SIXTEENTH ANNUAL REPORT

N. C. State University
Cooperative Tree Improvement
and Hardwood Research Programs

School of Forest Resources
North Carolina State University
Raleigh
May, 1972

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FOREWORD

Despite the trials and tribulations currently plaguing forestry, it has been a reasonably good year for both Cooperatives. There has been some difficulty in maintaining interest in hardwood activities, but significant progress has been made even there. Meanwhile, activity in the pine program is at an all-time high.

The Cooperative is at a peak of operational efficiency with a full complement of personnel, having at their disposal the new and excellent laboratory and office facilities. Even the computer operations are now "on stream" and the innovations and full utilization of these facilities have made for progress not dreamed of in years past. In addition, administrative changes involving a new dean and a new department head have been remarkably smooth.

Despite our optimism about the progress of forestry within the southern pine region, we have observed a "short-term" attitude developing in the timber industry that is disturbing. At least superficially, it appears that the thinking, planning and activities of some industries give little consideration to the timber supply of 10 to 25 years from now. The pressures causing this are easily understood but in no way lessen the potential seriousness of its effects. Everyone recognizes that considerable adjustment is necessary to survive during times of stress. We in forestry are in an ideal position to make adjustments because of the inherent flexibility of the timber inventory. However, if the short-term approach is followed too long or too intensively, a nearly irreversible point will be reached that will make recovery difficult. Even with a large timber inventory to draw upon, the fact must always be kept in mind that it takes much longer to rebuild the supply than to use it. Continuation of the present short-term trend will mean that some of today's leaders will fail to maintain their positions and some of today's organizations will cease to exist. A forest-based industry must necessarily take a long-range viewpoint if it is to remain viable in the long run.

These comments could easily be considered too harsh. Since Cooperatives are necessarily long-term, the fact that the members continue their support is proof of their concern for a continuing, reasonably-priced timber supply. It is amazing how fast the future becomes the present; it seems only yesterday that our main concern was to get seed orchards and progeny tests established. Now the major problems are how to best harvest seeds from the orchards, how to rapidly measure large trees in the progeny tests, and how to best design and establish advanced-generation seed orchards. The progress of the Cooperatives has truly made the long term shorter.

A Problem

What to do? How to proceed? Each year the problem of writing the annual report becomes more difficult. How can it be kept easily readable and to a reasonable length while still projecting the full story of results and achievements from Cooperative activities? So much is going on and results are being obtained so rapidly that it is not possible to cover all activities without the report's becoming overly long.

So we have compromised! Each year we emphasize a few of our activities in the report. For some others, mention is made of what is being done, often by use of a highly summarized table or by means of a photograph to illustrate a key point. We have tried to keep the subject matter informal, but in spite of our best efforts the report has evolved into a semiresearch publication because many of the results presented are new and have not been published elsewhere.

IN RECOGNITION

Since initial organization at N. C. State in 1956, the Cooperative Programs have profited from the leadership and guidance of some very influential people. We wish to recognize and say "Thank you" to four such persons who have retired or will retire within the year.

Dr. Richard Preston, Dean Emeritus. Dick was the key in getting the Cooperatives organized and in setting the tone of the programs. The faith placed in him by members of the Cooperatives was responsible for large-scale investments in biological experimentation when neither he nor we could give absolute assurance of a payoff for the time and money expended. As an employer, he was easy to work for; his attitude was, "This is your responsibility, go to it!" It has been hard to see the "father" of the program retire, although retirement to him has meant a return to teaching. Those of us associated with the Cooperatives will ever be grateful for his leadership, foresight and trust in what was then a daring and somewhat risky enterprise.

Orion Peevy, who started with us when he was an employee of North Carolina Pulp Company (now Weyerhaeuser Company), developed and until recently managed the largest and most active industrial tree improvement complex in the world. It must have been difficult for him to shift from timberland management with his former employers, the Bates and Eureka Lumber Companies, to grafting, pollinating, and progeny testing in an applied tree improvement program. But he made the change without a break in stride. In the process he became adept at locating those elusive select trees. It is only fitting that he has spent the last months of his career combing Weyerhaeuser's Carolina woodlands for select trees to broaden the genetic base of the company's tree breeding program. Our wish for Orion is that he maintain his active interest so he can watch the development of the fine work he started.

Walter Kolodij started work with the Cooperative with Champion Papers, Inc. (now U. S. Plywood-Champion Papers, Inc.). He was a natural for activities of the program and made a number of major and novel contributions to it. Perhaps the greatest contribution was his discovery that fusiform galls on valuable seed orchard trees could be arrested by peeling the bark from around them. Another major accomplishment was his suggestion--and a persistent suggestion it was--that the Cooperative would benefit from a NEWSLETTER. Walter's persistence paid dividends; under Bob Kellison's editorship the NEWSLETTER has developed into one of the most interesting and most important publications of the Cooperative. We know there will be no lag in Walter's activities with his wide interests and most wonderful family.

Dr. T. E. "Waldy" Maki, Carl Alwin Schenck Professor of Forestry, is retiring June 30, 1972. Waldy was directly responsible for the organization and administration of the Cooperative from the beginning, and his help and support were largely responsible for the quality of the programs. It was only because Waldy was to be his superior that Bruce Zobel decided to leave Texas to come to North Carolina. Waldy's common sense and mollifying influence when things went wrong kept the ship on an even keel. His wisdom about the southern pines and hardwoods and his knowledge about the soils of the region were drawn on very heavily and greatly shaped the direction that the Cooperative took. Although he often kept in the background, we must recognize that his contribution to the Cooperative was a major one. We hope we can say it will continue to be major because, despite his vocabulary, we feel he does not know the meaning of retirement and we expect to call on him for help for years to come.

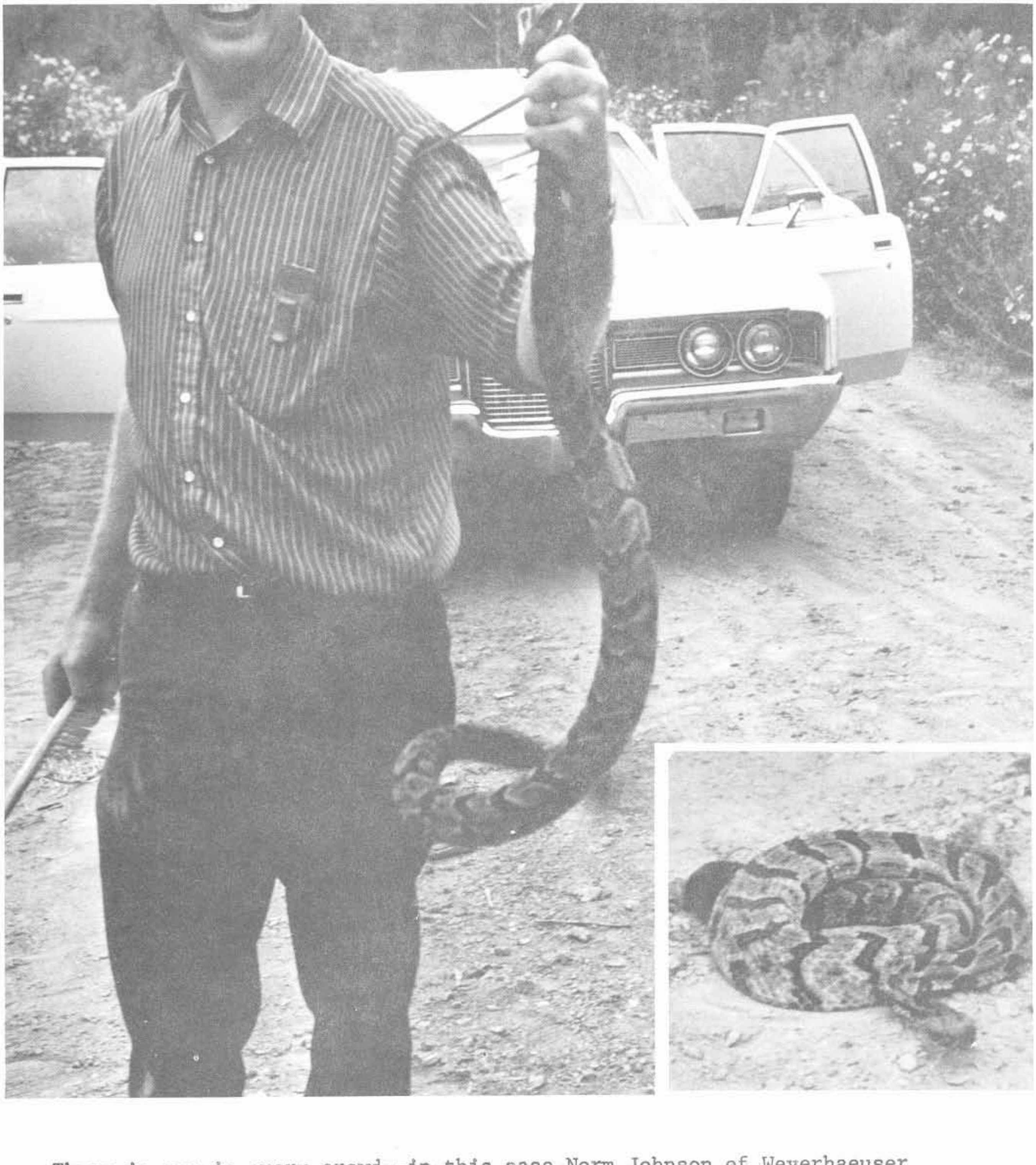
We look forward to maintenance of close ties with all four of the retirees. They can't do other than look back with justifiable pride on their basic and necessary contributions which have made the Cooperative so successful. In his own way, each has made an invaluable contribution. Thanks to all of you, from the staff of the Cooperative.

THE COOPERATIVE TREE IMPROVEMENT PROGRAM--PINE

Introduction

Activities are "busting out all over." The seed crop was the biggest ever, and several members of the Cooperative are now using only genetically improved seed in their regeneration programs. When the Cooperative was initiated, the idea of 3,000 acres of production seed orchards seemed 'way out, yet we are already there. The production of 100 million trees from the seed orchards in one year could hardly be visualized, yet we passed this by 20 percent in 1971. Progeny tests for a number of orchards are now completed and over 200 second-generation selections have been made. We now have over 1,000 acres of control-pollinated progeny tests from which to judge the value of seed orchard parents and from which to select for advanced generations. Specialty orchards have been established and some are coming into production. Tree selection, grading and orchard establishment are continuing at a more rapid rate than anticipated and, along with hybrid tests and fume resistance studies, it's difficult to keep abreast of it all.

Hurrah! We finally did it! Data on wood properties amassed since the Cooperative was formed have been summarized in N. C. Agricultural Experiment Station Technical Bulletin 208. These data were based on tens of thousands of trees which had been cut and sampled from base to merchantable top, giving reliable whole tree and acreage values. Pulping studies of known genetic material have been completed. Results from these studies have been translated into economic values as a guide to members of the Cooperative in the best use of their time, effort and money.



There is one in every crowd--in this case Norm Johnson of Weyerhaeuser Company. That is a fair-sized rattlesnake he is handling. During this exhibition he had no close friends.

Seed Production

One major objective of the Cooperative is to supply all needs of its members with genetically improved planting stock. We estimate that nearly all of the seed requirements for all members should be obtainable from seed orchards within the next five to six years. In 1969 enough seed were obtained for 40 million trees, and in 1970 we came close to the estimated 100 million trees. The 1971 cone crop from seed orchards in the Cooperative should supply about 120 million seedlings.

Seed Yields and Germination

Much concern has been expressed over the yields and germination of seed from seed orchards. The problem is most severe in certain slash pine orchards in the Gulf Coastal Plain, where yields below 0.5 pounds of seed per bushel of cones and germination rates below 50 percent have been obtained from orchards where pollen was plentiful. To date only scattered reports of poor yields and germination have been received for loblolly pine seed orchards.

For the past five years we have been systematically assessing the yields and germination of orchard seed and had planned to do this for all seed orchards in the Cooperative. However, the problem encountered in the southern slash pine orchards has resulted in formation of a Seed Orchard Survey Committee by the Southern Forest Tree Improvement Committee. The charge of that group, which includes J. B. Jett of the N. C. State Cooperative Programs, was to standardize procedures for evaluating production and quality of cones and seeds from all orchards requesting the service. The studies of seed yield and germination are being made at the Forest Tree Seed Laboratory of the U. S. Forest Service at Macon, Georgia. These uniform tests, which will give comparable results for several species throughout the South, are of great value to the Cooperative.

Prior to the formation of the Seed Orchard Survey Committee we sent a questionnaire to members of the Cooperative inquiring whether low seed yields and poor germination were being encountered and, if so, what action was suggested. Of the twenty-one answers, only three felt there was a problem, but the majority felt that studies should be started to determine the effect of insecticides, fertilizer and irrigation on seed yield and quality. Some information is already available from special studies and general observations; it is being supplemented by studies started during the past year.

Overall, seed production from the older orchards has been very satisfactory. Several loblolly pine orchards have produced the predicted yield of 50 bushels of cones per acre, which is equivalent to 50 or more pounds of seed per acre. One small research orchard belonging to Westvaco Corporation produced 110 bushels of cones per acre in 1971. Slash pine yields in the working territory of the Cooperative have been surprisingly good, as exemplified by the 687 bushels of cones obtained last fall by International Paper Company, Georgetown, South Carolina, from their 12-acre orchard.

Seed yields usually increase rapidly with orchard age and as younger grafts come into production. This is well illustrated by the orchards of International Paper Company, Georgetown, South Carolina, where combined yields of slash and loblolly pines increased from 12 pounds of seed in 1963 to more than 1700 pounds in 1971 (Table 10). Germination of loblolly pine seed from these orchards has been summarized for yearly collections from 1966 through 1971. For the South Coastal orchard, germination was 72 percent on 2,150 pounds of seed; and for the North Coastal orchard it was 80 percent on 660 pounds of seed. Both values are percentages based upon total seed, not upon sound seed alone.

The danger of damage to our seed orchards by ice is ever present. Shown is the Weyerhaeuser Company orchard immediately after an ice storm. Hundreds of potential bushels of cones are on the ground. Despite this damage, recovery has been good.

Table 10. Increasing production of seed in the loblolly and slash pine orchards of International Paper Company, Georgetown, South Carolina

Year	Lbs. of Seed	Year	Lbs. of Seed
1963	12	1968	476
1964	17	1969	655
1965	23	1970	1,321
1966	305	1971	1,720
1967	449		

In years of poor cone crops, seed quality is often erratic. For example, in the Kimberly-Clark orchard at Coosa Pines, Alabama, rather poor results were obtained from both Virginia and loblolly pines in 1970; ranking is shown in Table 11 as the best clone, poorest clone, and average for the orchard.

Table 11. Clonal differences of loblolly and Virginia pines for percent sound seed, sound seeds per cone, and number of seeds per pound in the seed orchards of Kimberly-Clark Corporation, Coosa Pines, Alabama, in a year of low cone production

	Loblolly Pine	Virginia Pine
Percent Sound Seed:		
Best clone	92	81
Poorest clone	18	28
Orchard Average	57	57
Sound Seed/Cone:		
Best clone	47	21
Poorest clone	3	3
Orchard Average	17	9
Number Seed/Pound:		
Smallest seed	17,800	44,200
Largest seed	11,600	29,750
Orchard Average	14,600	36,910

Seed production from the same orchards was much better in 1971. A summary of yields and cost of collection, supplied by Kimberly-Clark, is shown in Table 12.

Table 12. Yields and costs of cone collection from seed orchards and wild stands in 1971 by Kimberly-Clark Corporation, Coosa Pines, Alabama

Kind of Seed	Total Bushels	Pounds of Seed	Pounds of Seed/ Bushel	Collection[1/] Cost/1 Pound Seed
Seed Orchard Loblolly	911	862	0.95	$3.78
Seed Orchard Virginia	310	182	0.51	16.50
Field Collected Loblolly	98	108	1.10	2.45
Field Collected Longleaf	72	58	0.81	1.93

[1/] Does not include supervisory costs of about $0.50/bushel.

In 1971 the 6-year-old loblolly seed orchard of Tennessee River Pulp and Paper Company yielded an average of 45 seeds/cone with a soundness of 89 percent (see Table 5, Fifteenth Annual Report). Germination results after fourteen and twenty-one days for the same seed lots are shown in Table 13. There was poor germination of seeds from clone 19-2 at both fourteen and twenty-one days, but when carried twenty-eight days 90 percent of the seeds had germinated.

Care must be taken in interpretation of seed soundness. It is important whether percentage is based on total seed or on sound seed; if based on total seed, values are lower (Table 13) and may be considerably lower, dependent on how rigorously the seed have been cleaned.

Table 13. Rate and percentage of germination for fifteen clones from the seed orchard of Tennessee River Pulp and Paper Company

	14-Day Germination		21-Day Germination	
Clone Number	% Germ. Total Seed	% Germ.[1] Apparently Sound Seed	% Germ. Total Seed	% Germ. Apparently Sound Seed
19-2	29	41	48	68[2]
19-17	79	97	82	101
8-504	93	99	94	100
8-512	86	100	86	101
1-22	88	95	92	99
1-23	79	96	81	98
8-509	86	97	87	98
19-21	67	87	74	95
8-503	75	98	77	100
19-12	82	95	85	98
19-3	96	98	96	98
1-60	72	98	73	100
8-501	85	97	86	99
8-531	97	101	98	101
19-18	95	-	98	-
Average	81	93	84	97

[1] Percentage sound seed determined by air separation with a Dakota blower

[2] When carried to 28 days, 90 percent of the apparently sound seed of clone 19-2 germinated.

Variation in yields of seed among orchards of the same organization and among those of different organizations may be considerable. For example, yields among six different loblolly orchards of Weyerhaeuser Company in North Carolina ranged from a low of 1.0 pound of seed per bushel of cones to a high of 1.8 pounds/bushel. Their overall yield from 424 bushels of cones was 1.43 pounds of seed/bushel.

Cone and seed production from the orchards within the Cooperative has been summarized for 1971 in Table 14. The continued increase in yields each year is most heartening.

Table 14. Cone and seed yields in 1971 from pine seed orchards of the Cooperative

Species	Bushels of Cones	Pounds of Seed	Pounds of Seed/ Bushel of Cones
Coastal Source Loblolly Pine	4564	5320	1.18
Piedmont and Mountain Source Loblolly Pine	1914	2081	1.09
Slash Pine	3795	2904	0.80
Virginia Pine	323	187	0.58
Pond Pine	14	5.5	0.39
White Pine	28	10	0.36
Shortleaf Pine	9	5	0.53
Totals	10,647	10,512.5	-

Fertilization, Irrigation and Cone Production

Results of studies underway in the Cooperative relative to increasing seed production by use of fertilizers and irrigation can be summarized as follows:

1. The increase in seed production resulting from fertilization is substantial.
2. On most soils, irrigation is beneficial, especially in dry years.
3. Best results occur when irrigation and fertilization are combined.

In a study continued from time of grafting (1963 - 1965) by Catawba Timber Company, fertilization and irrigation have consistently increased cone yields. Results obtained in 1971 are shown in Table 15. It is of interest that height was not affected by treatment, while diameter increased directly with fertilization and irrigation.

Table 15. Effect of continuous fertilization and irrigation on cone yield and tree growth of 8-year-old loblolly pine grafts 1/

Treatment	Cones/ Tree	Avg. Ht. of Graft (Feet)	Avg. Diam. of Graft (Inches)	Clones Not Producing Cones
Control	15	29	7.3	4
Fertilization Only	20	29	7.8	3
Irrigation Only	27	29	7.5	3
Fertilization and Irrigation	38	29	8.3	2

1/ Study by Catawba Timber Company, Catawba, South Carolina

It is generally conceded that fertilization and irrigation treatments change the flowering pattern of clones already flowering, but the extent to which nonproductive clones could be induced to flower by the treatment has not been known. Results from Catawba Timber Company indicate that fertilization is effective in initiating earlier female flower production to some extent, whereas the irrigation treatment results in initiating male flower production. Overall, however, the treatments are much more effective in increasing flower production of already flowering clones than causing nonflowering clones to start production.

In another continuing study, the Virginia Division of Forestry reported differential effects in the production of loblolly pine flowers from certain combinations of nutrients. Patterns of flowering response are not always consistent except that nitrogen appears to be essential for optimum production of flowers of either sex (Table 16).

Table 16. Flower production by fertilizer treatment for loblolly pine grafts 1/

Treatments Pounds/Acre		Number of Flowers Per Sample Limb	
Ammonium Nitrate	Triple Superphosphate	Female	Male
600	500	13.1	1.2
450	750	11.2	1.2
450	250	9.5	1.0
300	1000	9.9	1.4
300	500	9.2	1.1
300	0	9.8	.79
150	750	11.0	1.1
150	250	10.1	1.4
0	500	6.2	.96
0	0	4.8	.70

1/ Study by Virginia Division of Forestry

Code for abundance of male flowers (Female count is actual flowers per tree): 0 - None; 1 - Light; 2 - Medium; 3 - Heavy

Preliminary results from a fertilization study in the white pine seed orchard of the Virginia Division of Forestry showed nitrogen to be particularly effective in flower stimulation. But later results from the same study indicated that nitrogen had no overall effect; some clones increased flowering with increased nitrogen, while others decreased. At this time there is no explanation for these puzzling results.

Effects of fertilization on seed production from older loblolly pine grafts obtained by Westvaco Corporation, Georgetown, South Carolina, will help guide orchard management for maximum productions. Major results from the five-year study which was terminated in 1971 were:

1. Nitrogen stimulated seed production most, and nitrogen plus phosphorus gave a considerable increase over the checks (Table 17). Cone production from the phosphorus only treatment was less than from the check.

2. Cone length varied by treatment but cone diameter did not; a useful relationship of cone length to cones/bushel was developed.
3. Seeds per cone were increased 10 percent by nitrogen fertilizer. Seasonal and clonal differences affected seeds/cone more than did fertilizers.
4. Fertilization of the parents did not affect germination rates of seeds obtained.
5. The number of germinable seeds (based on cones/tree, seed/cone, and germination percent) is the best estimate of seed orchard and clone productivity. On this basis, nitrogen fertilizer increased yield 100 percent, and nitrogen plus phosphorus increased yield 80 percent over the checks.

Table 17. Clonal differences in cone and seed yields and quality as affected by five years of fertilizer treatments 1/

	Avg. No. Cones/Tree/Year							
Clone	N	P	N plus P	Check	Sound Seed/ Cone	Percent Filled Seed	Germ. Percent	Germinable Seed/ Tree
7-56	1138	396	539	675	59	85	93	40,160
11-8	316	65	249	92	34	75	99	5,970
11-9	913	640	864	361	46	79	87	27,160
11-10	192	49	169	174	52	76	81	6,580
Totals	2559	1150	1821	1302	48	79	90	-

1/ The bulk of the cones were produced the last year (1970). Study made by Westvaco Corporation, Georgetown, South Carolina.

Cone and Seed Insects

From the beginning of the seed orchard program, cone and seed insects have been one of our most serious problems. Many controls have been tried in the past, but none have been completely successful under all conditions. Systemics such as Thimet give satisfactory control under some conditions but are ineffective under others. Timing of application of this chemical is most important; control is never completely effective when applied after vegetative growth of the plant is in full progress. Current restrictions caused by environmental awareness have made use, and even testing, of some chemicals nearly impossible. Since seed orchards constitute a small potential market, tree improvement programs must rely heavily on chemicals developed for agricultural purposes to control cone, seed, and vegetative insects.

We have noticed for years that Dioryctria damage to cones and to trees is clonal. Most organizations have one to several very susceptible clones in their orchards; when these are heavy cone and seed producers, loss by insects can be very serious. Several organizations have concentrated control only on the susceptible clones, thereby reducing the cost of control and possibly ameliorating adverse environmental effects.

Clonal differences in cone damage from Eucosma cocana were found in the Virginia pine seed orchard of the N. C. Forest Service in 1971. Overall damage was 13.7 percent but the cones of four clones were 48 percent infested whereas only 4.5 percent of the cones of all other clones were damaged (Table 18). Such knowledge of differential susceptibility to cone and seed insects must be obtained for all orchards so control measures can be concentrated on the high value trees.

Table 18. Clonal differences in infestation of Virginia pine cones by Eucosma cocana 1/

Clone Number	Percent Infested
16-102	56
16-51	52
16-79	43
16-27	32
Average of 4 susceptible clones	48.0
Average of other 16 clones in the orchard	4.5
Average of all 20 clones in the orchard	13.7

1/ Study by the N. C. Forest Service

Another group of insects that cause damage are the seedworms (Laspeyresia spp). A 5 percent loss in loblolly pine seed can be attributed to them but they are much less destructive than the cone worms (Dioryctria spp).

Control of cone worms has proven to be difficult. Several orchard managers feel that Guthion is a satisfactory control. International Paper Company reports that losses were reduced from 18 percent on unsprayed trees to approximately 5 percent on trees sprayed with Guthion. In tests on loblolly pine, the Virginia Division of Forestry found that Gardona, a relatively new and reportedly very safe spray, reduced Dioryctria losses from 18 percent to 2 percent. They also found Gardona to be quite effective in controlling tip moth. Sevin controlled cone worms only one-half as effectively as Gardona, while Bidrin gave satisfactory control when placed directly into bore holes in the trunks of trees, although some trees were damaged by the treatment.

Seed from Special Orchards

As additional seed are needed, new orchards are established with the best clones which have shown high general combining ability, heavy seed production, graft compatibility and disease resistance; these are sometimes called 1.5-generation orchards. The area of such improved orchards is already over one hundred acres and is growing yearly. The wide distribution of the best general combiners is a prime example of the use being made of genetic information from progeny tests.

We occasionally obtain outstanding good combinations or specific combiners that have little special utility in regular seed orchards. However, if the two clones involved in this outstanding combination flower in sequence and if selfing is not a problem (many trees are nearly self-incompatible), they can be used to great advantage by establishing two-clone orchards. Four such orchards are now a reality.

Thinning Seed Orchards

There is always a certain amount of resistance to thinning the seed orchards because of the fear that cone production will drop. But this fear has proven to be unfounded and the thinned orchards continue to produce heavily. When asked his opinion of the value of thinning orchards, Walt Chapman of Kimberly-Clark Corporation stated, "If you want cones you must thin. The trees which had been released in both our Virginia and loblolly orchards produced far more cones than did those not released. We must take advantage of the progeny tests to thin the orchard, deleting the poor clones from the orchard so that maximum seed production can be obtained from the best clones." The performance of the 30-plus orchards we have thinned attests to Walt's judgment.

In an emergency one has to do the best he can. This necessity was responsible for the "makeshift" cherry-picker put to use by American Can Company to collect the first heavy cone crop from their seed orchard.

In order that the program continue without a dangerous amount of inbreeding, new germ plasm must be inserted in the breeding orchards. Such is the use to be made of trees from this one-year-old planting of selected families sent to Georgia-Pacific Corporation from South Africa. Several of the families have grown very well.

Cone Collection

After years of effort, the seed orchards are coming into full production. The major problem now is the collection of cones and seed. For the most part, collection has been adequately handled, but a disturbing attitude of reluctance to rise to the crisis during the period of cone collection has developed among a few members of the Cooperative. Normally, cones can be harvested over a three-week period; however, if a period with warm days, cool nights, low humidity, and wind is encountered, collection time may only last for two weeks. In 1971 it rained throughout the cone collection period, allowing ten weeks before the cones opened, but this is very unusual.

The attitude that "we can't afford to rent a cherry-picker" or "we can't afford to hire more men" is short-term thinking indeed. Several members of the Cooperative would each have lost 200 or more bushels of loblolly cones in 1971 if specially favorable weather conditions had not prevailed. Consider these facts for loblolly pine:

A bushel of cones = 1.2 lbs. of seed.
A pound of seed = about 8,000 plantable seedlings.
A bushel of cones - 9,600 plantable seedlings.
Planting at an 8' x 10' spacing = about 560 trees per acre.
One pound of seed plants about 16.5 acres.
Improved yield from orchard seed is 10 percent or more.
At harvest time, 50 cords/acre would be obtained from commercial seed.
At harvest time, 55 cords/acre would be obtained from orchard seed.
Five cords/acre x 16.5 acres = 82 extra cords/lb. of seed.
Loss would be 82 cords x 200 (bushels) x \$x/cord = 16,400 x \$x/cord = loss that would have been sustained if the 200 bushels had not been collected.

It is obvious that rental of a cherry-picker or hiring a few more men would pay off handsomely. In fact, an organization <u>cannot</u> afford <u>not</u> to spend the little extra necessary to save all the seed from their orchard.

The cone collection period can be expanded about three weeks by the following:

1. Collect cones from the clones as they mature. Certain clones will be one to two weeks early, others one to two weeks late.
2. Collect two weeks prior to normal harvest and ripen the cones by storing them under moist and cool conditions.

Work on the vacuum harvester is continuing but the machine is not yet operational. The system seems to work, so emphasis now is on the development of a machine fast enough and rugged enough to withstand operational conditions.

Progeny Testing

Each year this laborious phase of a tree improvement program becomes larger. The oldest open-pollinated tests are twelve years in the field, and the oldest control-pollinated plantation is ten years of age. Eight-year measurements of several main and supplemental control-pollinated tests have been completed and will not be remeasured until they are thinned, except for special characteristics such as wood specific gravity.

Control-pollinated Tests

Acreage of control-pollinated progeny tests for Cooperative members varies from 0 for several of the newer members to 186 acres for Weyerhaeuser Company and over 150 acres for Union Camp Corporation. The total of 1081.6 acres under test, which will continue to expand for several more years (Table 19), will supply a huge amount of data to rogue orchards and an unparalleled opportunity for advanced-generation selections.

Table 19. Control-pollinated progeny tests in the Cooperative

Species and Geographic Location	Acreage Planted Through 1971	Acreage Planted in 1972	Total Acreage Planted
Loblolly pine - Coastal Plain	416.0	126.8	542.8
Loblolly pine - Piedmont	284.8	85.6	370.4
Virginia pine	23.8	9.2	33.0
Slash pine	78.1	11.6	89.7
Pond pine	32.7	0.0	32.7
Shortleaf pine	3.0	3.3	6.3
Hybrid pines	6.7	0.0	6.7
Total Acreage	845.1	236.5	1,081.6

Of the total, 666.4 acres are in main tests,[1/] which include 4,745 lots, 388.2 acres are in supplemental tests[1/] which include 4,589 lots, and 27.0 acres are in special tests in which fertilizers, maximum growth, disease resistance, and hybrids are being evaluated. Problems encountered in the testing program include heavy losses to fire, careless logging and Pales weevil infestations. Some tests have been completely destroyed and reestablished; the reestablished acreages are not included in the 1,081.6 total acres shown in Table 19.

Evaluation of the progeny is based on a sequential pattern of measurements. Except for a survival count, measurements at the end of the first year are optional. The first meaningful measurements are obtained after the fourth or fifth and after the eighth years. Performance of the progeny has been gratifying overall, in that the crosses have outperformed the commercial checks. Progeny test results based on 67 tests, 1854 separate seed lots, and over 75,000 trees in approximately 150 acres of progeny tests are shown in

[1/]The main test consists of six replications for each of three years, for a total of 18 replications; the supplemental test consists of three replications for three years, for a total of nine replications.

Progeny tests have developed to the age and size that sound data can be obtained. Shown is Westvaco Corporation's 11-year-old open-pollinated test just prior to the second thinning, the first thinning having been made at 7.5 years of age. Growth between thinnings averaged nearly four cords/acre/year.

Table 20. However, some tests have shown much more superiority than others. A part of the difference in performance between orchards is in the "luck of the draw" in obtaining the commercial checks, some of which are much better than others.

Table 20. Fourth-year total height of the best crosses, the poorest crosses, the commercial checks, and the plantation average for 67 separate control-pollinated progeny tests

Geographic Source	Best 10% of the Crosses	Plantation Average	Commercial Check	Poorest 10% of Crosses	Percent Superiority of Best 10% over Commercial Checks
	feet				
Atlantic and Gulf Coastal Plain 1/	8.10	7.53	7.07	6.29	14.6
Piedmont	9.01	8.20	7.92	7.05	13.8
All Orchards Combined	8.43	7.77	7.37	5.99	14.4

1/ Because some of these tests were planted in excessively wet, minimally prepared sites, the first four years' growth was very poor but most are growing well at year 8.

Data from a 10-year-old control-pollinated study by Westvaco Corporation in which pollens from eight fathers were used on the same mother show the complexity of progeny assessment (Table 21). Note the differences among crosses related to the pollen parent. Use of pollen from 11-18 produced a fast growing, relatively rough family which was not greatly affected by disease. Pollen of 7-56 produced a slim, tall tree with excellent form, and tree 11-9 passed to its offspring the ability to produce a large diameter stem of below average height but which is very disease resistant. To complicate interpretations, the mother tree (11-2) generally produces relatively fast growing, poorly formed, disease susceptible progeny.

Table 21. Characteristics of 10-year-old, control-pollinated families, all with the same mother but different fathers. Numbers in parentheses indicate ranking of the cross.

Cross	No. Reps Measured	DBH (In.)	Height (Ft.)	Crown Score	Straightness Score 1/	Rust Infection Score 2/
11-2 x 7-34	5	7.7 (3)	45.7 (5)	3.4 (7)	3.8 (6)	2.9 (7)
11-2 x 7-56	4	6.9 (6)	45.8 (3)	1.3 (1)	3.0 (2)	3.4 (8)
11-2 x 11-9	5	7.8 (2)	45.1 (7)	2.3 (3)	3.5 (4)	1.7 (1)
11-2 x 11-14	5	6.4 (7)	41.5 (8)	3.1 (5)	4.1 (8)	2.6 (5)
11-2 x 11-18	5	8.2 (1)	47.6 (1)	3.4 (6)	3.9 (7)	2.3 (3)
11-2 x 11-19	3	7.5 (4)	45.2 (6)	3.9 (8)	3.6 (5)	2.5 (4)
11-2 x 11-20	5	7.0 (5)	45.7 (4)	2.0 (2)	2.9 (1)	2.7 (6)
11-2 x 11-41	4	7.7 (3)	46.4 (2)	2.9 (4)	3.2 (3)	1.9 (2)

1/ Based on a subjective grading, with 1 being the best, 6 the poorest

2/ A severity index; the higher values indicate more severely infected.

The performance of each family, as determined by the main and supplemental control-pollinated progeny tests, gives a good idea of the worth of the cross and of the parental clones involved. At Savannah, Georgia the Union Camp Corporation has summarized one main test in which the crosses were planted in each of three year blocks (Table 22).

Table 22. Family differences in growth, form and fusiform rust infection of 4-year-old, control-pollinated progeny in the Coastal Plain. The progenies occur in each of three year blocks, being planted in 1965, 1966 and 1967.

Family	Height (Ft.)	Height Rank	Crown Form Rank	Straightness Rank	Fusiform Rust Percent-Rank	Overall[1/] Rank
14 x 8	12.4	1	2	5	11	2
14 x 37	12.3	2	7	5	9	4
14 x 25	12.0	3	5	5	3	1
12 x 8	11.8	4	11	11	12	10
6 x 37	11.7	5	9	7	1	3
16 x 37	11.6	6	7	10	7	7
18 x 39	11.4	7	1	1	13	3
5 x 25	11.4	8	10	6	2	6
14 x 39	11.1	9	3	2	10	5
16 x 8	11.1	10	2	4	14	7
18 x 25	10.9	11	4	3	4	3
5 x 8	10.8	12	8	8	5	8
Comm. Ck.	10.7	13	9	9	6	10
S.P.A.[2/]	10.1	14	6	7	8	9

[1/] Obtained by ranking the sum of the ranks for the four traits assessed. Direct addition of ranks can be misleading; each characteristic should be weighted by its relative value to be meaningful. However, the method gives a quick estimate of the general worth of the cross.

[2/] A seed production area from the Piedmont of South Carolina. (Growth from Piedmont sources is less than that from the Coastal Plain when grown in the Coastal Plain.)

Based upon unweighted ranks, clone 14 is best. However, its progeny shows a high level of rust infection when crossed with susceptible clones. Families in which clone 8 occurs, except when crossed with resistant clone 5, are heavily infected with fusiform rust. Clone 12 is represented in only one cross and it produces very crooked progeny. Family 12 x 8 shares the lowest rank with the commercial check. Overall superiority in height growth of the select trees at 4 years of age was 12.7 percent over the commercial checks. A fairly strong positive correlation between stem straightness and crown form was found. Rust susceptibility is randomly distributed without regard to height growth, so fast growing, resistant strains can be developed.

Open-pollinated Tests

Excellent growth information is being obtained from the older, open-pollinated progeny tests. Data from one plantation belonging to International Paper Company, Georgetown, South Carolina are shown in Table 23. These stands were thinned at 7.5 years and again at 11 years of age. The planting was made in 1960 with a 7' x 7' spacing; no cultural practices such as fertilization or cleaning were done until the stand was thinned in 1967 at 7.5 years of age. Following thinning the plantation was control-burned and no further management was applied prior to a second thinning at 11 years of age.

Major results from the open-pollinated test were:

1. Growth rates were 2.3 cords/acre/year at 7.5 years and 2.8 cords/acre/year at 11 years.
2. Differences between the fastest and slowest growing open-pollinated families are large (1.9 to 2.7 cords/acre/year at 7.5 years and 2.2 to 3.3 cords/acre/year at 11 years), even though all progeny are from parent trees initially selected for fast growth.

Table 23. Family differences in growth and yield of an open-pollinated test on a good Coastal Plain site near Georgetown, South Carolina 1/

	1967 Data 2/					1971 Data 3/							Growth 1967-1971
Family	Ht. (Ft.)	DBH (In.)	Sp. Gr.	Cords/ Acre/ Year	Tons/ Acre/ Year	Ht. (Ft.)	DBH (In.)	Sp. Gr.	Cords/ Acre/ Year	Tons/ 4/ Acre/ Year	Double Bark Thick- ness (In.)	Moisture 5/ Content Percent	Cords/ Acre/ Year
7-2	32	5.7	.38	2.3	2.1	48	7.6	.42	2.7	2.8	.85	144	3.8
7-18	32	5.7	.38	2.7	2.6	47	7.5	.41	3.1	3.1	.92	145	3.8
7-22	30	5.3	.38	2.1	2.0	48	7.2	.41	2.7	2.7	.79	146	4.0
7-29	32	5.4	.39	2.3	2.3	45	7.3	.41	2.6	2.6	.71	146	3.0
7-33	32	5.6	.38	2.5	2.4	47	7.3	.41	2.8	2.9	.81	146	3.4
7-34	33	5.4	.40	2.5	2.5	50	7.2	.44	3.0	3.2	.87	130	4.0
7-43	31	5.4	.36	2.3	2.1	47	7.1	.41	2.8	2.8	.84	145	3.8
7-52	32	5.4	.39	2.3	2.2	49	7.4	.43	3.0	3.2	.87	133	4.6
7-56	34	5.4	.39	2.6	2.5	52	7.4	.43	3.2	3.4	.89	135	4.7
7-58	31	5.4	.38	2.4	2.3	47	7.0	.42	2.6	2.6	.84	125	3.0
7-59	31	5.5	.39	2.1	2.1	49	7.6	.44	2.9	3.1	.86	136	4.5
7-62	30	5.0	.38	1.9	1.8	46	6.7	.44	2.2	2.4	.83	127	3.0
7-67	32	5.4	.38	2.3	2.2	47	7.0	.41	2.8	2.8	.72	146	3.7
7-70	31	5.3	.38	2.2	2.1	47	7.0	.41	2.6	2.6	.80	144	3.3
7-71	32	5.6	.40	2.4	2.4	49	7.8	.43	3.3	3.5	.82	137	5.1
7-72	31	5.2	.40	2.0	2.0	47	6.8	.43	2.4	2.6	.78	138	3.4
Plant. Avg.	32	5.4	.38	2.3	2.2	48	7.2	.42	2.8	2.9	.82	139	3.8

1/ International Paper Co. 8-Oaks test area
2/ When trees were 7.5 years of age
3/ When trees were 11 years of age
4/ Tons of dry wood
5/ Percent based on dry weight of wood

3. Average specific gravity of the families changed from .38 to .42 in 3.5 years, and the ranges among families changed from 0.36 to 0.40 at 7.5 years to 0.41 to 0.44 at 11 years. Small ranges in specific gravity would be expected because all parents were chosen as having high specific gravity, but even then the difference of 0.03 is nearly 2 lbs./cu. ft. and is reflected in tonnage yields. Note that there were fast-growing families with either high or low specific gravities.
4. Tonnage production of dry wood at age 11 is nearly on a 1:1 basis with cord production, except for the higher gravities. The 2.9 tons/acre/year obtained from this fast-grown plantation is good.
5. Family differences are striking. For example, 7-62 is inferior all around; 7-18 and 7-56, which were superior at age 7.5, are still outstanding at age 11, and 7-71 has moved from good to excellent. Note the height differential that is developing (45 to 52 feet) among families by year 11. After roguing clones such as 7-62, 7-70 and 7-72, increased tonnage yields from seed of the rogued seed orchards will be nearly 10 percent.
6. The periodic growth from 1967 to 1971 was impressive. Family 7-71 produced 5.1 cords/acre/year during that time, while 7-56 produced 4.7 cords/acre/year.
7. Bark thickness information is essential for determining accurate wood yields. For example, families 7-29 and 7-67 have thin bark and produce more wood than the standard volume tables would indicate.

One of the most intensively studied open-pollinated progeny tests is Westvaco's at Georgetown, South Carolina. This plantation, which is now 12 years old, was thinned at 7.5 years of age and then fertilized before the eighth growing season. It was then remeasured at year 10. Following are some general conclusions:

1. Survival was good, averaging about 95 percent.
2. Height growth has been excellent, averaging 44.7 feet at 10 years, 44.5 without nitrogen fertilizer, 45.1 feet with nitrogen. As often observed, nitrogen has little effect on height growth.
3. Volume growth has been excellent, averaging 2.6 cords/acre/year at 10 years, with different families ranging from 2.2 to 3.1 cords/acre/year.

Nitrogen fertilizer increased overall volume production by 0.38 cords/acre/year over the nonfertilized control. However, growth of some families was actually depressed as much as 0.20 cords/acre/year following fertilization.

For comparison with open-pollinated progeny tests in the Coastal Plain, growth of a 12.5-year-old plantation growing in the Piedmont of South Carolina on lands of U. S. Plywood-Champion Papers, Inc. is summarized in Table 24. The site of the plantation is an abandoned field which had been badly eroded.

Table 24. Growth of open-pollinated progeny in an eroded Piedmont field of South Carolina on lands of U. S. Plywood-Champion Papers, Inc. 1/

	1971	1968 to 1971	1968
Cords/acre/year	2.1 2/	2.7	1.8
Tons dry wood/acre/year	2.1 2/	3.0	1.7
Specific gravity	0.41	-	0.38
Wood density (lbs./cu.ft.)	25.6	-	23.7
Moisture content (percent)	136	-	161
Height Growth (Ft.)	39	11	28
Diam. Growth (In.)	6.9	3.1	3.8

1/ The 1968 thinning removed approximately half the trees.

2/ Total production, including 1968 thinnings

In a study of 4-year-old, open-pollinated progeny, American Can Company found some striking differences in survival and growth between the averages of the progeny and the commercial check (Table 25). In this test, fertilization had relatively little effect on growth.

Table 25. Comparison of survival and growth of orchard and routinely planted loblolly pine on lands of American Can Company in Alabama

	Survival (%)	DBH (In.)	Height (Ft.)
Seed Orchard	87	1.7	11.4
Commercial Check	69	1.3	9.6

Broadening the Genetic Base for Advanced Generations

Continued progress in any genetics program is dependent upon the maintenance of a broad genetic base. Maintaining such a base is difficult for an individual organization but easier in a cooperative with many members among whom material can be exchanged. Even in a Cooperative a conscious effort must be made to develop and incorporate new material and new genetic combinations into the program.

Methods being used within the Cooperative to broaden the genetic base include:

1. Crossing trees from different environments where there has been no previous chance for gene exchange. Such a project for loblolly pine was started several years ago by Dr. Ron Woessner, who crossed seed orchard parents from throughout the South and outplanted the progeny at ten different locations. Although the first major measurements will not be made until 1972-73, several parental combinations appear

to be most promising. The best of these combinations will be selected for use in second-generation seed orchards.

2. Infusing new selections from wild stands or plantations into the breeding system. These selections are first evaluated in open-pollinated progeny tests; then the best parental clones will be tested more fully for use in advanced-generation seed orchards.
3. Crossing among second-generation selections from different orchards and different geographic areas.
4. Crossing among limited numbers of the very best clones which have not been adequately tested by the standard tester system.

Second-generation Selections

More than 200 second-generation selections have been graded and grafted. The trees are "chosen by the computer" following the fourth- or fifth-year measurements, and checked and/or field graded after the fifth or sixth growing season. Only about one-fourth of the potential candidates survives the field screening. Volume superiority, which is emphasized, is more than 50 percent and occasionally as much as 100 percent over the average of the plantations. Statistics of some second-generation selections are shown in Table 26. Superiority in height of the second-generation selections over the plantation average is about 35 percent. In addition to the emphasis on growth rate, only straight, well formed, disease-resistant trees are accepted.

As outstanding trees are located they are established in clone banks, where they are evaluated for graft compatibility and flowering ability, while the select tree in the progeny test is monitored for continued superior performance. After they have proven themselves at about 10 to 12 years of age, the very best selections from several members of the Cooperative are grafted into a production second-generation orchard. In an effort to take advantage of the known improvements as soon as possible, several organizations are establishing second-generation orchards prior to completion of testing, knowing that some trees included will not meet expectations and must be removed from the orchard.

Table 26. Second-generation selections from preliminary screening at four years of age

Plantation Location	Number of Trees Selected	Average Height of Selections (Ft.)	Average Plantation Height 1/ (Ft.)	Height of Commercial Checks (Ft.)	Percent Height Superiority of Selects Over Plantations
Coastal Virginia	12	10.4	8.2	7.5	27
Coastal N. Carolina	53	11.9	7.8	7.5	52
Coastal S. Carolina	22	11.6	9.4	8.7	23
Coastal Georgia	13	14.9	11.4	10.8	31
Piedmont N. Carolina	31	9.8	7.3	7.2	34
Piedmont S. Carolina	19	11.4	8.6	8.4	32
Piedmont Georgia	16	11.7	9.1	8.9	28
Piedmont Alabama	25	10.6	7.6	7.4	39
Total	191				
Average		11.4	8.5	8.1	35

1/ From unrogued orchard; includes commercial check

Wood Studies

The Summary Publication

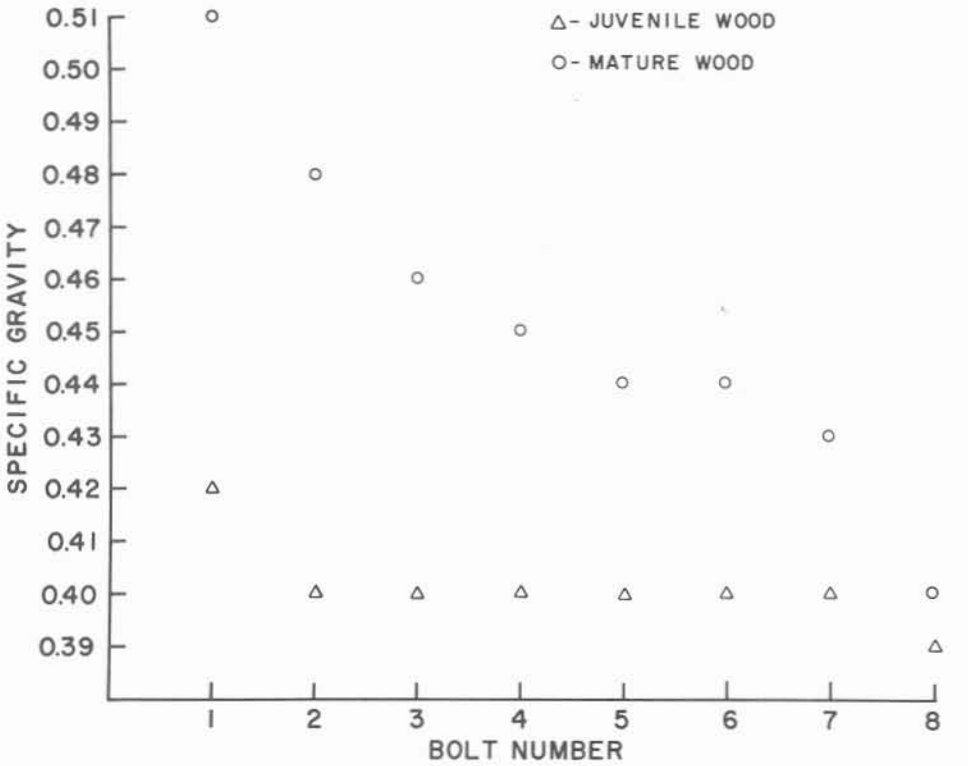
Research on wood studies within the Cooperative has steadily progressed from variation studies of natural stands to laboratory pulping of known genetic material. The results of twenty years of work on wood have been summarized in the North Carolina Agricultural Experiment Station Technical Bulletin 208, "Wood Density of the Southern Pines." We consider this to be the most important publication during the sixteen years of the Cooperative. It includes a mass of data not heretofore available and adds to those previously published.

An example of the kind of study which contributed to the wood properties publication is one by American Can Company (Table 27), which involved the felling of 61 trees ranging in age from 10 to 35 years. Samples were obtained at five-foot intervals from base to a four-inch top on which wood specific gravity and moisture content determinations were made.

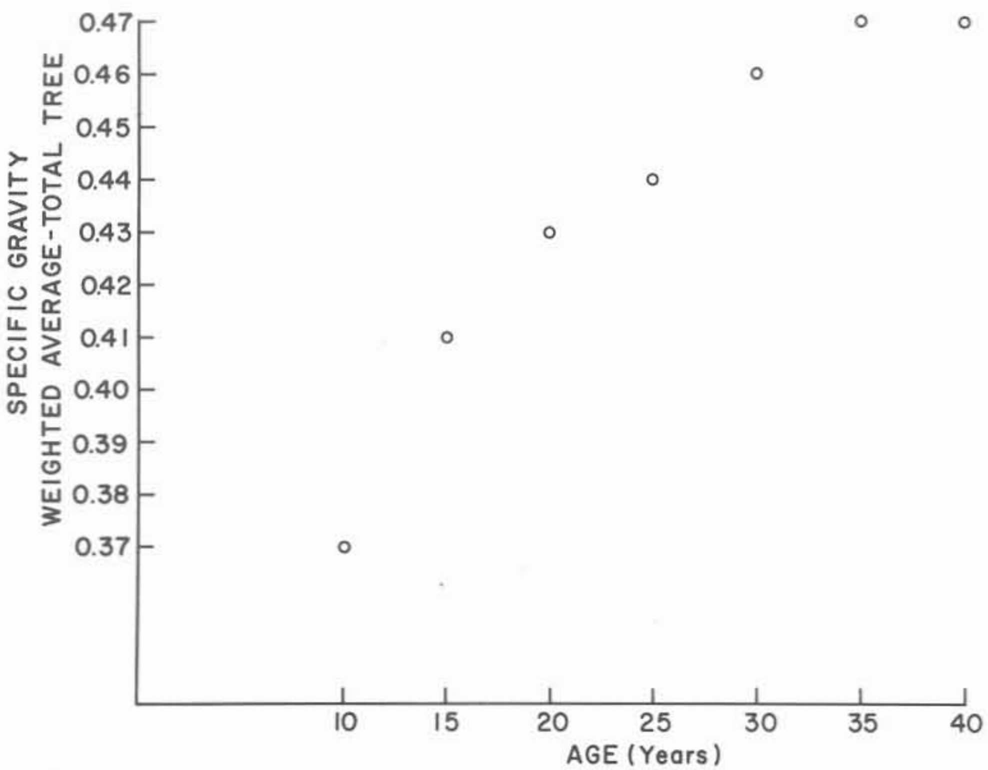
Table 27. Weighted wood properties of the merchantable bole of loblolly pine from lands of American Can Company in Alabama

Age Class	Number of Trees	Moisture Content (Wedge) (%)	Specific Gravity (Wedge)	Lbs./Cu.Ft. (Wedge)
10 - 15	29	134	.42	26.2
16 - 20	18	115	.43	26.8
21 - 25	12	122	.43	26.8
35	2	98	.50	31.2

Another example of information included in the summary publication is indicated in Table 28, which shows the effect of age on wood properties of loblolly, shortleaf and Virginia pines growing in east Tennessee and north Georgia.



Nearly twenty years of work on wood has been summarized in the publication "Wood Density of the Southern Pines." Shown is one graph from that publication which summarizes the relationship of juvenile to mature wood in loblolly pine.



Although well documented in a series of earlier publications, the effect of stand age on total merchantable tree specific gravity of loblolly pine is summarized in graph form. Note the rapid change at the young ages.

Table 28. Dry weight per cord in pounds and tons for three age groups of loblolly, shortleaf, and Virginia pines grown in east Tennessee and north Georgia 1/

Loblolly Pine

Age Class (Years)	0 - 25	26 - 40	41+	14 2/
Age Range (Years)	14 - 25	26 - 40	41 - 49	14
Average Age (Years)	19	33	44	14
Weight - Lbs./Cord	2,043	2,116	2,215	1,627
Weight - Tons/Cord	1.021	1.058	1.107	0.813
Lbs./Cu.Ft.	26.3	27.8	28.8	23.5
Number Trees Sampled	52	14	15	25

Shortleaf Pine

Age Class (Years)	0 - 25	26 - 40	41+
Age Range (Years)	-	27 - 40	41 - 150
Average Age (Years)	15	36	71
Weight - Lbs./Cord	2,068	2,231	2,352
Weight - Tons/Cord	1.034	1.115	1.176
Lbs./Cu.Ft.	28.0	28.8	29.4
Number Trees Sampled	9	44	95

Virginia Pine

Age Class (Years)	0 - 25	26 - 40	41+
Age Range (Years)	19 - 23	26 - 40	41 - 99
Average Age (Years)	21	35	48
Weight - Lbs./Cord	2,110	2,354	2,437
Weight - Lbs./Ton	1.055	1.177	1.218
Lbs./Cu.Ft.	28.1	28.5	29.1
Number Trees Sampled	11	21	128

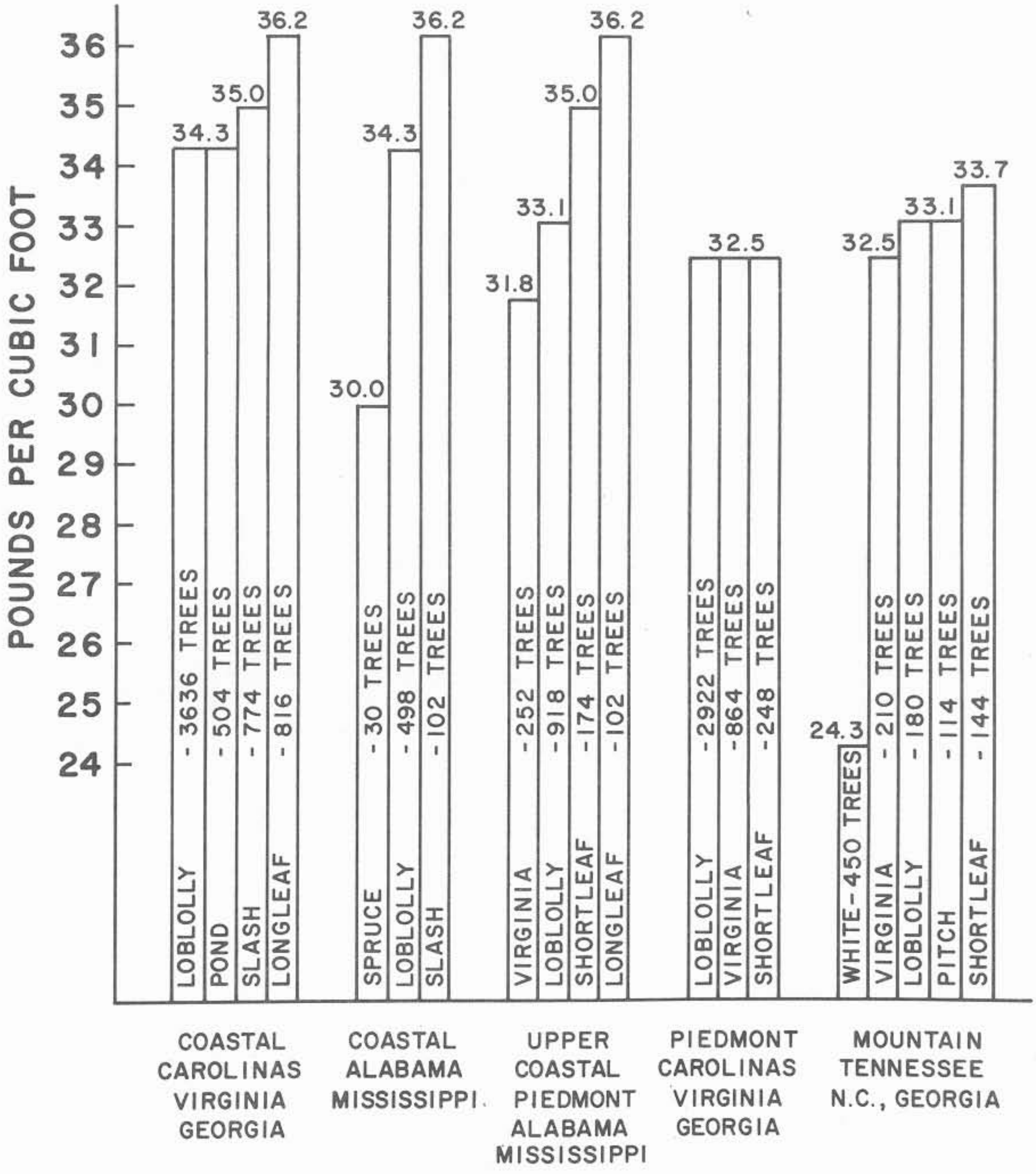
1/ Study by Hiwassee Land Company

2/ From a plantation; all others are from natural stands

Many data on wood have been obtained from routine analyses of select trees analyzed for use in the seed orchards. These values, obtained from wood samples at breast height, are summarized in Table 29.

Table 29. Wood properties of select trees used in the seed orchard program, by species and province

		Wood Density				Tracheid Lengths (mm)
		Juvenile		Mature		
	Number Trees	Spec. Grav.	Lbs./ Cu.Ft.	Spec. Grav.	Lbs./ Cu.Ft.	30th Ring
Loblolly Pine						
N.C., S.C. & Ga. Piedmont	558	.44	27.5	.52	32.5	4.48
Ala.-Miss. Piedmont	140	.43	26.8	.53	33.1	4.47
Atlantic Coastal	620	.45	28.1	.54	33.7	4.45
Ala.-Miss. Coastal	123	.46	28.7	.53	33.1	4.53
Florida Coastal	58	.48	30.0	.58	36.2	4.16
N. C. Deep Peat Coastal	24	.49	30.6	.56	35.0	4.60
Eastern Shore Coastal	39	.42	26.2	.51	31.8	4.29
Mountains	30	.44	27.5	.52	32.5	4.62
Pond Pine						
Atlantic Coastal	86	.49	30.6	.54	33.7	3.93
White Pine						
Mountain	75	.32	20.0	.38	23.7	4.17
Longleaf Pine						
Ala. Piedmont	32	.40	31.2	.57	35.6	4.69
Atlantic Coastal	143	.53	33.1	.57	35.6	4.58
Slash Pine						
Piedmont	23	.46	28.7	.57	35.6	4.66
Gulf Coastal	22	.48	30.0	.56	35.0	4.61
Atlantic Coastal	147	.46	28.7	.55	34.3	4.44
Virginia Pine						
N.C., S.C. & Ga. Piedmont	144	.46	28.7	.52	32.5	4.16
Ala. Piedmont	64	.46	28.7	.50	31.2	3.96
Mountain	38	.46	28.7	.52	32.5	4.01
Shortleaf Pine						
N.C., S.C. & Ga. Piedmont	59	.46	28.7	.52	32.5	4.64
Ala.-Miss. Piedmont	20	.46	28.7	.54	33.7	4.55
Ala.-Miss. Coastal	14	.46	28.7	.57	35.6	4.57
Mountain	25	.47	29.3	.54	33.7	4.48
Total	2484					



Wood studies in the Cooperative have resulted in a mass of data. These have been summarized for different geographic areas to show species differences within and among areas.

Many wood studies have dealt with other than specific gravity and moisture content and have been reported in the wood density paper. As an example, Table 30 shows characteristics of tracheids of young trees, mature wood only, and topwood of mature trees.

Table 30. Wood qualities of 11-year-old loblolly pines compared to older trees and topwood of mature trees 1/

Wood Property	11-Yr.-Old Trees	Mature Trees 2/ (Merchantable Wood)	Mature Trees 3/ (Topwood Only)
Specific Gravity	.42	.48	.41
Lbs./Cu.Ft.	26.2	30.0	25.6
Tracheid Length (mm)	2.98	4.28	3.59
Cell Wall Thickness (microns)	3.88	8.04	6.72
Lumen Size (microns)	42.25	32.78	32.47
Cell Diameter (microns)	50.01	48.86	45.91

1/ Data are from thirty-six 11-year-old trees from a progeny test of International Paper Company. Sixteen mature trees are represented, and top values are from six mature trees.

2/ Juvenile wood excluded

3/ Average for the top four 5-foot bolts, having a mean diameter of five inches

Pulping Studies

Special pulping studies have been completed by Hammermill Paper Company and International Paper Company during the past year. The Hammermill study consisted of pulping 12-year-old loblolly pines of high, average, and low specific gravity; results were compared with mill run chips. In addition, an assessment was made of the cost and availability of juvenile wood. When summarized it was found that the cost of producing pulp from juvenile wood (12-year-old trees) was about 80 percent greater than for pulp produced from mature wood. Much of the high cost was related to harvesting young trees. The 12-year-old trees produced low pulp yields, with properties inferior for certain paper products but superior for others.

The International Paper Company study tested the effects of tree form on pulp yields and paper quality. Another facet of the study was related to effects of fusiform rust on pulp and paper properties. Such studies are essential to fully understand the value of different tree qualities in a selection program and how much time and effort should be expended on each.

Special Wood Studies

During the past year a number of special wood studies were made, among which are:

1. Wood of Caribbean Pine

   Five trees were felled and sampled at 10-foot intervals from base to merchantable top. The results for two trees are summarized in Table 31; tree-to-tree variation in wood specific gravity and extractives was large, with specific gravity values of individual first bolts ranging from 0.45 to 0.63.

Table 31. Variation between and within two trees of Caribbean pine for wood specific gravity, moisture content, and extractives

	Wood Density					
	Unextracted		Extracted		Extractives	Moisture Content
	Spec. Grav.	Lbs./ Cu.Ft.	Spec. Grav.	Lbs./ Cu.Ft.	(%)	(%)
Tree 3						
Bolts:						
Butt	.605	37.8	.552	34.5	9.7	56
1	.536	33.5	.493	30.8	7.7	77
2	.485	30.3	.460	28.7	5.5	85
3	.426	26.6	.414	25.8	3.0	115
Tree 5						
Bolts:						
Butt	.556	34.7	.523	32.7	6.0	84
1	.472	29.5	.457	28.5	3.3	118
2	.484	30.2	.473	29.5	2.3	98
3	.484	30.2	.473	29.5	2.4	98
4	.476	29.7	.448	28.0	6.1	96

2. Wood density of Virginia Pine Progeny

When Hiwassee Land Company established their Virginia pine seed orchard in Chatsworth, Georgia, they interplanted open-pollinated and control-pollinated seedlings among the grafts. After the grafts became established, seedlings were harvested and wood samples were obtained (Table 32). Specific gravity ranged from 0.34 to 0.40; this variability indicates changes that could be made in breeding for specific gravity.

Table 32. Wood specific gravity of 5-year-old, open- and control-pollinated progeny of Virginia pine 1/

Open-Pollinated Progeny			Control-Pollinated Progeny		
Family	Specific Gravity	Lbs./ Cu.Ft.	Cross	Specific Gravity	Lbs./ Cu.Ft.
1-13	0.36	22.5	1-13 x 1-30	0.37	23.1
1-30	0.36	22.5	1-78 x 1-30	0.37	23.1
1-52	0.37	23.1	1-3 x 1-4	0.37	23.1
1-29	0.38	23.7	1-52 x 1-4	0.38	23.7
1-4	0.36	22.5	1-3 x 1-29	0.40	25.0
1-86	0.37	23.1	1-13 x 1-29	0.40	25.0
1-3	0.38	23.7	1-30 x 1-4	0.36	22.5
1-69	0.35	21.9	1-13 x 1-52	0.39	24.4
1-78	0.38	23.7	1-13 x 1-4	0.37	23.1
1-72	0.36	22.5	1-52 x 1-30	0.37	23.1
1-35	0.34	21.2	1-3 x 1-13	0.39	24.4
1-74	0.35	21.9	1-3 x 1-30	0.36	22.5
1-79	0.36	22.5	1-78 x 1-13	0.38	23.7
			1-30 x 1-29	0.36	22.5
			1-78 x 1-4	0.38	23.7
			1-29 x 1-4	0.34	21.2
Average	0.363	22.7		0.374	23.3

1/ Study by Hiwassee Land Company

3. A large study on the relationship of site preparation and spacing to wood quality of 8-year-old and 14-year-old slash pine is just now being completed by Brunswick Pulp and Paper Company. It includes

spacings from 6' x 6' to 12' x 12' and site preparations of bedding, harrowing, burning and their combinations. General trends were:

a. Spacing differences did not affect specific gravity of slash pine.

b. On the 14-year-old trees, different site preparations had no effects on wood. On the 8-year-old trees there was little difference among treatments although trees on site-prepared areas had slightly higher specific gravities than did those of the untreated check.

c. There were large differences in wood qualities from the different environments (sites) in which the trees were tested. The 14-year-old trees, tested in six areas, had specific gravity averages which ranged from 0.479 to 0.501. The specific gravity of the 8-year-old trees, tested in five areas, had averages ranging from 0.409 to 0.427.

The general conclusion is that neither spacing nor site preparation has much effect on specific gravity, while location of plantation has a definite effect.

Miscellaneous Studies--Pine

Hybridization

Although not highly publicized, one activity of the Cooperative relates to assessing the value of hybrids for specialty or problem sites. The loblolly-x-shortleaf cross is under test by American Can Company, to assess disease resistance of the hybrid and relative growth of the hybrid and both parental species. Westvaco Corporation, Georgia Kraft Company, and Union Camp Corporation are testing the loblolly-x-pitch hybrid for its ability to grow on shallow soils and in areas where environmental extremes are encountered.

Union Camp Corporation has established an extensive test of hybrids with slash pine to determine their suitability for both very dry and very wet sites. Results of third-year measurements are shown in Table 33.

Table 33. Comparison of hybrids to the parental and other species for survival, growth and rust infection on wet and dry sites. The data were obtained after the third growing season.

Source	No. of Lots and No. of Trees Tested	Survival (%)	Height (Ft.)	Rust Infected (%)
	Dry Site			
Slash x drought-resistant loblolly	7 (110)	86	6.6	40
Slash x longleaf	5 (39)	90	5.2	12
Slash parent	5 (50)	92	6.4	54
Loblolly - drought-resistant parent	1 (75)	90	6.8	1
Longleaf parent	1 (54)	54	2.6	0
Sand pine	2 (47)	60	6.3	0
	Wet Site			
Slash x wet site loblolly	10 (268)	90	4.5	44
Slash parent	4 (42)	100	5.4	38
Loblolly-wet site parent	2 (23)	96	4.4	7
Spruce pine	1 (17)	85	2.1	0

1/ Study by Union Camp Corporation. The dry site was a deep sand; the wet site was a swampy area nearby.

Although results are only preliminary because of the young age of the test material, some trends are evident:

1. The Texas drought-resistant source was relatively rust-resistant.

2. Slash pine parents were very rust-susceptible.

3. Survival of hybrids was usually satisfactory.

4. Most important, although not shown in the table, is the very large difference among crosses of the same species. One slash x drought-resistant loblolly had only 68 percent survival while another had 100 percent; progeny of one cross was 67 percent infected by fusiform rust while progeny of another cross had only 8 percent infection. All crosses having one drought-resistant loblolly as a parent were highly infected by fusiform rust. Although most slash-x-longleaf crosses had less than 10 percent rust infection, certain crosses were 74 percent infected. All the highly infected families of this cross had the same mother but different fathers. Variation in height growth related to parent used in the cross was similar to rust infection; family differences of the same species cross ranged from 2.8 to 5.8 feet in height.

Results from a study by Union Camp Corporation in Alabama of the shortleaf-x-slash hybrid, the parental species and loblolly pine are shown in Table 34. It is evident that shortleaf has passed on its fusiform rust resistance to the progeny.

Table 34. Comparisons of shortleaf-x-slash hybrids to the parental species and to loblolly pine for height, survival and rust infection in Alabama 1/

Source	Height (Ft.)	Survival (%)	Rust Infected (%)
Shortleaf x slash	7.5	86	2
Slash pine	7.8	76	40
Loblolly pine	8.5	85	27
Shortleaf pine	4.3	95	0

1/ Study by Union Camp Corporation

Disease Resistance

The Cooperative has emphasized the gains to be achieved by breeding for disease resistance. As a result, seven members have established special orchards to produce trees with increased fusiform resistance. The magnitude of the gains to be obtained was summarized in a recent publication.[1/] The authors concluded that in a stand only 25 percent infected, a 30 percent improvement in resistance would reduce infection to only 17 percent. But the same 30 percent improvement in a 60 percent infected stand will lower the infection to 42 percent. Gains are summarized in Table 35. Calculations to determine the gain from special disease resistance orchards such as those in the Cooperative, which include 14 selected parents, showed a predicted improvement as great as 66 percent. It was concluded that gains from the specialty orchards would be highly beneficial when only 37 percent of the mean was achieved.

Table 35. Predicted and realized gains from breeding for resistance to fusiform rust as determined by mass selection, progeny testing, and mass selection plus progeny testing. Based on the 1963 and 1964 control-pollinated planting of International Paper Company loblolly pine heritability study.

	Predicted Gain (%)		Realized Gain (%)	
	1963	1964	1963	1964
Mass selection (choosing only disease-free parents)	16	9	25	2
Progeny testing	20	9	20	13
Mass selection plus progeny testing	36	18	45	15

[1/] Zobel, B., Blair, R. and Zoerb, M. 1971. Using research data--disease resistance. Jour. of For. 68(8):486-489.

Activity on disease resistance is at an all-time high. Several hundred disease-free trees have been selected from stands such as this plantation in Georgia that are 90 to 95 percent infected.

Our progeny tests have given good information on disease resistance. However, damage from the disease to the extent shown in one of International Paper Company's tests at Georgetown, South Carolina has hindered assessment of volume growth. Some of the more susceptible families are essentially gone after ten years in the field.

Selfing

As controlled crosses are made for the progeny tests, attempts are made to self many of the clones. Many of the selfs are completely unsuccessful or produce so few seeds as to be negligible. Even when sound, germinable seeds are produced, the plants are often inferior in growth to progeny of outcrossed parents.

In cooperation with Hoerner-Waldorf, we have established a holding area for more than 100 selfed families at Tillery, North Carolina. These families will be used for a whole series of breeding experiments which will have application to a tree improvement program. The idea has been suggested that trees which self well will produce good outcrosses. In a very preliminary study, the growth of selfs at three years was assessed and compared with the performance of their outcrosses. It's too early to draw any conclusions but differences in performance of selfs are considerable (Table 36).

Table 36. Ranked means for three-year heights of selfed seedlings planted in 1969 at Tillery, North Carolina

Family	Rank	Mean[1/]	Geographic Source	Outcrossed Performance
8-1	1	7.2	Coastal Plain	G
9-12	2	7.0	Piedmont	F
8-7	3	6.6	Coastal Plain	F
8-33	4	6.5	Coastal Plain	F
6-9	5	6.5	Piedmont	F
6-20	6	6.4	Piedmont	G
9-5	7	6.4	Coastal Plain	G
3-13	8	6.3	Piedmont	G
6-41	9	6.3	Piedmont	F
9-6	10	6.2	Coastal Plain	G
8-127	11	5.9	Coastal Plain	F
8-68	12	5.8	Coastal Plain	F
3-8	13	5.3	Piedmont	F
8-53	14	5.2	Coastal Plain	F
6-33	15	4.9	Piedmont	F
6-2	16	4.8	Piedmont	F
10-25	17	4.7	Coastal Plain	F

[1/] Measurement is in feet.

Fume damage to forest trees is becoming more common. In this area some trees were killed, some injured, and some showed no outward appearance of injury due to the pollutants. The Cooperative is involved in breeding for resistance to fumes; special studies are underway by the Virginia Division of Forestry, the North Carolina Forest Service, and N. C. State University.

The arboretum of Hoerner-Waldorf has developed well. In the background are native southern pines the same age as the western pines in the foreground. After the wild temperature fluctuations in February, 1972, many of the exotics such as the ones shown have died.

Needle Cast and Fume Damage

A long observed problem in the southern pines, especially in pond and slash pines, is a severe browning of the foliage during the fall and winter caused by various needle cast pathogens. Damage appears to be worsening each year. Little mortality occurs but growth must certainly be affected. No matter how severe the attack, there are occasional trees that stay bright green, apparently nearly totally resistant to the needle cast. Studies of resistance to these diseases are essential, particularly if growth is being seriously affected.

The intensive studies on resistance to fume damage undertaken last year by the Virginia Division of Forestry, the North Carolina Forest Service, and Bob Weir of our staff are already yielding results. The Virginia Division of Forestry, who built their own chamber to field test trees for resistance to ozone, reports rather substantial differences in damage among families of both loblolly and shortleaf pines; differences in resistance were more than fourfold between the best and poorest families.

Oh, my! What the members of the Cooperative have to put up with! Here Associate Director Kellison is trying to outdo the graft of the mutant pine. Who won?

Membership of the Pine Cooperative

Organization	Working Units and States
American Can Company (Southern Woodlands Division)	Ala., Miss.
Catawba Timber Company (Bowaters Carolina)	S. C., N. C., Va., Ga.
Chesapeake Corporation of Virginia	Va., Md., Del., N. C.
Container Corporation of America	Ala.
Continental Can Company, Inc.	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	Va., N. C., S. C., Ga., Fla.
Hammermill Paper Company	Ala.
Hiwassee Land Company (Bowaters Southern)	Tenn., Ga., Ala., Miss.
Hoerner-Waldorf Corporation (Halifax Timber Division)	N. C., Va.
International Paper Company	S. C., N. C., Ga.
Kimberly-Clark Corporation (Coosa River Division)	Ala.
Masonite Corporation	Miss.
North Carolina Forest Service	N. C.
South Carolina State Commission of Forestry	S. C.
Tennessee River Pulp and Paper Company	Tenn., Ala., Miss.
U. S. Plywood-Champion Papers, Inc.	Alabama Div.--Ala., Tenn. Carolina Div.--S. C., N. C., Ga.
Union Camp Corporation	Savannah Div.--Ga., S. C., Ala. Franklin Div.--N. C., Va.
Virginia Division of Forestry	Va.
Westvaco Corporation	South--N. C., S. C. North--Va., West Va., Ohio
Weyerhaeuser Company	N. C. Div.--N. C., Va. Miss.-Ala. Operations--Miss., Ala.

GRADUATE STUDENTS

No applied program can continue to be efficient without a foundation of basic research. In the past, many basic studies have been done by graduate students associated with the Cooperative, but in recent years money for funding graduate research has become increasingly difficult to obtain. Granting agencies such as the National Science Foundation have restricted funds for most studies except those related to environmental problems. The lack of funds will seriously affect the quantity and quality of basic information available to the Cooperative.

We have maintained 15 to 20 graduate students in the Cooperative, with the desired goal being 15. As a result of the high costs for graduate studies and less grant monies, there has been a drop in number of graduate students from the United States working with the Cooperative Programs. Despite this, the overall graduate program in the Cooperative has not dropped because of a major change in the proportion of United States students to foreign students; the latter are usually financed by their home governments. Most of the foreign students do a good research job; but because of language, culture, time, interest, and travel restrictions, they often undertake studies of a different type than do the domestic students. Whether foreign or from the United States, the graduate research of the student is almost always based upon the plant materials and information made available from studies and tests of the Cooperatives or upon material which will directly benefit the Cooperative. Often the work is done directly on lands of the cooperators with data and information of a semiclassified nature. The availability of such data to the students allows for more meaningful studies and results in research often not possible by the cooperator.

In previous annual reports we have listed students and student projects to illustrate their contribution and value to the Cooperative. In this report we shall describe several student studies to illustrate the type and value of work done.

A. Inheritance, growth, form, and wood qualities of juvenile loblolly pine

About ten years ago a study was initiated with International Paper Company, Georgetown, South Carolina, to determine the feasibility of developing a strain of loblolly pine with high density juvenile wood. Nearly 1,000 trees were sampled, and from these were chosen 40 that had the desired juvenile wood characteristics. Enough seeds were obtained from 34 of the parents for a progeny test which is now over six years old. Growth and wood data, obtained after the third and the fifth growing seasons, were the subject of a Master of Science thesis by Dimitrios Matziris of Greece.

Results of the study indicate that it is readily possible to improve the density of juvenile wood by breeding. At five years, wood density of progeny from parents with high specific gravity juvenile wood was nearly 2 lbs./cu.ft. heavier than from parents with low gravity. There is reason to believe that by year 10 the difference due to parentage will increase to nearly 5 lbs./cu.ft. A change of this magnitude indicates that both yields and paper quality can be affected to a marked degree by parental selection.

Matziris also worked out inheritance of various characteristics of 5-year-old loblolly pine, as shown in Table 37. In addition to calculating inheritance patterns, Matziris determined a number of correlations between characteristics. He found specific gravity and tracheid length were relatively independent; he also found growth rate and specific gravity to be essentially independent although the faster growing trees had slightly higher specific gravities than did the slower growing ones.

Table 37. Heritability estimates for ten characteristics of five-year-old, open-pollinated loblolly pine[1/]

Characteristic	h^2 [2/]
Specific gravity	0.47
Tracheid length	0.97
Moisture content	0.80
Total height	0.44
Diameter (DBH)	0.26
Volume	0.28
Bark thickness	0.28
Straightness	0.66
Crown form	0.31
Fusiform infection (score)	0.17
Percentage of fusiform infected trees	0.26

[1/] Study by International Paper Company

[2/] h^2 narrow sense heritability on an individual basis, except for fusiform rust infection in which a special formula was used. Values can vary from 0 to 1; the higher the value, the stronger the inheritance.

B. Effect of fertilizers and mother tree on growth of sycamore on poor, medium, and good sites

Using plant material and resources from four members of the Cooperative, in a study for his Ph. D. Degree, Jay Kitzmiller completed a comprehensive assessment of the effect of fertilizers and mother tree on the growth of sycamore on poor, medium, and good sites. Fertilizer results were reported in the hardwood section of this report; genetic results are shown here:

1. The best families were outstanding on both the good and excellent site.

2. Heritabilities varied, depending on the fertilizer regime, and were somewhat higher with the best fertilizers; values are shown in Table 38.

Table 38. Effect of fertilizer on heritability estimates, h^2, of height growth in two-year-old sycamore for 28 mother trees grown on an excellent bottomland and a good upland site 1/

Nitrogen Levels	Combined Sites	Upland Site	Bottomland Site 2/
Control	0.38	0.42	0.37
200 lbs./acre	0.61	0.49	0.39
400 lbs./acre	0.57	0.53	0.10
600 lbs./acre	0.51	0.52	0.19

1/ Study on the lands of Chesapeake Corporation in the Piedmont of Virginia

2/ There were several poorly drained areas that flooded the second year and upset growth patterns; by chance these occurred in the heavily fertilized plots.

3. Large family differences were found; the best family was 24 percent taller than the average and 72 percent taller than the poorest family. Family performance was relatively stable over both environments and different fertilizer regimes.

The results indicate that parents chosen as superior on one site or under one fertilization regime are also superior under other conditions. Response to fertilizer is so outstanding that its use is mandatory on nearly all sites where sycamore will be grown.

C. Analysis of a Virginia pine seed orchard

In conjunction with Kimberly-Clark Corporation, a half-diallel analysis of a 22-clone seed orchard of Virginia pine was done by John Kundt for his Ph. D. research. As is usual with a half-diallel, some crosses did not materialize but 114 were obtained for the main test and 90 others were used in the preliminary tests.

After one year in the greenhouse or in the nursery, the seedlings were outplanted on lands of Kimberly-Clark Corporation as a backup "seedling seed orchard" to their main orchard. Field measurements will be obtained in 1973 when the trees are five years old. Application of the results found by Kundt must be made carefully because all data are from young trees grown in the nursery or greenhouse. Major conclusions were:

1. Crosses were not obtained with uniform ease; some parents, such as 12-14, could hardly be forced to cross with others, even though the few progenies produced were very good.
2. Greatly differing general and specific combining abilities were obtained. Only one clone (12-29) had poor general combining ability for all five characteristics studied (height, diameter, branchiness, germination, and bud set). In contrast, three clones, 12-15, 12-40 and 12-41, were outstandingly good for height. The cross 12-26 x 12-27 was outstanding for specific combining ability; if good performance continues in the field, these two clones could be considered for use in a two-clone orchard.

3. When tested for efficiency, a six-clone tester system gave the most information on general combining ability per work unit. The five-tester system used by Kimberly-Clark was good to determine general combiners but missed the best specific combiners altogether.
4. Narrow sense heritability estimates were highest for height growth and number of branches and lowest for diameter growth.
5. Kundt concluded that a typical seedling seed orchard, which combines progeny testing with seed production, should not be used.

D. Competition in loblolly pine

A number of factors controlling tree growth are becoming better understood but little is known about competition. In forest trees as in other crops, certain genotypes were suspected of growing well or poorly, depending upon the genotypes with which they compete.

To determine how important competitive ability is in loblolly pine, graduate student Tom Adams grew trees free of competition, in competition with their full sibs, and in competition with several other families in a greenhouse study. Some family combinations grew better in competition with themselves than with others. Some grew better with certain families while growing more slowly with other families. Some families grew well, irrespective of the type of competition. The results indicate that differential competitive ability will probably be very important in forest trees and work should be concentrated in this area.

E. Monoterpene composition of loblolly pine

A Ph. D. study by Don Rockwood, dealing with aspects of monoterpene composition of loblolly pine, gave guidelines for sampling of terpenes for the use of such information in basic research. He compared stem xylem, branch cortex and bole wood as sources of terpenes. The conclusion was that branch cortex terpenes were the best to use for many studies.

The research dealt with within-tree, seasonal, and year-to-year fluctuations in terpene composition; results indicate that sampling must be done under uniform conditions if results are to be usable. Stem xylem terpenes are moderately heritable, with values following a north to south gradient. Branch cortex terpenes are highly heritable, with negligible within-tree variability. There was some indication that branch cortex oleoresins are correlated to fusiform rust resistance and that they remain following infection of the tree. Rockwood concludes that indirect selection using terpenes may be an efficient method of locating resistant parents.

F. The financial maturity of natural stands of southern hardwoods

In an M. S. thesis, using data from the Hardwood Growth and Yield Study, Dick Porterfield developed volume growth curves and harvesting cost equations for eight forest site types. These results were then used to determine financial maturity for each site type at three, six and nine percent interest rates. Major conclusions of the study were:

1. The muck swamp subtype, which can be harvested with a rubber-tired skidder, ranks first among all forest site types in profitability. The limited accessibility of this subtype, however, remains as a major deterrent for intensification of forest management.
2. Hardwood forest site types of the Coastal Plain are generally more profitable than those of the Piedmont or mountains.
3. Annual monetary returns from natural hardwood stands are low, being the result of poor volume yields and low stumpage prices.

4. Financial rotation ages for the various forest site types ranged from 25 to 34, from 19 to 26, and from 16 to 23 for the 3, 6, and 9 percent interest rates, respectively.

Despite the bleak economics of hardwood management of natural stands as derived from this study, all is not as bad as it appears. Porterfield showed that an increase in stumpage price or in volume growth would have significant effects on financial maturity of the stands and would thus make the monetary rate of return more favorable.

The six student research projects described above, three for the M. S. and three for the Ph. D. Degrees, give some idea of the variation and scope of work underway. Other studies dealing with fusiform resistance, inheritance of mycorrhizal infection, inheritance in wood specific gravity and related characteristics, economic studies on hardwood plantations, economic studies on tree improvement, variation in wood of sycamore, and fume resistance of loblolly pine are nearly completed or well underway.

There can be no doubt about the value, the high caliber, and the contributions that student research have made to the success of the Cooperatives.

PUBLICATIONS

Each year we include a list of recent publications in the Annual Report. Activities in this area have been especially heavy in 1971-72 and many publications were completed.

In response to numerous requests, we also include a separate mimeographed list of all publications since the program was initiated. The supply of many of the publications shown has been exhausted.

Adams, T., Roberts, J. and Zobel, B. 1972. Intergeneric interactions among seedling families of loblolly pine (Pinus taeda L.). Theoretical and applied genetics. (In press)

Barefoot, A. C., Hitchings, R. G., Wilson, E. H. and Kellison, R. C. 1971. Related aspects of the morphology of loblolly pine and papermaking. Symp. on "Effect of Growth Acceleration on Wood Properties," Madison, Wis., November. 69 pp.

Blair, R. L. and Zobel, B. 1971. Predictions of expected gains in resistance to fusiform rust in loblolly pine. 11th Southern Forest Tree Improvement Conference, Atlanta. 16 pp. Abstract pp. 4-5.

Dorman, K. W. and Zobel, B. J. 1971. Genetics of loblolly pine. For. Ser. Res. Paper, U. S. D. A. (In press--mimeo 69 pp)

Johnson, J. W. 1971. Effects of forest floor inclusion and ashing on nutrient analyses of forest soils. Ph. D. Thesis, N. C. State Univ., Raleigh. 113 pp.

Kellison, R. C. 1971. Tree improvement in southern pines--A decade of progress. Talk given at 20th LSU For. Symp., Baton Rouge, La., May. 10 pp.

Kellison, R. C. 1971. Seed orchard management. Talk given at 11th SFTIC Meeting, Atlanta, June. 7 pp. Abstract pp. 12-13.

Kellison, R. C. 1971. The future of tree improvement in the southern pines. Alabama Chapter Annual Meeting, SAF, Mobile, Ala. August. 7 pp.

Kellison, R. C. 1971. Hardwood management philosophies and practices. Talk given at Southeastern Hardwood Symp., Dothan, Ala., Sept. 15-16. 9 pp.

Kellison, R. C. and Zobel, B. J. 1971. Wood and fiber properties of five southern hardwoods. Talk given at 25th Annual Meeting, FPRS, Pittsburgh, Pa., June 27 - July 1. 17 pp.

Kellison, R. C. and Zobel, B. 1972. Genetics of Virginia pine. (In press)

Kitzmiller, J. H. 1972. Response of sycamore (Platanus occidentalis L.) families to nitrogen fertilization. Ph. D. Thesis, School of Forest Resources, N. C. State University, Raleigh. 120 pp.

Kinloch, B. B., Jr. and Zoerb, M. H. 1971. Genetic variation in resistance to fusiform rust among selected parent clones of loblolly pine and their offspring. Paper given at 11th SFTIC Meeting, Atlanta, June. 4 pp.

Kirk, D. G., Breeman, L. G. and Zobel, B. J. 1972. A pulping evaluation of juvenile loblolly pine. Tappi (In press). TAPPI For. Biol. Comm., Appleton, Wis., May.

Kundt, J. F. 1972. A diallel analysis in Virginia pine (*Pinus virginiana* Miller). Ph. D. Thesis, School of Forest Resources, N. C. State University, Raleigh. 106 pp.

Lamontagne, Y. 1971. Variation among bud characteristics, needle morphology and needle anatomy among white pine populations of the southern Appalachians. M. S. Thesis, School of Forest Resources, N. C. State University, Raleigh 98 pp.

Matziris, D. 1971. Inheritance of juvenile characteristics in loblolly pine (*Pinus taeda* L.). M. S. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 105 pp.

Porterfield, R. L. 1971. The financial maturity of certain southern mixed hardwood stands. Tech. Rept. 45, School of Forest Resources, N. C. State University, Raleigh. 49 pp.

Rockwood, D. L. 1972. Aspects of monoterpene composition in loblolly pine. Ph. D. Thesis, School of Forest Resources, N. C. State University, Raleigh. 120 pp.

Stonecypher, R. W., Zobel, B. J. and Blair, R. L. 1972. Inheritance patterns of loblolly pine from an unselected natural population. For. Sci. Monograph (In press).

Toda, R. 1970. Abstracts of Japanese Literature in Forest Genetics and Related Fields, Vol. I, Part A, 236 pp. (Review by W. D. Miller and Bruce Zobel, N. C. State University, Raleigh). Forest Science, March, 1972.

von Weissenberg, K. 1971. Indirect selection for resistance to fusiform rust in loblolly pine. Ph. D. Thesis, School of Forest Resources, N. C. State University, Raleigh. 85 pp.

Zobel, B. 1971. Genetic manipulation of wood of the southern pines, including chemical characteristics. Talk given at 3d Plenary Meeting, International Academy of Wood Science Meeting, Raleigh, March. 25 pp. Paper No. 3409, Jour. Series, N. C. State University, Agriculture Experiment Station, Raleigh. Wood Science & Technology 5(255-271).

Zobel, B. J. 1971. The genetic improvement of southern pines. Scientific American, November. pp. 94-103.

Zobel, B. 1971. Wood for forest industries. American Paper Industry 53(1): 26-36.

Zobel, B. J. 1971. Gene preservation by means of a tree improvement program. Canadian For. Tree Impr. Program, St. George, B. C., Canada. August. Sump. on Conservation of Forest Gene Resources.

Zobel, B. J., Blair, R. and Zoerb, M. 1971. Using research data--disease resistance. Jour. For. 68(8):486-489.

Zobel, B. J., Kellison, R. C. and Kirk, D. G. 1972. Wood properties of young loblolly and slash pines. Given at Madison, Wis., Nov. 10-11. For. Prod. Lab.-API-TAPPI Symp. on "Effect of Growth Acceleration on Wood Properties." pp M1-M22.

Zobel, B. J. and Kellison, R. C., Matthias, M. and Hatcher, A. 1971. Wood density of southern pines. 69 pp. mimeo. Tech. Bull. No. 208, N. C. State University, Agriculture Experiment Station, Raleigh. (In press)

Zobel, B. J. and Kellison, R. C. 1972. Short-rotation forestry in the Southeast. TAPPI, Feb. 14-16, New York. 17 pp. Tappi (In press)

Zobel, B. J., Weir, R. W. and Jett, J. B. 1972. Breeding methods to produce progeny for advanced-generation selection and to evaluate parent trees. Paper presented at TAPPI Forest Biology Comm., Appleton, Wis. (May 1 - 16) (In press)

Zobel, B. J. 1972. Breeding programs for coniferous forest trees--pines. Presented at VII Seminario Panamericano de Semillas, Cd. Obregón, México. 15 pp.

Zobel, B. J. 1972. Industry's increasing and changing requirements for wood. To be presented at Seventh World Forestry Congress, Buenos Aires, Argentina, October. 7 pp.

Zobel, B. J. 1972. Genetic implications of even-aged forest management. To be presented at the Second North American Forest Biology Workshop, Corvallis, Oregon, August. 6 pp.

Zobel, B. J. 1972. The three-ring-per-inch, dense southern pine--can it be developed? Jour. of For. (In press). 2 pp.

Zobel, B. J. 1972. Genetic effects on wood qualities. Presented at the Sixth TAPPI Forest Biology Conf. (May). Part of a panel, "Innovation by Systems Analysis"

Zobel, B. J., Kellison, R. C. and Breeman, L. 1971. Wood properties of young, fast-grown loblolly and slash pine. Symp. on utilization of fast-grown timber, Madison, Wis. (In press)

Zobel, B. J. 1971. Challenge of the seventies--wood and forest industries. Amer. Paper Ind. 53(1).