 1983, the Cooperative added its newest member, International Forest Seed Company located in Birmingham, Alabama. "IFSCO" has already made excellent progress in breeding the most rust resistant selections in the Cooperative. They intend to accelerate the breeding and testing of rust resistant trees through several generations as rapidly as possible. Selections developed in this accelerated recurrent selection program will be available for members to use in advanced generation disease resistant orchards. "IFSCO" also intends to market rooted cuttings of the most rust resistant selections. We welcome International Forest Seed Company to the program and commend them on the rapid progress made to date.

Current membership of the Cooperative includes 26 forest based industries and the forestry organizations of three states. Among the industry members, there are 11 supplemental units bringing the total membership to 40 working units.

PUBLICATIONS OF SPECIAL INTEREST TO MEMBERS OF THE COOPERATIVE

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