THIRTIETH 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. The 1985 harvest of cones and seeds was the fourth largest in program history.

   a. Members of the Cooperative harvested 52,155 bushels of loblolly cones from which 37.8 tons of seeds were extracted.

   b. Second generation orchards of the Cooperative produced 2,619 pounds of seed.

   c. Second generation orchard production has been sufficient in the last four years to reforest 155 thousand acres of land.

   d. Champion International's first generation coastal orchard at Tillery, N. C. set a new record of 2.36 pounds of seed per bushel of cones.

2. Analysis of first generation progeny test data has been done to guide recommendations for advanced generation test measurement schedules and procedures.

   a. Advanced generation tests will be measured one time at age six.

   b. Traits to be assessed include tree height, fusiform rust (presence or absence) and stem straightness (above or below average).

3. The proportion of total selections available in a breeding region is a determining factor for optimal seed orchard establishment time.

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

   a. Succulent tissue (summer) grafting in a greenhouse can be successfully done using wax grafting methods.

   b. Pollen germination is very sensitive to moisture contents ranging below 15%, and tests will give erroneous germination results unless pollen dried below 15% MC is rehydrated.

   c. The performance of unimproved seed lots from Livingston Parish, LA, Marion County, FL, Gulf Hammock, FL and Eastern Shore, MD were compared using eight year data from the good general combiner tests. While some promising opportunities are revealed, we must be cautious not to place too much emphasis on results of source trials prior to half rotation.

   d. Florida sources of loblolly show higher susceptibility to pitch canker than Lower Gulf or South Atlantic Coastal Plain sources.

5. A total of 13 graduate students are working in association with the Cooperative on M.S. and Ph.D. programs.

6. A total of 29 members operate 41 working units in the Cooperative program.

INTRODUCTION

The North Carolina State University-Industry Cooperative Tree Improvement Program has completed 30 years of operation. Progress has been substantial through this period. Starting with eleven charter members in 1956, program support has grown to 29 members operating 41 working units. All eleven of the charter members remain active in the tree improvement program.

Program members manage 20 million acres of forest land and produce 600 million genetically improved loblolly pine seedlings each year. Seedling production by Cooperative members represents 40% of the trees planted in the United States annually. Program members have reforested over 10 million acres with genetically improved seedlings which are expected to yield 7 to 12 percent more volume at age 25 which will in turn generate 18 to 32% more value per acre when fully merchandized at harvest. One hundred and fifty-five thousand acres have already been planted with second generation genetically improved seedlings of loblolly pine. Members are aggressively pursuing the breeding and testing of second generation and plantation selections to form the foundation for a third cycle of improvement. Plans have been formulated and implemented to provide a sound basis for continued improvement well into the 21^{st} century.

Members of the Cooperative can be proud of the accomplishments of the last 30 years. The success which has been achieved through the Cooperative is the result of unwavering commitment, strong financial support and true cooperation among member organizations. We are now poised on the threshold of a new cycle of genetic improvement, a cycle which promises to yield benefits far exceeding those of the first 30 years. While we are comfortable with past accomplishments, we are eager to accelerate our efforts in the future.

SEED ORCHARD PRODUCTION

Cone and Seed Yields

The 1985 harvest of cones and seeds from loblolly pine seed orchards was the fourth largest in program history (Table 1). A total of 52,155 bushels of cones were harvested from which 37.8 tons of genetically improved seeds were extracted. This harvest is sufficient to produce 605 million seedlings which is slightly above the annual seedling needs of the membership.

The fourth largest crop in program history has been characterized by many as a "poor" year. We have become "spoiled" with outstanding seed production in seven of the previous eight years. It is apparent from the yields in Table 1 that 1985 was dramatically lower than the record harvest of 1984. Overall loblolly seed production fell from the record 80.1 tons to 37.8 tons, a 52% drop. While many individual orchards experienced yield reductions on a per acre basis of more than 52%, these reductions were offset in the total program figures by new and younger orchards beginning their first meaningful production.

Table 1. Production of cones, seeds and seedlings from Cooperative members' loblolly pine seed orchards over the last 8 years, including an estimate of acres that could be regenerated with improved seedlings if all the seed were used.

Harvest Year	Bushels of Cones	Tons of Seeds	Millions of Seedlings	Millions of Acres Regenerated
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
1984	105,239	80.1	1,281	2.14
1985	52,155	37.8	605	1.01
Totals	427,379	307.0	4,912	8.21

Production losses encountered in some individual orchards were due to insect attack. A surprise outbreak of Dioryctria merkeli destroyed 90% of the crop in one orchard and caused 40% to 50% losses in several orchards. We have doubled our efforts to monitor and control Dioryctria merkeli in these epidemic areas. Additional crop losses were attributed to drought and late spring cold injury to both male and female flowers in the spring of 1983. At least one orchard that has been a heavy producer, had production severely reduced from pitch canker (Fusarium moniliforme var. subglutinans) infection. At this time, we have no effective means to control the occasional pitch canker outbreak.

Table 2. Cone and seed yield comparisons for 1984 and 1985.

	Bushels of Cones		Pounds of Seeds		Pounds of Seed per Bushel of Cones	
Species	1984	1985	1984	1985	1984	1985
Loblolly Pine:						
Coastal 1st gen.	77,686	34,798	114,113	49,462	1.47	1.42
Piedmont 1st gen.	22,431	14,962	39,734	23,467	1.77	1.57
Coastal 2nd gen.	4,308	2,024	5,374	2,325	1.25	1.15
Piedmont 2nd gen.	814	371	947	294	1.16	0.79
Slash Pine:						
1st gen.	8,711	7,898	9,909	6,311	1.14	0.80
2nd gen.	96	20	93	2	0.97	0.12
Longleaf	3,018	1,022	2,494	535	0.83	0.52
Virginia	364	175	283	96	0.78	0.55
Sand	30	30	24	21	0.80	0.70
Shortleaf	76	21	64	16	0.84	0.76
Fraser Fir	218	16	704	54	3.22	3.37
Total All Conifers	122,756	61,337	177,371	82,583		

A comparison of cone and seed yields for the record setting 1984 year and the 1985 harvest of first and second generation loblolly orchards is presented in Table 2 along with statistics for six other conifer species in the program. The loblolly seed production in 1985 represented 92% of the total conifer seed harvested. Virtually all species had smaller seed crops in 1985. White pine cone and seed production was not noted in the table because white pine cone beetle attacks eliminated the entire cone crop. Scientists with the U. S. Forest Service are helping to develop control measures for this devastating insect.

Table 3. Second Generation Seed Orchard Yields.

	Loblolly Pine	
Year	Bushels of Cones	Pounds of Seed
1982	692	763
1983	1,611	1,966
1984	5,122	6,321
1985	2,395	2,619

Second generation cone and seed production statistics from 1982 through 1985 are listed in Table 3. In this four year period, a total of 11,669 pounds of second generation loblolly seeds have been produced, which is enough to produce 93 million seedlings and to regenerate nearly 155 thousand acres. Production sufficient to meet total regeneration requirements from the second cycle of improvement is fast becoming a reality.

Production Leaders

Once again, we are pleased to recognize those cooperators who have set the standards for excellence in seed production. In 1985, an "off" production year for many, a new record was set for pounds of seed per bushel of cones. Champion International's first generation coastal orchard in Tillery, N. C. produced 650 bushels of cones on 20.5 acres from which 1537 pounds of seed were extracted. The record 2.36 lbs/bu yield broke the previous high of 2.30 lbs/bu also set by the folks at Champion in 1982. Congratulations are in order for the orchard managers, Ray Brown (now retired) and Marc Davison, for breaking their own record.

Other outstanding yield figures noted for the 1985 harvest included:

- Westvaco Corp. - 2.06 lbs/bu from 1200 bushels harvested in their Virginia piedmont orchard
- Great Southern Paper Co. - 2.01 lbs. per bushel, placing them among the production leaders for two consecutive years
- South Carolina Commission of Forestry - 1.99 lbs. per bushel

Several cooperators who harvested and extracted seeds by clone experienced seed yields approaching three pounds per bushel of cones for some specific clones. Effective orchard management practices have allowed cooperative members to realize production efficiencies once thought to be impossible. Congratulations to all the production leaders!

Greenhouse breeding facilities such as the above belonging to Westvaco Corporation have proven to be very effective in accelerating advanced generation breeding. Pete Wallace explains a pruning treatment designed to enhance flowering.

SELECTION, BREEDING AND TESTING

Breeding Work Intensifies

Members of the Cooperative have experienced excellent flower crops the last two years, thus accelerating progress toward our breeding and testing goals. Breeding on over 700 second generation selections and 3100 plantation selections is approximately 50% complete. The first field trials were established in 1982 and through the spring of 1986, 14 test series have been planted. Based on the current rate of progress, we expect that test establishment will peak about 1990.

Some interesting progress reports have been received during the last year. Pete Wallace, accelerated breeding facility manager for Westvaco, recently reported some outstanding seed yields from control pollinations. Westvaco averaged 106 sound seed per cone from a sample of 720 cones. This represents approximately 77% filled seed which is superb for control pollination work. The two best cones yielded 201 and 202 total seed per cone with average seed potential for these cones estimated at 211.

Pete Wallace also reported some preliminary efforts at dealing with "black" cones that occasionally occur in greenhouse breeding. He harvested the cones as soon as they showed symptoms of "blackening", dried them quickly and extracted the seed. Many of the seeds were not completely mature and may not store well. However, he obtained 52 sound seed per cone during his first efforts at this salvage operation. Experience has shown that, if allowed to proceed uninterrupted, the "blackening" process results in completely "mummified" cones and essentially no seed yield. Pete's process shows promise for reducing losses due to "black" cones.

With virtually all member organizations progressing rapidly in breeding and testing work, the Cooperative staff has focused on resolving

Packaging Corporation's containerized breeding efforts include an innovative approach of using a twin wire trellis to minimize wind throw of the potted trees.

questions pertaining to measurement and selection procedures for the advanced generation tests. The extensive analyses and subsequent recommendations are summarized in the following section.

Measurement and Selection Plans for Advanced Generation Tests

The second generation and plantation selection breeding and testing program will require a tremendous effort on the part of every Cooperative member. This cycle of breeding involves nearly 4000 selections, more than twice that of the first generation program. The size of the test population therefore requires that the breeding and testing program be as efficient as possible while not sacrificing essential information.

Several years ago, an analysis of first generation data was undertaken to determine the test design for the advanced generation program. This analysis showed that the plot size and number of locations could be reduced without adversely effecting the precision of test results. Based on this analysis, plot size was reduced from 10 trees per plot to six trees per plot, and the number of locations was reduced from six to four. This represented a 53% reduction in the number of trees required to test a given cross, which is a significant savings in both breeding and test establishment work.

During the past year, another analysis was undertaken to optimize measurement and selection in advanced generation tests. The analysis utilized first generation progeny test data to determine the optimum age for measurement and the optimum set of traits for assessment. In the next few pages, the procedures used for the analysis and the results obtained are discussed.

Optimization of Measurement and Selection Age:

The optimum selection age, and associated measurement age, are determined by a combination of biological and economic considerations. The biological factors determine gain per year efficiencies while economic considerations determine present value of the gains per year. Since the optimum selection age may differ depending upon whether gain per year or present value is optimized, both biological and economic factors have been considered.

Biological Considerations:

Data from 18 first-generation tests (Table 4) were used in the analysis to determine the biological optimum age for selection. These 18 tests were selected using the following criteria:

1. Tests had to have measurements available through age 12, and preferably through age 16.

2. Since tests with a high level of precision were desirable, tests selected were required to have a coefficient of variation for height (on a rep x family basis) of less than 15%.

3. Survival of at least 75% was required at age 8.

4. Tests with 20 or more crosses were preferred.

5. Six replication main tests were selected where possible.

6. A range of coastal and piedmont sites were to be represented in the subset selected.

7. Rust infection levels of at least 20% were required for those tests contributing to any analysis of fusiform rust.

Of the 18 tests selected, 15 met all seven criteria. Two tests with less than 20 crosses and one supplemental test (three replication test) were included in the subset since they had 16 year measurements. The majority of the tests in the final set had coefficients of variation of less than 10% and survival rates near 90%. We are confident that the tests selected are the best available for the desired analyses.

Table 4. Tests used to determine the biologically optimum age for measurement and selection in advanced generation tests.

First Generation Genetic Tests	Measurement Ages	# Crosses	Age 8 Measurements[1]: Coef. of Var. height (%)[2]	% Surv.	Height (ft.)	% Rust
1. 1966 SC Piedmont	4, 8, 15	18	3.7	93	26.6	92
2. 1970 SC Piedmont	5, 8, 12	56	6.0	84	25.5	89
3. 1971 SC Coastal	4, 8, 12	28	5.5	89	28.7	56
4. 1967 NC Piedmont	4, 8, 13	22	6.2	88	20.4	61
5. 1966 VA Coastal	4, 8, 14	24	9.1	91	21.5	1
6. 1967 VA Coastal	5, 8, 13, 16	35	7.6	80	21.1	0
7. 1969 VA Coastal	5, 8, 12	21	5.1	92	21.1	0
8. 1966 NC Coastal	4, 7, 14	43	11.8	88	12.2	22
9. 1967 NC Coastal	4, 8, 13	60	9.3	76	15.8	30
10. 1969 NC Coastal	4, 8, 12	58	8.3	88	21.1	39
11. 1966 AL Piedmont	4, 8, 14	29	7.6	95	17.9	50
12. 1967 AL Piedmont	5, 8, 13, 16	41	9.7	86	19.1	42
13. 1968 AL Piedmont	4, 8, 12	31	7.5	93	20.8	24
14. 1970 AL Piedmont	4, 8, 12	28	6.6	94	19.1	5
15. 1971 VA Coastal	4, 8, 12	56	13.1	95	20.2	10
16. 1967 GA Piedmont	4, 8, 13, 16	30	5.1	84	28.3	67
17. 1966 SC Coastal	4, 9, 13, 16	13	5.1	88	24.2	23
18. 1967 GA Coastal	4, 8, 12, 16	23	7.0	87	35.5	57
	Average	34		88	22.2	37

1/ May actually be 7, 8 or 9 years of age when measured.

2/ Coefficient of variation based on rep x cross interaction.

Data from these 18 tests were analyzed to compare the gains per year from family selection at different ages. Methods employed in the analysis were similar to those used by Lambeth (1980, Forest Science 26:571-580). The efficiencies for gain per year were calculated as the ratio of the correlated gain expected from juvenile selection to the gain expected from selection at "rotation age" taking into account differences in generation intervals. Rotation age was defined as 25 years for all analyses. The equation used in calculating the gain efficiencies is presented in Table 5.

Table 5. Equation used for calculation of gain efficiency.

$$E = \frac{Gain_{M|J}}{Gain_M} = \frac{i_J\, h_J\, h_M\, r_{G_{J.M}}\, \sigma_{P_M}}{i_M\, h^2_M\, \sigma_{P_M}} \times \frac{T_M}{T_J}$$

where: E = gain efficiency

$Gain_{M|J}$ = gain per year at rotation based on selection at juvenile age

$Gain_M$ = gain per year at rotation based on selection at rotation

i_J, i_M = selection intensity at juvenile and mature ages, respectively

$r_{G_{J.M}}$ = juvenile-mature family mean correlation

h_J, h_M = square root of family mean heritabilities at juvenile and mature ages, respectively

σ_{P_M} = phenotypic standard deviation at mature age

T_M = generation interval for mature selection = M + 10[1/] where M = 25

T_J = generation interval for juvenile selection = J + 10[1/] where J = 4,5,...12

[1/]Ten years were added to the generation interval to account for the time to complete the breeding for all diallels in a breeding region.

Since direct estimates of heritabilities and genetic correlations were unavailable, the intraclass correlation coefficient was used to approximate the heritability and the age-age cross mean correlation was used to approximate genetic correlations (see Fig. 1 and Table 6 for estimates). As long as the ratio of additive to non-additive variance does not change with age, the intraclass correlation coefficient (t), and the cross mean correlation are directly proportional to the heritability and genetic correlation. It is reasonable to assume that the ratio of the variances remains stable over ages and, thus, use of these approximations in the absence of direct estimates will not adversely effect the results of the analyses.

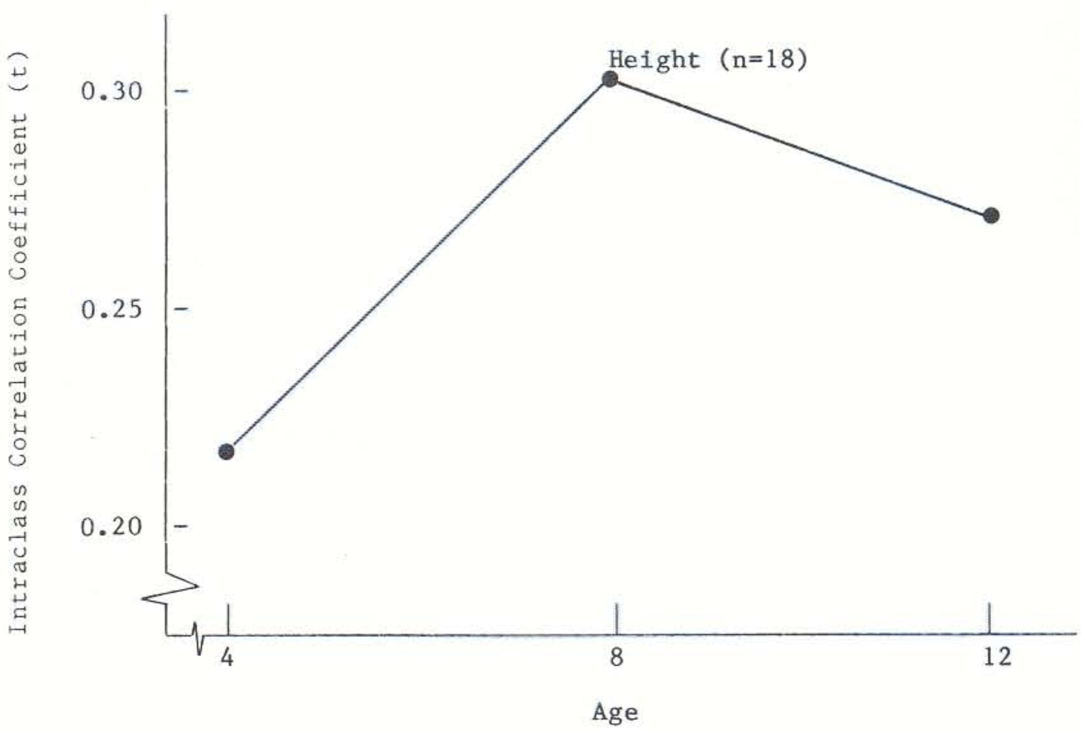

Figure 1. Intraclass correlation coefficients for height which approximate heritability at ages 4, 8 and 12.

Table 6. Predicted juvenile-mature family mean correlations for height.

Juvenile Age	$r_{J.25}$*	95% Confidence Interval	
		High	Low
4	.53	.69	.38
5	.59	.73	.45
6	.64	.76	.52
7	.68	.79	.57
8	.71	.81	.61
9	.74	.83	.65
10	.77	.85	.69
11	.79	.86	.72
12	.81	.88	.75

*Value estimated according to procedures outlined in Lambeth 1980. Forest Science 26:571-580.

In the analysis, the selection intensity at juvenile ages (i_J) was the same as selection intensity at maturity (i_m). Therefore, the efficiency equation from Table 5 was simplified as shown below.

$$E = \frac{h_J \, r_{J \cdot M}}{h_M} \times \frac{T_M}{T_J}$$

Genetic gain efficiency can then be estimated as a function of three factors:

- The ratio of genetic control at young and mature ages (h_J/h_M).
- The correlation or strength of association between genetic control at young ages and genetic control at maturity ($r_{J \cdot M}$).
- The ratio of time for the generation interval from mature selection and juvenile selection (T_M/T_J).

As genetic tests grow older, the correlation ($r_{J \cdot M}$) is expected to increase. However, the ratio of generation interval (T_M/T_J) will decrease with each additional year of delay in measurement and selection. When these factors are combined in the gain efficiency equation (E), an optimum age for selection can be determined (Figure 2).

The optimum age for family selection for height is age 8 when the goal is maximizing gain per year. Selection efficiencies calculated for rust and straightness at ages 4, 8 and 12 also showed age 8 to be the optimum age for family selection for those traits. Therefore, based on these estimates and assumptions, age 8 is the biological optimum age for family selection to maximize the gain per year.

Figure 2. Efficiency of family selection for tree height at ages 4 through 12.

In an attempt to determine the effect of changes in heritability and correlation estimates on the gain per year efficiencies, a sensitivity analysis was performed for height using a range of estimates for heritabilities and correlations. Both high and low juvenile-mature correlations derived from the 95% confidence interval were calculated and compared (Table 6). Gain efficiencies were evaluated with heritability (intraclass correlations shown in Figure 1) peaking at ages 8, 6 and 4, and remaining constant over ages.

When h_J/h_M and $r_{J \cdot M}$ were varied for the sensitivity analysis, the optimum age for selection varied from three to ten (Table 7). Selection before age six would only be justified if all heritabilities were equal or if heritability was maximum at age 4, and the juvenile-mature correlations were much higher than calculated. The likelihood of high heritabilities at very young ages (less than 4 years) in conventional field tests is low. Microsite variation, transplant shock, weed competition, tipmoth damage, seedling culture effects, and other environmental factors can cause extreme variation in very young genetic tests.

Table 7. Age at which the gain per year efficiency is maximized under different heritabilities and juvenile-mature correlations.

Heritability estimates	High estimate $r_{J \cdot M}$ (95% conf. int.)	$r_{J \cdot M}$ Actual estimate	Low estimate $r_{J \cdot M}$ (95% conf. int.)
	Age for Selection		
All equal	3	6	10
Peak at age 4	4	6	10
Peak at age 6	6	6	10
Peak at age 8	8	8	8

It is likely, however, that the advanced generation tests in the Cooperative will have higher heritability estimates for all traits at all ages. Intensive management of tests is being emphasized which will make tests more uniform (i.e. increase h^2), but it is possible that more rapid stand development will cause heritabilities to peak at earlier ages. If heritability peaks at age six rather than eight, selection at age six is the best alternative unless the juvenile-mature correlations are lower than actual estimates.

The actual values of $r_{J \cdot M}$ are very similar to estimates from other studies with loblolly pine. The impact of better test management in second generation tests on the age-age correlation is difficult to predict. Until more information is available on the effect of growth rate and stand development on juvenile-mature correlations, the values currently available should be used. With these values, age six or eight was the most efficient age for family selection (Table 7).

Economic Considerations:

It is informative to consider a present value analysis of the gain efficiencies previously discussed. The purpose of such analysis is to examine how sensitive the gain efficiencies are to the monetary value of time. Genetic gains determined for the younger selection ages (less than eight) are smaller, yet these gains may be more valuable because they are realized sooner. Additionally, in a long term multi-cycle, recurrent selection program, these smaller increments of gain from selection at younger ages can be realized more often.

The present value estimates of the gains per year (actually the relative efficiency values) for selecting on height at ages 4, 5, 6, 7 and 8 are shown in Figure 3. The trend shows an increase in present values with decreasing selection age. The results in Figure 3 were developed using a 6% interest rate; similar results were apparent for interest rates ranging from 2% to 10%.

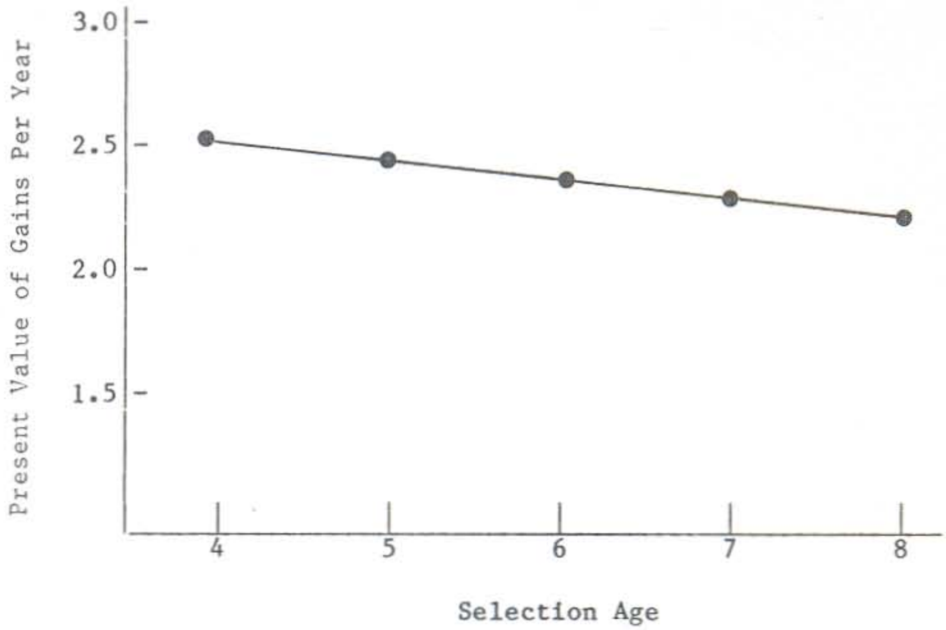

Figure 3. Present value of relative gains per year for height realized at different times.

It is important to emphasize that the values plotted in Figure 3 are present values, not net present values. The distinction is that present value examines only the benefit side of the equation, while net present value factors in the costs of breeding, testing, orchard establishment, orchard management, and seed harvest that are associated with each cycle of improvement. We must guard against following the trend displayed in Figure 3 to the point of choosing a selection age that is so young that gain per cycle will be economically unattractive in terms of net present value. A net present value analysis was not done for the general case of the Cooperative because each individual member has a different program size and, therefore, varying economies of scale. Variations in accounting systems and program management intensities add to the complexity of cost estimation, such that a general analysis becomes very difficult or, at best, of limited value.

Recommended Measurement and Selection Age:

Conclusions from the analysis of the biological factors indicate that selection at ages 6, 7 or 8 are near optimum for a reasonable set of assumptions. Present value analysis indicates a slight trend toward greater value from earlier selection. While the results of net present value analysis are not known, it is unlikely that they would support selection at very young ages where the gains per cycle are small and the risk of an unstable biological system is increased. All factors considered, it is recommended that advanced generation tests of loblolly pine in the N. C. State Tree Improvement Cooperative be measured one time at age six. This recommendation represents an aggressive posture, yet one that has an acceptably low risk of reducing long term gain.

Other factors were also considered when deciding on age six as the measurement age. The longer tests remain in the field, the greater the chance of loss from insect and disease outbreak, fire, and vandalism. In addition, trees older than six become increasingly difficult to measure, and the accuracy of measurements and precision of data analysis can decrease.

All loblolly pine tests in the Cooperative's advanced generation program will be measured at age six. When measurements are completed for all four tests in a test series, families from which selections are desired will be identified. These families will be screened to determine the best individual trees. Since the tests in a given test series are planted in each of two years, and selection lags one growing season behind measurement age, the individual trees will be seven and eight years of age at the time of selection.

Trait Assessment:

The same set of 18 progeny tests were also analyzed to help determine which traits should be measured to evaluate family performance. Family mean correlations among traits at age 8 are shown in Table 8. The age six data were not available from first generation tests but should be similar to age eight data.

Table 8. Cross mean correlations among traits at age 8.

	Height	% Rust	Straightness
DBH	0.75		
Volume	0.85		
% Rust	-0.13*		
C-score		0.97	
% Stem		0.84	
Straightness	-0.11*	-0.09	
Crown			0.66

*A negative correlation for % rust and straightness indicates a favorable relationship to height.

Clearly volume at rotation age is the growth measure we want to improve. In a general sense, height at a young age is as good an indicator of mature volume as early measurements of diameter or volume. However, diameter is influenced by missing trees or stocking variations in the stand, which is another way of saying it has low heritability or low genetic control.

The correlations reported in Table 8 show weak but favorable correlations between height and both % rust and straightness. The correlation between % rust and straightness is slightly negative. All of the correlations between these three traits are very small and can be considered to be essentially zero.

Fusiform rust infection in first generation progeny tests was assessed using a five point severity index. The correlations between both cronartium score and percent stem infection with rust infection (presence or absence of rust) are extremely high. All three traits, therefore, provide essentially the same rust information.

Form was assessed in first generation tests by separately scoring crown and straightness. A favorable correlation between crown and straightness of .66 was obtained from the 18 tests used in the analysis.

Based on the correlation analysis among traits, it is recommended that measurements in advanced generation tests include assessments for height, rust and straightness. Only the presence or absence of rust will be recorded. Straightness will be assessed using a 2 point scale--above or below average. We believe that these assessments will provide the information necessary for determining family performance while bringing some efficiency to the costly measurement process.

After two growing seasons, Chesapeake's first progeny test of plantation selections is off to an excellent start.

When Should Third Generation Orchards Be Established

In the Cooperative's breeding program, a period of 10-12 years is required for completion of breeding and test establishment. The first test series in the advanced generation program (two tests in each of two years) was established in 1982 and 1983, with most breeding regions planting their first test series in 1984-1985. We project that the peak establishment year will occur in 1992. Selection from the advanced generation testing program will begin in 1990 and continue through 2003.

The objective of this analysis was to determine the optimum time to establish third generation seed orchards in the Cooperative. Greater gain can be made by waiting until all of the genetic tests of second generation and plantation selections have been evaluated, but the value of the time lost must also be considered.

The strategy evaluated utilized combined family and within family selection. It is assumed that the best individual trees from each of the best families would be selected for inclusion into seed orchards. Approximately 500 parent clones will be bred and tested in most of the breeding regions in the Cooperative (see 1982 Annual Report). With 500 parent clones, 1250 crosses will be produced with the six-parent disconnected diallel mating scheme. Of the 1250 total crosses, only 250 unrelated crosses can be identified in any one set. For purposes of analysis, we hypothesized selecting the best individual tree from each of the best 24 crosses from the best 250 unrelated crosses based on mid-parent general combining ability estimates.

We have made no attempt to estimate the absolute amount of gain which might be obtained from the current cycle of breeding. We assumed that the amount of gain would be sufficient to warrant the establishment of a new seed orchard or seed orchard blocks. Only the relative gains from selecting early versus late in the testing period were evaluated.

Since every test will be measured on the same schedule, the distribution of tests reaching selection age will be the same as the distribution of test establishment. Based on the expected distribution of test establishment, the number of families available for selection in each of the selection years from 1992 through 2003 was calculated (see Table 9). The relative amount of expected gain for each year of selection and the discounted value of those gains (6% interest rate) are also shown in Table 9.

Table 9. Expected gains from selecting before entire population is available.

Years into selection period	Number of Families available	Percentage of families available	Family selection intensity	Relative gains (Percentage of total possible gain)	Discounted value of expected gains (6%)
12 (2003)	250	100.0	1.764	100.0	49.7
11 (2002)	244	97.6	1.752	99.5	52.4
10 (2001)	236	94.4	1.723	98.3	54.9
9 (2000)	221	88.4	1.705	97.6	57.7
8 (1999)	197	78.8	1.651	95.3	59.8
7 (1998)	163	65.2	1.551	91.2	60.6
6 (1997)	125	50.0	1.411	85.4	60.2
5 (1996)	86	34.4	1.192	76.4	57.1
4 (1995)	53	21.2	0.861	62.7	49.7
3 (1994)	28	11.2	0.252	37.6	31.6
2 (1993)	13	5.2	.	.	.
1 (1992)	5	2.0	.	.	.

The relative gain estimates show that 91% of the expected gain will be achieved seven years into the selection cycle. The discounted value of the relative gain is also greatest seven years into the selection program. Therefore, optimum time for orchard establishment should occur in 1998. The estimates shown are specific to selecting 24 clones from 250 mid-parent combinations, using a 4:1 ratio of the relative benefits of family and within family selection, and to the expected time schedule for test establishment. Analyses of other orchard scenarios, such as parental orchards and orchards with more (35) or fewer (10) clones, showed similar optimums for time of orchard establishment. The distribution of selection availability appears to be an overriding factor in determining optimal seed orchard establishment time.

Work continues by members of the Cooperative to develop new ways of accelerating the breeding effort. Shown is early pollen production resulting from grafting loblolly on Japanese red pine rootstock. The work was done by Westvaco Corporation.

RESEARCH RESULTS AND ASSOCIATED ACTIVITIES

Summer Wax Grafting

Numerous grafting methods have been utilized for loblolly and other southern pines over the years. Recently, seed orchard managers have benefitted from the use of two methods: 1) wax grafting of winter dormant scions and 2) summer grafting of actively growing scions. Wax grafting methods are faster and less expensive than the traditional methods of covering the graft union and scion with plastic bags, kraft bags, and/or aluminum foil. In particular, the aftercare and management of the grafts is much simpler and cheaper than required by earlier techniques.

Summer grafting has not been used as often as winter dormant grafting for loblolly pine. Typically the success is lower (about 70%) in the summer when compared to dormant season (90+%), due mainly to the increased tendency of the scion to dessicate. The main benefits from summer grafting are to increase the supply of scarce scion material and to extend the grafting over a longer period of time in order to spread out the seasonal work load. The number of scions from a clone, especially a new selection, can be increased several fold with the judicious use of summer grafting, and orchard establishment can proceed more rapidly.

Grafting of succulent material is not a new method, but virtually all of the grafting has been done using plastic bags to cover the graft. Previously, wax grafting has not been commonly used with summer grafting for fear of burning the relatively succulent scion shoots and needles. In the summer and fall of 1985, two experiments were conducted to determine if wax grafting methods used for winter dormant grafting could be used for succulent tissue grafting.

Scions were collected from five clones in June, 1985. Only healthy, vigorous scions, usually 0.10 to 0.15 inches in diameter, with resting buds were collected. Although shoots with elongating buds can be successfully grafted, we did not use these more succulent scions in the first experiment. All trees were grafted on potted rootstock in a greenhouse one day after the scions were collected. To prepare the scions for grafting, all of the needles were pulled from the stem. Side veneer grafts were made, and the entire graft union was wrapped with a grafting rubber so that only the terminal bud(s) were exposed. The grafts were then covered with one of the following:

1. Bag - a polyethylene bag was placed over the entire rootstock and scion, firmly tied to a bamboo stick at the top, and loosely tied at the bottom.

2. Wax - standard household canning paraffin, melted at 175°F to 195°F, was applied with a paint brush to completely cover the scion bud and grafting rubber.

3. Parafilm® - (American Can Co.)* a waterproof, flexible, stretchable thermoplastic film was wrapped around the scion bud (2 layers) and the grafting rubber (2-4 layers) to completely seal the scion.

The number of surviving grafts was determined 9 weeks after grafting, and the growth (length) of each surviving scion was measured 13 weeks after grafting.

For the second experiment, scions were collected from grafts made in the first experiment. The most succulent scions available were collected from these trees to see if the hot wax would damage the scions.

Scions were collected from the donor plants in October and immediately grafted onto the rootstocks. Because the scions were more succulent, only

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*No criticism or endorsement is implied for products not mentioned or evaluated.

needle fascicles greater than 1 inch long were pulled from the shoots. Attempts to remove smaller fascicles damaged the stems. Four weeks after grafting, surviving grafts were counted, but scion elongation was not measured.

The concern that wax grafting may damage actively growing scions is unwarranted. In both experiments, covering the graft union and scion with hot paraffin gave excellent results. In Experiment I where more lignified scions were used, the wax method gave the highest success and the greatest scion elongation (Table 10). The grafts wrapped in Parafilm® were less successful, and the bag treatment gave the poorest results. The poor success of the trees covered with the polyethylene bag was probably due to very high temperatures in the bag. Although not measured, the temperature inside the bags was estimated to routinely exceed 100°F.

Even in the second experiment where very succulent scions and rootstocks were used, the wax treatment gave excellent results. A small amount of burning on the needles and/or stem was evident on the grafts sealed with hot paraffin, yet survival was very acceptable (Table 11). The second experiment was done in early fall and the lower temperatures in the

Table 10. Grafting success and scion elongation for different grafting methods used in Experiment I.

Method	% Success[1/]	Scion length (in.) at 3 months
Wax	95.6 a	7.7 a
Parafilm®	84.4 ab	7.0 a
Bag	68.9 b	6.3 a

[1/]Treatment means followed by the same letter were not significantly different at $p = .05$.

Table 11. Grafting success for different grafting methods used in Experiment II.

Method	% Success[1/]
Bag	97.1 a
Parafilm®	94.3 a
Wax	88.2 a

[1/]Treatment means followed by the same letter were not significantly different at $p = .05$.

bag may have contributed to the near perfect results with the bag treatment. The very succulent grafting in experiment II was successful in all cases. Four of the five clones used in Experiment II had 100% graft survival for all three methods of grafting.

Parafilm® worked well in both experiments and would be a more suitable material to cover the grafts with than the plastic bags. We have used Parafilm® when relatively few grafts need to be made or if we did not have the hot paraffin readily available. The ease of applying the wax makes it better to use than the Parafilm® when doing production grafting.

One of the keys to successful summer grafting is to minimize water stress to the trees. All of the trees in our studies were grown in pots and watered on a regular basis. We do not know how successful summer wax grafting might be with field grown rootstock, but we suspect that if moisture is not limiting, good success could be realized. We are confident that wax grafting on potted rootstocks in a greenhouse can be very successful and in comparison to the summer grafting methods currently in use, it is by far the easiest to use.

The ease and convenience of wax grafting has been successfully extended to soft tissue (summer) grafting.

Pollen Moisture Content Influences Pollen Germination

With all of the second generation and plantation selection breeding underway, the Cooperative is processing and testing more pollen lots than ever before. As we process more and more pollen each spring, we are reminded that we still have much to learn about pollen quality and *in vitro* germination test procedures and their ultimate impact on sound seeds per cone.

It has been standard practice to determine moisture content and percentage germination of the pollen lots to be stored each year. Recently, we questioned the necessity of rehydrating the samples used for germination testing. Experience had shown that "dry" pollen needed rehydration or the *in vitro* germination test results would be very poor. However, we did not know at what moisture content rehydration was required for accurate germination testing.

During the late fall of 1985, a study was initiated to evaluate the relationship between pollen moisture content and percent germination. Nine lots of stored pollen were rehydrated for the standard 16 hours over sulfuric acid solutions ranging from 35 to 80 percent concentration. Each acid solution has a corresponding relative humidity that in an enclosed environment allows the pollen to reach a target equilibrium moisture content (EMC). The target EMC content of the pollen lots spanned a range of 4 to 19 percent moisture. This corresponds to the range of moisture contents for pollen routinely processed for storage.

Germination test results were very sensitive to pollen moisture content under the range of moisture contents we examined (Figure 4). It is important to rehydrate the pollen to ensure that the moisture content is at least 15 percent. At less than 15 percent EMC, germination test

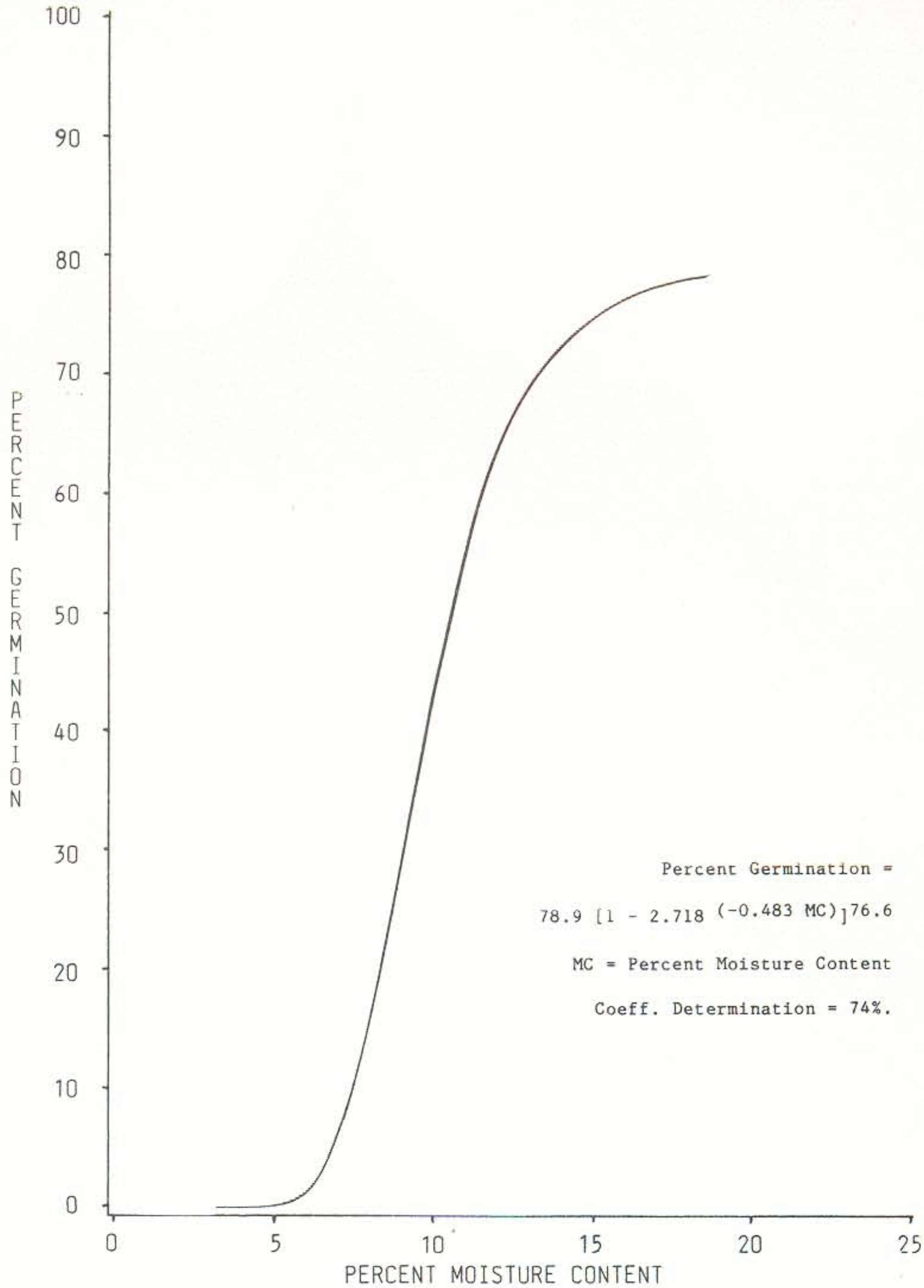

Figure 4. Germination test results at varying moisture contents.

results changed appreciably with modest changes in moisture content. As a result, we recommend the rehydration of all pollen lots, including "fresh ones", that are to be tested for percent germination. Freshly extracted pollen under a forced air system commonly has a moisture content of less than 10 percent. Without rehydration, this "new" pollen would test much lower than its potential.

Evaluation of Loblolly Pine Pollen Quality

Although the results of *in vitro* pollen germination tests are used to evaluate pollen quality, the relationship between test results and seed yields has not been adequately determined. Understanding the relationship between pollen test results and seed yields would improve the efficiency of controlled pollinations and could improve the effectiveness of supplemental mass pollination.

With this impetus, a graduate research project was initiated this spring with the following objectives:

1. To study the relationship between pollen germination test methods and measures of pollen vigor.
2. Correlate the results of germination test methods and vigor analyses with seed yields.
3. To compare germination test methods.

The work outlined above is being undertaken by Graduate Research Assistant Ray Moody in conjunction with his Masters Degree Program. This work is partially supported by and receiving important guidance from Dr. Dave Bramlett of the U.S.F.S.. We will be interested to follow the results of Ray's investigations over the next 18 months.

A well cared for 5 year-old progeny test showing excellent development. Test layout and management are receiving increased emphasis as we develop the foundation for the next generation.

Performance of Diverse Sources of Loblolly Pine Throughout the Cooperative's Working Area

In most of the Good General Combiner (GGC) Tests[1/] established by Cooperators from 1975 to 1977, bulked, unimproved seeds from four different sources of loblolly pine were included:

LP - Livingston Parish, LA
MC - Marion County, FL
GH - Gulf Hammock (Levy Co.), FL
ES - Eastern Shore, MD and VA

Each of these sources has been evaluated in various seed source trials, but never as extensively as in the GGC Tests. The 52 tests which were measured at age eight are located in the Cooperative's eight test areas as well as three cold sites. In each study, the four sources were compared to some of the best half-sib families in the program.

The results for height, fusiform rust resistance, and survival are shown in Tables 12, 13 and 14. The performances of these sources are reviewed as follows:

Livingston Parish:

The growth of LP in most of the Areas was exceptional (Table 12). Performance levels [2/] were in the 60-80 range, except for Virginia and the three cold site tests. The good growth in the Lower Gulf and south Atlantic Coastal Plain was expected, but the very high values in the 10 tests in the Upper Gulf (72) and in the Piedmont of GA and SC (77), and NC (67) was surprising. The growth is much better in these more northern and inland locations than what has been seen in previous studies such as the Southwide Pine Seed Source Study.

[1/] See the Cooperative's 1985 Annual Report for more details about these tests.

[2/] Performance level is a standardized index of relative performance for seedlots with 0 = poorest, 100 = best, and 50 = average.

Table 12. Average performance level for height at age eight for the four seed sources included in the Good General Combiner Tests.[1/]

Test Location (NCSU Test Area)	Seed Sources: Livingston Parish, LA	Marion County, FL	Gulf Hammock, FL	Eastern Shore, VA & MD
1. Virginia	52 (6)	6 (6)	0 (6)	58 (5)
2. Coastal NC	84 (4)	29 (4)	30 (4)	17 (4)
3. Coastal SC	61 (2)	58 (2)	46 (1)	19 (2)
4. Coastal GA & FL	62 (7)	57 (7)	68 (3)	26 (6)
5. Lower Gulf	68 (12)	64 (12)	52 (8)	22 (12)
6. Upper Gulf	72 (10)	19 (10)	31 (9)	43 (9)
7. Piedmont GA & SC	75 (5)	35 (5)	36 (3)	35 (3)
8. Piedmont NC	67 (3)	5 (2)	0 (2)	55 (2)
-. Cold Sites	28 (3)	0 (3)	0 (3)	60 (2)

[1/] Number in parentheses is the number of tests the seed source is planted in within each Test Area.

The results for growth rate must be tempered with caution. The studies are only eight years old and are young for evaluating source movement. When screening for adaptability, half rotation age is typically considered a minimum. Already, the Livingston Parish source is exhibiting survival problems especially in the more northerly sites (Table 14). In other studies (see Wells, 1985. South. J. Appl. For. 9(3):180-185), mortality at mid-rotation age and later has been a problem. It is possible that the Livingston Parish trees in the northern and inland tests may exhibit significantly more mortality in coming years.

Rust resistance of the Livingston Parish source was generally good to very good (Table 13). This trend is very similar to results from other source trials, where LP has repeatedly demonstrated above average resistance.

With cautious optimism, we are in the early stages of selecting trees from Livingston Parish to develop a population for use in the Cooperative (the areas where LP will be usable will partly depend on its long term performance in the GGC tests). Several thousands of acres of

Table 13. Average performance level for % rust infection at age eight for the four seed sources included in the Good General Combiner Tests. [1/]

	Seed Sources			
Test Location (NCSU Test Area)	Livingston Parish, LA	Marion County, FL	Gulf Hammock, FL	Eastern Shore, VA & MD
1. Virginia	34 (1)	68 (1)	42 (1)	96 (1)
2. Coastal NC	64 (4)	57 (4)	31 (4)	63 (4)
3. Coastal SC	50 (2)	24 (2)	56 (1)	84 (2)
4. Coastal GA & FL	66 (7)	58 (7)	53 (3)	84 (6)
5. Lower Gulf	54 (12)	46 (12)	51 (8)	83 (12)
6. Upper Gulf	58 (4)	42 (4)	56 (4)	87 (3)
7. Piedmont GA & SC	63 (4)	44 (4)	61 (2)	78 (2)
8. Piedmont NC	69 (3)	22 (2)	62 (2)	86 (2)
-. Cold Sites	- (0)	- (0)	- (0)	- (0)

[1/] Number in parentheses is the number of tests the seed source is planted in within each Test Area. Only tests with at least 15% overall rust infection are included. Highest infection level was 80%.

Table 14. Deviation from average test survival at age eight for the four seed sources included in the Good General Combiner Tests.[1/]

Test Location (NCSU Test Area)	Seed Sources: Livingston Parish, LA	Marion County, FL	Gulf Hammock, FL	Eastern Shore, VA & MD
1. Virginia	-16% (6)	-29% (6)	-29% (6)	14% (5)
2. Coastal NC	- 5 (4)	4 (4)	-10 (4)	0 (4)
3. Coastal SC	-17 (2)	-32 (2)	-15 (1)	6 (2)
4. Coastal GA & FL	0 (7)	- 4 (7)	5 (3)	4 (6)
5. Lower Gulf	- 5 (12)	- 7 (12)	- 7 (8)	3 (12)
6. Upper Gulf	-11 (10)	-17 (10)	-17 (9)	7 (9)
7. Piedmont GA & SC	- 8 (5)	- 9 (5)	-19 (3)	9 (3)
8. Piedmont NC	-14 (3)	- 5 (2)	- 4 (2)	9 (2)
-. Cold Sites	-12 (3)	-59 (3)	-59 (3)	14 (2)

[1/] Number in parentheses is the number of tests the seed source is planted in within each Test Area.

plantations of Livingston Parish source were planted in the 1970's and should be an excellent source for plantation selections in the next few years. The first 24 LP selections were made in 1985 from Union Camp's plantations in coastal Georgia. We have also discussed the use of Livingston Parish with staff members of the Western Gulf Cooperative. Tree improvement programs west of the Mississippi River are much more advanced for LP than they are east of the river. Western Gulf is willing to help us develop the population in the coming years.

Marion County and Gulf Hammock, Florida:

The growth and survival of these two disjunct populations from the southern extreme of the loblolly pine range is straightforward. Only in the most southern tests (areas 4 and 5) are they acceptable for both growth and survival (Tables 12 and 13). Growth in coastal South Carolina is about average, but neither source survived well. Survival of the Florida sources is extremely sensitive to any northerly movement.

Rust resistance (Table 12) varied widely in the different tests. The Gulf Hammock source was average or better throughout SC, GA, AL, and MS and in Piedmont, NC. Marion County loblolly was generally more susceptible and more eratic than the Gulf Hammock source.

Results from this study and the Florida source provenance/progeny trial conducted in conjunction with the University of Florida Cooperative will help guide our use of MC and GH trees in the future. Hopefully, we will be able to merge the Florida trees with the other southern sources we are already breeding.

Eastern Shore:

This northeastern, disjunct source of loblolly pine is also fairly predictable. It grows well only in colder locations, areas 1 and 8 and cold sites (Table 12). In the warmer areas, it is unable to grow well, probably due to its inability to exploit the longer growing season. It also is extremely resistant to fusiform rust (Table 13) and survives well in virtually all Areas (Table 14).

The adaptability of Eastern Shore trees as well as other Virginia trees to cold climates is again demonstrated in the the GGC tests. Few other trees in the trials were as hardy as the Eastern Shore source, especially in the three cold site tests and in Virginia where survival was 14% above the test averages.

The Cooperative staff will continue to monitor performance of these sources in the good general combiner tests. Changes in performance may occur with additional time. Cold may play a role in causing changes in performance in some cases, and edaphic factors may be influential in other instances. There is a long standing admonition that we cannot overlook, "don't evaluate source performance too early in the life of the test."

Pitch Canker Infection Related to Seed Source

A study examining the relative performance of four loblolly pine seed sources was established in 1982 through the combined efforts of the N. C. State University-Industry Cooperative Tree Improvement Program and the University of Florida Cooperative Forest Genetics Program. The loblolly seed sources being tested include: a) South Atlantic Coastal Plain, b) Lower Gulf Coastal Plain, c) Marion County, Florida and d) Gulf Hammock, Florida. The possibility of consolidating sources for future breeding has value with respect to broadening the genetic base and reducing breeding program costs. The nature of future tree breeding strategies in the southeastern portion of the loblolly range will depend on results from these 10 provenance/progeny test plantings measured at or near half rotation.

Recently, the test planting of this study established by Container Corporation in Butler County, Alabama suffered a wide spread infection of pitch canker. Dr. George Blakesley, forest pathologist at the University of Florida, confirmed the pitch canker infection during the winter of 1984-85. Dieback symptoms were again noted by Container's research forester, Bob Loveless, during the winter of 1985-86. The amount and distribution of pitch canker was assessed in the test in February, 1986 by making an individual tree tally of all trees exhibiting terminal dieback. Overall, 18% of the trees showed the characteristic dieback symptom of pitch canker. Of major significance was the pronounced variation in pitch canker incidence among the four sources (Table 15).

Results from this study show that the loblolly sources from peninsular Florida are much more susceptible to pitch canker infection (37% and 25% infection) than the sources from the south Atlantic Coastal Plain and the Lower Gulf Region (7% and 4% infection). These data suggest a possible genetic basis for susceptibility/resistance. While results such as these are most interesting and potentially of value, they cannot be fully exploited until we know how to reliably characterize a "high hazard" pitch canker site, and we can develop an innoculation screening technique such as the one used for slash pine at the University of Florida.

Table 15. Variation in pitch canker incidence (% infected) among four sources of loblolly in a provenance/progeny trial planted in Butler County, Alabama.

	% Pitch Canker Infection*			
Seed Source	Mean %	Maximum %	Minimum %	Range
Lower Gulf Coastal	4	8	2	6
South Atlantic Coastal	7	14	2	12
Marion County - Fla.	25	38	13	25
Gulf Hammock - Fla.	37	49	26	23

*It is possible these data are confounded with "some" cold injury to the Florida sources, but this is thought to be very minimal if present at all.

Graduate Student Research and Education

The education of graduate students and the research they conduct as part of their degree program is an important activity of the Cooperative. During the past year, 13 students have been involved in graduate studies in close association with the Tree Improvement Cooperative. Seven have been pursuing Masters degrees and six were involved in Ph.D. programs. Of special note is the completion of degree programs by three students in the last year.

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 Cooperative, the School of Forest Resources - Department of Forestry, the N. C. State University Agricultural Research Service, the U. S. Forest Service, industry-sponsored fellowships, and foreign governments.

Summaries of thesis research (abstracts) of two students, Mike Harbin and Bailian Li, are included in this report immediately following the listing of current graduate students (next page). Their work is representative of the research conducted by graduate students in support of the Cooperative's applied tree improvement interests.

Student	Degree	Research Project
Bruce Emery	Ph.D.	Intensive roguing of seed orchards
Claudio Balocchi	Masters	Efficiency of genetic test designs for *Pinus radiata* in Chile
Gary Hodge	Ph.D.	Cold tolerant loblolly pine
James Hodges	Masters	Genotype-fertilizer interaction studies of slash pine (completed)
Anne Margaret Hughes	Masters	Seed quality studies in Fraser fir
Ruy Lima	Masters	Family stability for wood properties of *Pinus oocarpa*
Karen Miller	Masters	Histological response of shortleaf and shortleaf loblolly hybrids to *in vitro* innoculation with fusiform rust fungus
Ray Moody	Masters	Pollen vigor studies
Bialian Li	Masters	Geographic variation of Fraser fir (completed)
Bialian Li	Ph.D.	Genotype - environment interactions in loblolly pine
Kyung-Whon Pak	Masters	Genetic basis of fusiform rust resistance
Jim Richmond	Ph.D.	Genetic variations among populations of pine cone worms
Claire Williams	Ph.D.	Early selection in loblolly pine (completed)
Lisa Wisniewski	Ph.D.	Physiological studies of maturation and rejuvenation in loblolly pine

Soil pH Effects on Four Loblolly Seed Sources

Graduate student Mike Harbin, now tree improvement program manager for Chesapeake Corporation, completed his Masters degree in the last year. Results of his work are reported as follows:

The effect of soil acidity on growth traits and stem nutrient content of four sources of loblolly pine from the extreme southeastern U. S. was investigated. Fifteen half-sib seed orchard families from Gulf Hammock, Florida; Marion County, Florida; Lower Gulf Coastal Plain; and South Atlantic Coastal Plain were grown in medium with nominal acidities of pH 4.5 and pH 6.5. Following a growth period of 17 weeks, seedling height, root collar caliper, stem dry weight, and stem nutrient contents (%N, %P, %K, %Ca and %Mg) were examined between and within acidity levels.

All the traits examined, except for stem percent nitrogen and stem percent potassium, were significantly affected by soil pH. Seedlings grown on the high pH value substrate had less height growth, smaller root collar caliper, lower dry weight and lower concentrations of stem nutrients, with the exception of calcium and magnesium. The variation among families within sources was highly significant for all traits studied, indicating a large amount of genetic variation.

Significant source differences were detected for seedling height and stem percent phosphorus. The results suggest that the Lower Gulf source is slower-growing, despite having the heaviest seed. No source interaction with soil acidity was found. This evidence that the two Florida sources are genetically similar in response to soil acidity lends support to the idea of combining them in a breeding program.

Families within the Gulf Hammock source consistently showed the most edaphic instability over acidity regimes. Several families exhibited the ability to grow well on the high pH value substrate.

<u>Fraser Fir Seed Source Study</u>

Graduate student Bailian Li recently completed work on his Masters thesis. His research involved analysis of data from a Fraser fir seed source study.

Open-pollinated progeny of Fraser fir from different elevations of five natural mountain sources were grown in the greenhouse, transplanted to a nursery and subsequently outplanted at three field locations in western North Carolina. Height growth and root collar diameter were examined to determine the magnitude and patterns of variation in seedlings among natural mountain populations and within mountain populations.

Significant differences among family sources suggest that mass selection in natural populations followed by family selection in progeny tests may be effective for improving height growth and root collar diameter of the species. Individual-tree heritability estimates showed that height growth was under moderate genetic control (.21-.27) and root collar diameter was under weak genetic control, less than .10.

Geographic variation in growth rate among elevations and mountain sources can be important in seedling performance, especially when seedlings are to be planted at relatively low elevation sites. The seed sources from low elevations (1,500-1,650 meters) of southern mountain sources, such as Richland Balsam and Clingman's Dome showed better performance in all three plantings (Figure 5). Roan Mountain, where most seeds are collected for commercial use, was the poorest seed source in this study.

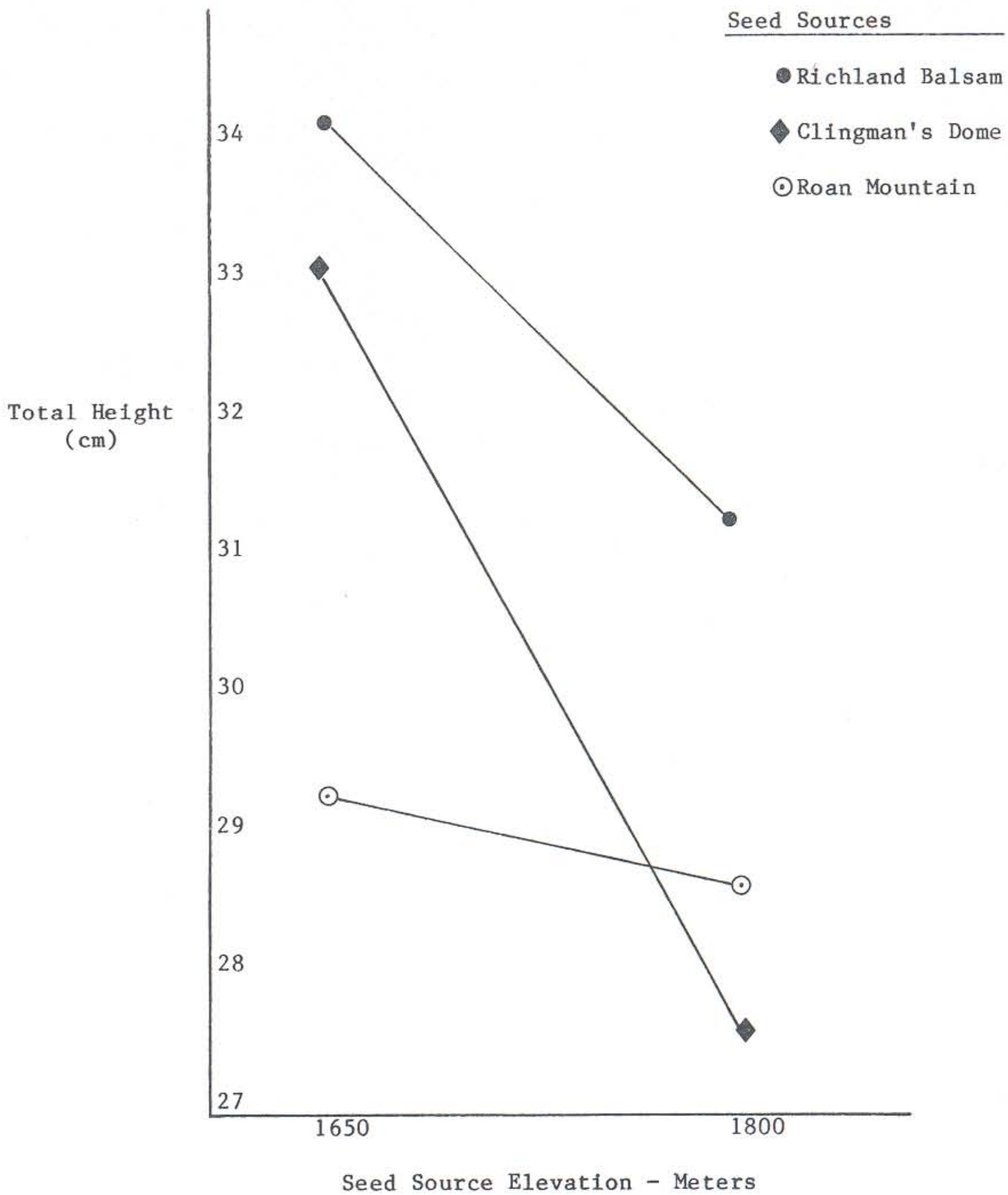

Figure 5. Fraser fir seed sources from lower elevations and more southerly mountains grew best. Total height in cm is averaged over three planting locations.

Program Staff

Listed below are Cooperative program staff members. The faculty level staff and those listed under support staff work full time on Cooperative activities except in the case of Mark Hubbard who has joint responsibility as a research technician to the Tree Improvement Cooperative and the Tissue Culture Research Program.

Faculty-Level Staff

Bob Weir - Director
J. B. Jett - Associate Director
Steve McKeand - Geneticist
Jerry Sprague - Tree Improvement Specialist

Associated Appointments

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

Support Staff

Alice Hatcher - Manager of Data Processing & Office Personnel
Judy Stallings
Jackie Evans

Vernon Johnson - Coordinator Laboratory & Field Technicians
Addie Byrd
Mark Hubbard

The Cooperative program staff has experienced two changes in the last year. Ms. Rosina Rubes left the program due to a reduction in force. Her responsibilities in data processing have been capably assumed by Jerry Sprague. We understand Jerry is a hard task master when it comes to deadlines and measurement errors! The second change occurred when Greg Ferguson resigned in November--We were pleased to hire Mark Hubbard as Greg's replacement. Mark is a 1985 graduate of N. C. State's forestry department and has experience working as a student intern with Brunswick Pulp and Paper Company. We are pleased to welcome Mark to the program.

MEMBERSHIP OF THE TREE IMPROVEMENT COOPERATIVE

Organization	States Where Operating
Alabama Forestry Commission	Ala.
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 Corp.	Alabama Region--Ala., Tenn., Miss. East Carolina Region--N.C., Va. West Carolina Region--S.C., N.C., Ga. St. Regis Acquisition--Ala., Fla., Ga.
Chesapeake Corporation of Virginia	Va., Md., N.C.
Container Corporation of America	Brewton--Ala., Fla. Fernandian Beach--Fla., Ga.
Continental Forest Investments	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.

MEMBERSHIP OF THE TREE IMPROVEMENT COOPERATIVE (CON'T)

Organization	States Where Operating
MacMillan-Bloedel Corporation	Ala., Miss.
North Carolina Forest Service	N.C.
Packaging Corporation of America	Tenn., Ala., Miss.
Rayonier, Inc.	Fla., Ga., S.C.
Scott Paper Company	Ala., Fla., Miss.
South Carolina State Commission of Forestry	S.C.
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.

Membership in the Tree Improvement Cooperative now totals 29 organizations. No changes in membership occurred during the last year. The 29 member organizations operate 29 base units and 12 supplemental units for a total of 41 active programs in the Cooperative.

PUBLICATIONS OF SPECIAL INTEREST TO MEMBERS OF THE COOPERATIVE

Amerson, H. V., L. J. Frampton, Jr., S. E. McKeand, R. L. Mott, and R. J. Weir. 1985. Loblolly pine tissue culture: laboratory, greenhouse and field studies. p. 271-287. In: R. R. Henke, K. W. Hughes, M. J. Constantin and A. Hollaender (eds.). Tissue culture in forestry and agriculture. Plenum Press, NY. 390 p.

Bramlett, D. L., F. E. Bridgwater, J. B. Jett and F. R. Matthews. 1985. Theoretical impact of pollen viability and distribution on the number of strobili to use for controlled pollinations in loblolly pine. Proc. 18th South. For. Tree Impr. Conf., Long Beach, MS. May 21-23, 1985. p. 194-203.

Bridgwater, F. E. 1984. The impact of genetic improvement of stem straightness on yield and value of lumber. p. 80-87. In: Proc. of a Symposium on "Utilization of the Changing Wood Resource in the Southern United States. Raleigh, N. C.., June 12-13.

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