FIFTEENTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

May, 1971

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FOREWORD

What a year! Some parts of it we would not like to experience again but overall it was a period of maximum results from the Cooperative Programs.

The Bad

As a result of the depressed economic situation, some projects, especially in hardwoods, were placed on a maintenance basis and basic studies were somewhat curtailed. Employment opportunities in forestry were down, and an overall general pessimistic attitude prevailed. Happily, at time of writing there seems to be an upturn in optimism and certain members of the Cooperatives are outspoken about their positive outlook for the future. Despite general curtailment of budgets and certain restrictions in activities and travel, most organizations continued to intensify forest management activities and the theme we have mentioned before, "Produce more wood per acre in the shortest period of time," has become rather standard operational procedure.

Other events occurred that are just as well forgotten. Ice storms damaged a couple of seed orchards rather badly. Fire took more than its usual toll of progeny tests; several organizations sustained losses so severe they must start over. We had the "privilege" of watching piles of one six-year-old progeny test burn, just at the age when meaningful data were becoming available, as the test area was being converted into a dog pen by an overzealous neighbor. Power lines and highways continued to "search out" plantations, and we even had an instance of careless operational forestry personnel plowing fire lanes through and logging across the nice, convenient open area occupied by progeny tests.

A further negative aspect which we would not want to repeat within the Cooperative is the feeling of being swamped, putting out "brush fires" brought on by understaffing and personnel changes. New computer programs plus changes in the computer facilities caused a serious backlog of data analysis that is just being cleared up. Another hitch encountered in our normal operations was the move to our fine new building; time was lost in the move and we are only now back to full operating efficiency.

The Good

For the past two years we have proudly stated, "Our seed orchards are in production," when enough seed was obtained to produce 10 million seedlings in 1968 and 40 million in 1969. But in 1970 a bumper seed crop was obtained and production of seedlings is expected to be between 90 and 100 million. We estimate only five to seven more years will be required before all present seed needs of the cooperators are met from seed orchards. However, as rotation ages are shortened and additional forest land is acquired by Cooperative members, seed needs and thus seed orchard acreage continues to increase.

Most pleasing is the use of current information developed over the past years at such a high cost and with so much effort. New improved orchards have been established, specialty orchards started, and second-generation selections made. Hardwood plantations can now be more efficiently established and natural regeneration more easily obtained based upon experience from past studies. Added information about wood of both pines and hardwoods is available. Economic studies have been completed which will allow future activities to benefit from sound financial as well as biological information. It has been a time of real satisfaction to see results, results, results for those members of the Cooperatives who have toiled so long to make this day possible.

For the first time in several years we are at full strength, following the addition of Bob Weir to the staff to fill the opening created by the resignation of Jim Roberds. The overall Cooperative Programs are at a peak of operational efficiency, a condition that will be necessary to meet the demands of future years.

A Major Decision

From the beginning of the Cooperative in 1956 we have attempted to operate a well-balanced program in which the applied phases were supported by basic research. We have delved fairly deeply into certain developmental and fundamental aspects such as population dynamics, physiological basis of disease resistance, physiology of wood formation, and tree breeding involving quantitative genetics. With the help of the strong supporting faculties at North Carolina State University it was possible to establish a center with considerable excellence in certain of these fields, which attracted the best United States students and scientists as well as many from other parts of the world. Although much of the research was done at the University by students or faculty, the plant material and field data usually came directly from lands of the Cooperative members. Funds for many of the more fundamental studies were obtained through special grants from the National Science Foundation, the National Institute of Health, the Hardwood Fellowship Program, the Industrial Disease and Insect Research Programs, the Ford Foundation, the Kellogg Foundation, and several others.

Activities of the applied tree breeding and forest management programs have developed rapidly and are the best known portion of our program. Seed orchards, progeny tests, economic studies of hardwoods, hardwood species-site and fertilizer activities all were pursued as rapidly as time, funds, and cooperative efforts permitted. Much of the applied work was done directly by members of the Cooperatives with our consultation and advice. Results from these activities have been immediately put to use in the operational programs of members of the Cooperatives.

With the staff and funding available, the Cooperatives have in the past been able to carry on both the fundamental and applied activities. However, with the termination of special grants and the current tight funding, it has become increasingly difficult to maintain quality in both endeavors. Therefore the decision has been made to concentrate activities on the tree breeding and applied silvicultural aspects and, secondly, to carry on as much supporting research as funding and staff will permit. We will attempt to obtain additional grant monies but such are currently very scarce. Special funds for research, such as the Union Camp Corporation Hardwood Fellowship and the Weyerhaeuser Company Research Grant have been most helpful in enabling us to bring in outstanding students to continue necessary research activities.

One result of the shortage of funds has been a limitation on assistantship monies. The graduate student load still is between 15 and 20 each year, but the ratio of fellowship to assistantship students changes every year, with a resultant large increase in foreign students and a decrease of local students. The inability to finance postdoctoral students, who in the past have made some excellent contributions, is being felt. During our deliberations, the type and quality of studies done in the past by students associated with the Cooperative was checked. The list was most impressive, with a broad spread of subject matter. Titles of theses and participating students are listed in Appendix 1 of this report.

THE COOPERATIVE TREE IMPROVEMENT PROGRAM--PINE

Introduction

The pine program continues to increase in size and scope of activities. Although no new members were admitted during the past year, nearly all organizations have expanded their goals and increased their seed requirements. Many more acres of both routine and specialty seed orchards have been established and expansion will continue into next year. Several organizations are obtaining sufficient seed from their orchards for their entire regeneration program. The largest seed collection in 1970 was from Weyerhaeuser's North Carolina orchards, which yielded enough seed to produce over 20,000,000 plantable seedlings. Several other members of the Cooperatives obtained enough seed orchard seed to produce about 10,000,000 trees each.

The greatest pressures in the pine program have been to speed results so advantage can be taken of progeny test results. To get useful amounts of genetically improved seed as soon as possible we had to employ short cuts to the desired scientific approach in the original seed orchards to gain precious time. On the second and later cycles of selection it was planned to go more slowly, using tested scientific methods, but this has not usually been possible. We are more scientific, yes, but still have strong pressures to reduce time requirements; this necessitates certain short-cuts to get commercial quantities of better genetically improved planting stock. The urgency makes the job more difficult and somewhat frustrating but it indicates the immediate use made of research results by members of the Cooperative.

Intensive site preparation is becoming more common, even on drier sites. Shown are beds on a sloping Piedmont ridge in Alabama on lands of Hammermill Paper Company. Such beds, made on the contour, result in catchment of water that would normally be lost.

The Production Seed Orchard Program

Seed orchard activities deal both with the production and research phases necessary for a properly balanced, long-term program. If we are to avoid working ourselves into a "dead end" due to excessive inbreeding we must from the start design crossing patterns and progeny tests for keeping the genetic base broad. We need to obtain maximum genetic gains without superspecialization, by producing strains of plants well adapted only to specialized environments, which has occurred in agriculture. Our plans are to develop seed suitable for maximum growth on a wide set of environments rather than to develop a different orchard for each major site classification. The agriculturists have devoted much of their activity in the past few years to broadening the adaptability base so their strains have broader usage. We can avoid this difficulty by maintaining adaptability from the start.

There has been some question about movement of trees from one area to another, which appears to be a relaxing of our "hard-nosed" insistence of staying within strict physiographic limits for a given seed orchard. As a sufficiently large base of the proper source has been built up and with greater experience based on research results, we are occasionally "salting" orchards with outside clones that are real winners. Use of such proven superior clones will improve the tree quality and growth from a given orchard without danger of loss of adaptability. Further, it will broaden the genetic base by producing gene combinations not previously available. Similarly, selections from commercial plantations of unknown source are being made, not to be used in production orchards until they have proven their genetic worth.

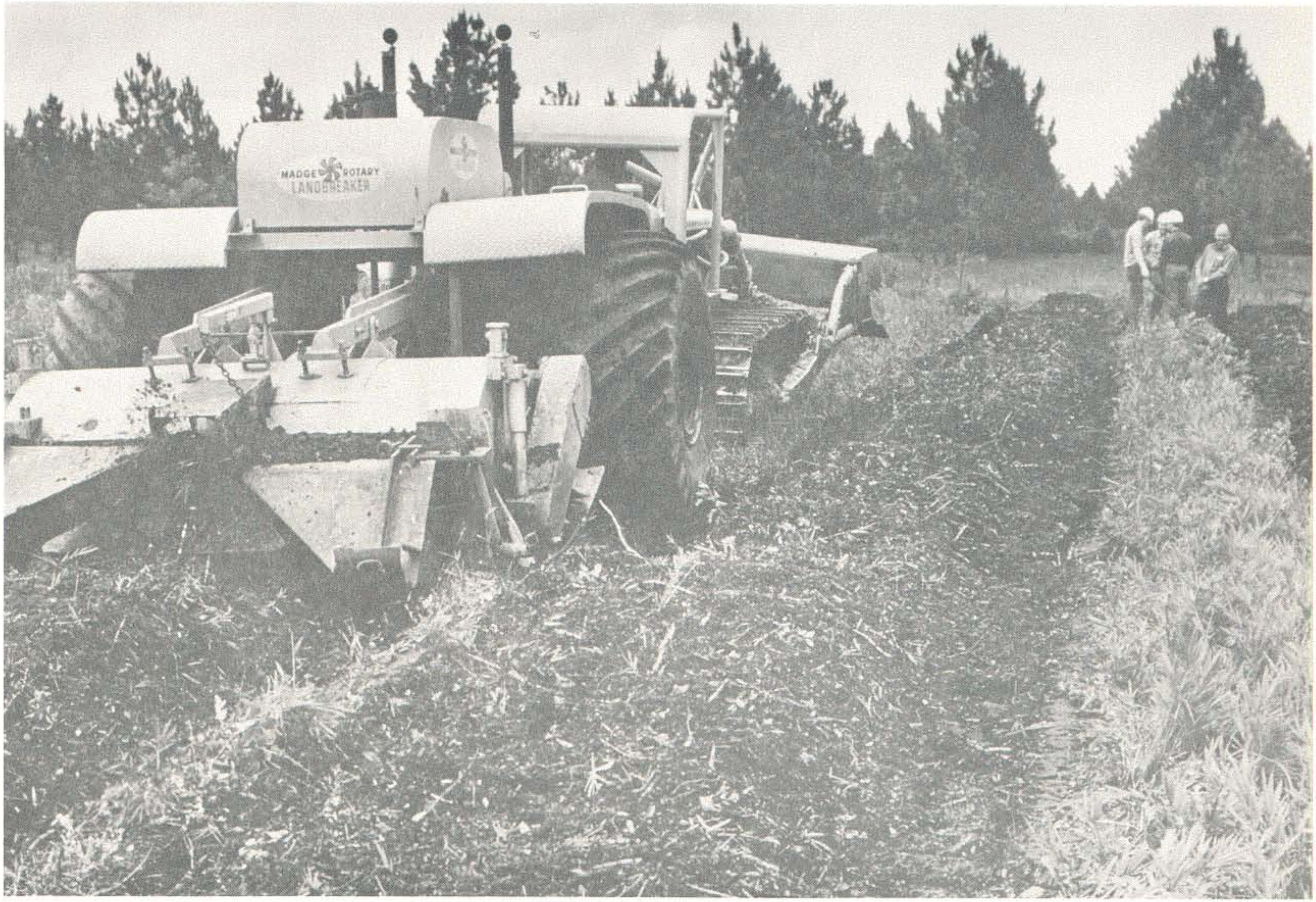
Species and Source Differences

We always face losses from ice, tornadoes or hurricanes. Ice storms damaged several seed orchards, especially in the Coastal Plain, rather severely this year although none were completely destroyed. Records kept by North Carolina Forest Service showed the following types of damage to grafts in their loblolly pine orchards:

Type Damage	Coastal Source	Piedmont Source
Bole broken	12%	3%
Major limb loss	15%	-
Minor limb loss	21%	8%
No damage	52%	89%

The greater resistance of Piedmont loblolly to damage by ice has been observed but not quantified before. Plantations from the two different source orchards react in the same manner as the grafts; also, greater dieback from freeze damage has been observed in the Coastal source loblolly pine. The open-pollinated progeny tests of Riegel Paper Corporation indicate that trees from Coastal Plain sources (grown in the Coastal Plain) have denser wood, are taller, larger in diameter and have straighter boles with smaller crowns and thinner bark than do trees of the Piedmont source grown in the Piedmont (Table 1).

The Cooperative has concentrated its work on loblolly pine but does considerable work with slash and Virginia pines and to a lesser extent with the other southern pines. In the more southerly portions of the working territory of the Cooperative there has been a major shift from slash to loblolly pine. There are many reasons for the shift in emphasis from loblolly to slash pine, chief of which are growth and yield differentials with loblolly now performing best in some areas where slash has been routinely planted. To illustrate the



Intensive site preparation has become widely accepted. One of the most intensive operations is being done by Weyerhaeuser with this landbreaker. The beds are excellent for both pine and hardwood production.

Table 1. Yields and wood qualities of 11-year-old open-pollinated progeny--Coastal Plain and Piedmont sources 1/

	Piedmont Orchard (Avg. of four families)	Coastal Orchard (Avg. of two families)
Specific gravity	0.39	0.43
Lbs./Cu.Ft.	24.5	27.1
Moisture percent 2/	145	134
Cords/Acre/Yr.	1.8	2.1
Tons dry wood/ Acre/Year	1.6	2.1
Height (ft.)	29.6	35.2
Diameter (in.)	5.4	5.3
Straightness 3/	3.36	2.87
Crown 3/	3.88	3.16
Bark thickness	0.53	0.41

1/ From seed orchards of Riegel Paper Corporation, Bolton, N. C. Piedmont orchard seed tested in the Piedmont and Coastal seed tested in the Coastal Plain.

2/ Based on dry wood

3/ Based on a subjective scale of 6, the lower values being straighter or smaller.

magnitude of differences obtained, growth and disease results for four-year-old progeny tests of loblolly and slash pine planted together near Savannah, Georgia on lands of Union Camp Corporation are shown (Table 2). In this area loblolly pine proved to be not only faster growing but much less infected by disease, although slash pine retains superior limb and crown characteristics.

The switch in species emphasis points up one of the Cooperative's major problems--obtaining a sufficient supply of loblolly pine seed from the more southern sources. There is great demand for any kind of Florida and South Georgia loblolly pine seed, and genetically improved seed from these areas is very scarce. A special need for the correct source of loblolly comes from the southern hemisphere subtropical countries, where growth of the southern source loblolly is much better than from more northern sources.

Table 2. Height, diameter, volume,1/ and percent rust infection comparison between 4-year-old loblolly and slash pines grown on the same site 2/

	Growth Rate							
	Height (ft.)		Diameter (in.)		Vol. (Cu.Ft./ Acre)		% Rust Infection	
	Slash	Loblolly	Slash	Loblolly	Slash	Loblolly	Slash	Loblolly
Fastest Growing Cross	11.7	17.2	1.9	2.8	62	150	67 3/	24 3/
Test Average 4/	10.3	15.4	1.6	2.5	43	114	93	57
Commercial Check	9.7	14.8	1.6	2.5	41	110	85	72

1/ Volumes calculated by using family averages

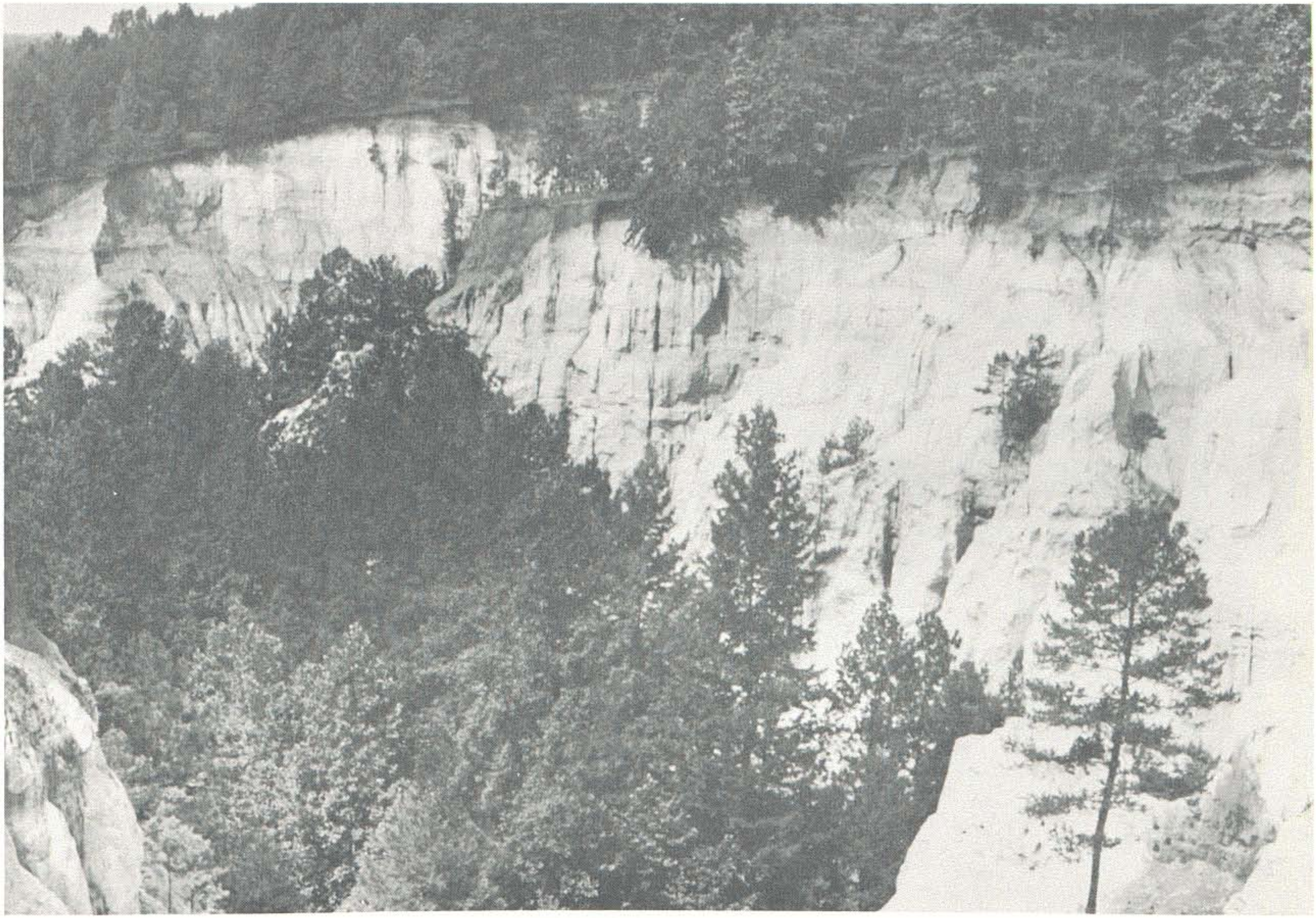
2/ Data from 4-year-old progeny tests of Union Camp Corporation, Rincon, Georgia

3/ Most resistant cross

4/ Includes all sources in the test, good and bad, as well as commercial checks.

Tree Selection

The bulk of selection activities during the past year has been concentrated on completing partially established orchards for sources such as Florida loblolly and Eastern Shore (Virginia) loblolly. A considerable amount of additional selection was devoted to "specialty" orchards for Cronartium resistance. As an example, Union Camp Corporation has made many selections of apparently resistant slash pine trees of superior growth and form in ten- to fifteen-year-old slash



Care of the environment must always be uppermost in forest management activities. Special care must be taken in the erodible soils such as in this part of Georgia. The "little" erosion shown is said to have been started by a cowpath. Any forest management operations on such soil must be done with the greatest of care.

plantations which are infected by fusiform rust in excess of 90 percent. Hammermill Paper Company is establishing a similar "specialty" orchard with loblolly pine.

A summary of pines graded to date is shown in Table 3.

Table 3. Trees selected for seed orchard use in the Cooperative Programs (to March, 1971)

Species		Number Trees Graded
Loblolly pine (P. taeda)		1535
Virginia pine (P. virginiana)		243
Longleaf pine (P. palustris)		194
Slash pine (P. elliottii)		192
Shortleaf pine (P. echinata)		116
Pond pine (P. serotina)		85
White pine (P. strobus)		75
Pitch pine (P. rigida)		21
Spruce pine (P. glabra)		12
Sand pine (P. clausa)		4
	Total	2477

Improved First-Generation Orchards

Progeny tests show most clones in the seed orchards produce trees superior to the commercial checks but some do not, so it is imperative that the inferior clones be rogued from the orchards. Such roguing produces greater gains than a quantitative statistical approach might indicate, because occasional highly inferior individuals (or freaks) appear that seriously degrade the quality of seed from an orchard. The problem is more serious when such an outstandingly poor individual is also a heavy seed producer. For example, U. S. Plywood-Champion's clone 3-6 produces 50 percent dwarfs and some progeny from clone 3-17 are poor growing mutants with retarded needle development; crossing for progeny tests indicated that Union Camp's clone 10-6 produces good cone and seed crops but few of the seeds germinate. Such inferior clones are removed from the seed orchards, resulting in a considerable upgrading. Over thirty seed orchards have been rogued, several for the third time.

Because of increased seed needs due to rapid expansions, many members of the Cooperative have taken advantage of progeny test results to establish new orchards, bringing together the very best performing clones of their own and of their neighbors in a new orchard. Hundreds of acres of such improved first-generation orchards have been established, made up of such outstanding clones as International Paper's 7-56, Riegel's 9-15, Weyerhaeuser's 8-33, Kimberly-Clark's 12-12, Bowaters' 1-60, Chesapeake's 4-19, and many others. The genetic quality of the improved orchards will be between first- and second-generation orchards.

Harvest and Yield of Seed Orchard Seed

Each year we summarize the production of seed orchard seed for all members in the Cooperative. In 1969, 3,361 pounds of seed were obtained, enough to produce about 40,000,000 seedlings. The yields increased greatly in 1970 to 8,588 pounds (enough to produce between 90 and 100 million seedlings (Table 4). Although there was a generally good loblolly pine cone crop in 1970, some of the more northerly orchards had low yields in pounds of seed per bushel. The northern orchards have usually been lower-yielding than the southern orchards, but the difference was especially large this past year. Prospects for cone harvest in 1971 are only moderate, but some orchards had a good flower crop the spring of 1971. Despite the smaller crop, the total production is not expected to decrease because acres of productive orchard are increasing each year.

Variation is the necessary ingredient for success in a breeding program. Species such as white pine certainly possess it, as seen from the contrasting types in a plantation of the North Carolina Forest Service.

Table 4. Acreage, cone and seed yields from conifer seed orchards established in the Cooperative

Species	Bushels of Cones (1970)	Pounds of Seed (1970)	Pounds of Seed/ Bushel of Cones
Coastal Source Loblolly Pine	3305	4872	1.47
Piedmont and Mountain Source Loblolly Pine	1841	2106	1.14
Slash Pine	1744	1545	.88
Virginia Pine	186	59	.31
Pond Pine	7	5	.70
White Pine	2	0.6	.30
Totals	4085	8587.6	

Many members of the Cooperative are obtaining yield and quality data of seed to help guide their harvesting and regeneration operations. Shown in Table 5 are seed data from one of the more northerly orchards, that of Tennessee River Pulp and Paper Company. Although pollen is relatively scarce as a result of the young age of the grafts, the percentage of sound seed was overall very high. The large variation in seed size from about 11,500 to 19,000 seeds per pound is not unusual.

Table 5. Seed variation among clones from a northern loblolly pine seed orchard--Tennessee River Pulp and Paper Company, Counce, Tennessee

Clone	Sound Seeds per Cone	Percent Sound Seed	Number Seed per Pound
1-22	42	93	13,000
1-23	53	96	17,500
1-60	53	100	15,250
19-2	60	98	14,000
19-3	42	87	17,250
19-12	37	92	12,000
19-17	31	79	15,500
19-18	23	67	18,750
19-21	48	96	13,500
8-501	66	90	12,750
8-503	50	95	12,000
8-504	51	96	13,500
8-509	49	86	11,500
8-512	26	76	16,750
8-531	40	85	14,000

For comparison to loblolly pine, the size of seeds obtained from 15 different clones of Westvaco's pond pine seed orchard are shown in Table 6. The range is very wide, with the average being in the neighborhood of 35 to 40 thousand seed per pound. Note one clone produced very small seed.

Table 6. Variation in number of pond pine seeds per pound--Westvaco Orchard

No. Clones	Seeds/Pound
4	29,400 - 31,900
4	35,200 - 38,900
3	40,000 - 40,400
3	45,000 - 50,600
1	78,000

Quality of trees in a seed orchard is often indicative of the quality of the progeny they will produce. Shown is a beautifully straight loblolly pine graft in the Georgia Kraft seed orchard in central Georgia. Every ramet of this clone is very straight.

Fertilization and Irrigation of Seed Orchards

Several members of the Cooperative have made extensive tests in seed orchards to determine the effects of fertilization and irrigation on seed production. Last year we reported results from Hoerner-Waldorf's orchard in which the cone yields were as follows:

Treatment	Cones per Graft
Control	17.4
Irrigation only	23.8
Fertilization only	41.2
Irrigation-plus-fertilization	66.6

Another study started by Catawba Timber Company in 1964 on one-year-old grafts and treated continuously thereafter gave the following results in 1970:

Treatment	Cones per Graft
Control	49
Irrigation only	92
Fertilization only	86
Irrigation-plus-fertilization	148
Operational orchard (routine fertilization)	92

It is obvious from these long-term studies that fertilization and irrigation are beneficial. Relative importance depends on soils and year, with irrigation especially beneficial in dry years, but the combination of irrigation and fertilization is always best. If maximum seed production is to be obtained, fertilization is essential and irrigation is recommended for most seed orchards.

The Vacuum Seed Harvester

The final report, blueprints and parts list of the vacuum seed harvester as compiled by the Seed Harvest Committee have been sent to all members of the Cooperative. Their conclusions need not be repeated here but can be summarized as "The system works fine but the machine as developed needs considerable alteration."

Following are statements from the final report prepared by Barry Malac and Marvin Zoerb of Union Camp Corporation following extensive testing of the machine:

1. The vacuum seed harvester, as a key element in the entire seed harvesting system, did not perform satisfactorily in its present configuration. However, this statement must be qualified:
   a. The function of seed pickup was almost 100 percent successful.
   b. The function of seed cleaning and separation was only about 15 percent successful.
2. Tree shaking of loblolly pine for the purpose of removing seed from the cones which were allowed to ripen and open on the trees was 87 percent successful.
3. The calculated cost of harvesting loblolly pine seed with the shaker-sweeper system appears reasonable, provided the recovery of usable seed is improved.
4. The forward speed of the vacuum harvester is too slow to allow an efficient and economical operation and must be increased.
5. The vacuum sweeper must be redesigned to make its operation more trouble-free.
6. The final degree of purity of seed achieved with the shaker-sweeper system was about 75 to 80 percent. This may or may not be acceptable.
7. There should be no major obstacles connected with developing and maintaining suitable ground conditions within an orchard:
   a. A relatively level and even ground
   b. A relatively complete and continuous grass cover
   c. Precleaned ground prior to seed harvesting
8. The shaker-sweeper seed harvesting system, on the whole, still holds a great promise to become fully operational.

9. For smaller orchards (perhaps up to 50 acres in size) the best alternative for the time being may be a harvesting system utilizing hydraulic buckets.

10. Large orchards (over 50 acres) of southern pines with persistent cones will have to be harvested with systems such as the shaker-sweeper system described here.

In the appendix of the report, comparative costs of using various harvesting systems are reported (based on an analysis by Michael Barry, Union Camp Corporation).

Summary

Four different methods of collecting pine seed from loblolly cones have been evaluated and are summarized as follows:

Method	Size of Orchard (acres)	Seed Yield/ Season (lb.)	Initial Equipment Investment (dollars)	Number Men Required	Cost per Pound (dollars)
Tree climbers	100	3,000	None	100	20.22 1/
Hydraulic bucket	100	3,000	None 2/	14	6.53 1/
Vacuum machine	100	3,000	104,000	12	10.91 3/
Improved vacuum machine	100	3,000	82,000 4/	10	8.84 3/

1/ Cost per pound of seed before it has been separated from the cone. Cones have been loaded into containers and are ready for shipment from the orchard.

2/ For the purposes of this study it was assumed that nine hydraulic buckets and carriers would be available for rental at a cost of $6 per operating hour.

3/ Cost per pound of seed before it has been separated from pine needles. Seed and needles have been loaded into bags and are ready for shipment from the orchard.

4/ If the present vacuum sweeping machine could be redesigned so that forward speed could be increased 25 percent and the effective sweeping width could be increased to 8' from 6', the number of machines required to sweep 100 acres could be reduced from 7 to 5. The result would be a decrease in initial investment, number of personnel required, and a corresponding decrease in collection cost per pound of seed.

Subsoiling has proven to be a most useful practice in seed orchards. Shown is the fine root development following cutting of a large root in the seed orchard of International Paper Company, Georgetown, South Carolina. Tree health and cone production both are improved.

Specialty Seed Orchards

The main seed orchards are designed to produce seed for the normal, average conditions in an industrial ownership. There are specific problem conditions, however, that are so different from normal that the production orchard seed will not be satisfactory. Specialty orchards can produce better adapted stock, making areas economically productive that would be submarginal with the normally improved planting stock. Several such specialty orchards have been, or are being, established by members of the Cooperative.

Disease Resistance

Seven members of the Cooperative have established or are establishing orchards totalling some 50 acres for production of disease-resistant progenies to plant where fusiform rust is especially severe. Each year additional resistant clones will be added to the original 14 now being used, as determined from progeny tests.

Wet Site Loblolly Pine

Several companies have large acreages of swamp or pocosin lands in which normal planting stock "phases out" five to ten years after establishment. Tests over the past six years have shown progenies from certain clones are well adapted to such wet areas. These have been brought together for "wet site" orchards now being established by Riegel Paper Corporation, Weyerhaeuser Company, and Westvaco Corporation.

Low Site Index Areas

Extensive tests are under way to find sources or species that will do well on deep sands or on eroded Piedmont soils. Although current tests have not yet delimited outstanding sources well enough to warrant establishment of special orchards on an operational scale, tests are under way with Virginia, sand, and loblolly pines.

Inter- and Intraspecific Hybrids

A number of hybrids developed for possible use under adverse environmental conditions are under test. One shortleaf orchard for production of loblolly-x-shortleaf hybrids has been established by American Can Company to produce trees with high resistance to *Cronartium fusiforme*. Various hybrids are being tested by Union Camp Corporation for their adaptability to dry and wet sites, and Westvaco Corporation has done considerable work on the loblolly-x-pitch pine cross for possible use on shallow soils and at higher elevations in the upper Piedmont. No seed orchards have yet been established.

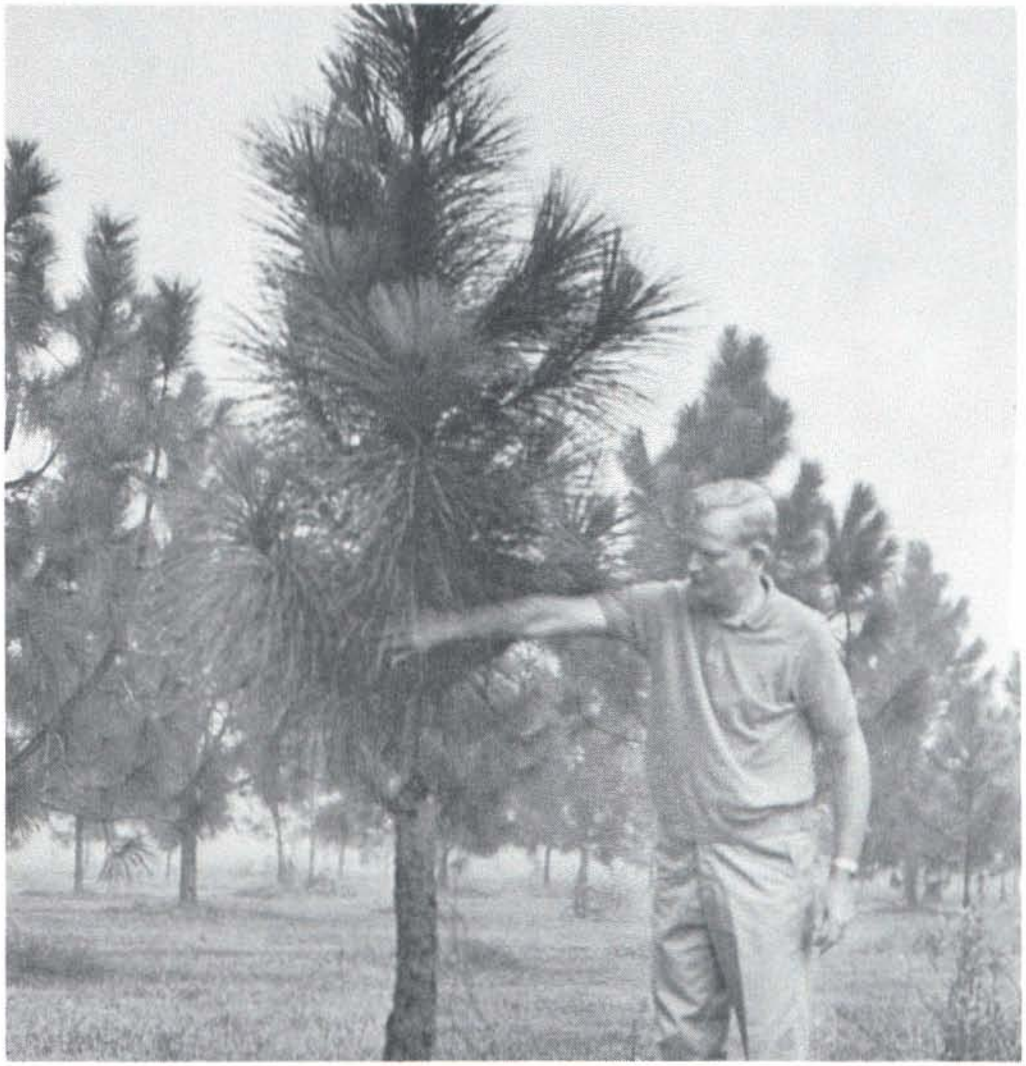
Wood Properties

A number of studies have indicated the strong inheritance of wood specific gravity and tracheid length. Orchards to produce trees with special woods have been established for many years. Additional ones may soon be added to produce pine wood especially useful as a supplement to hardwood and to produce juvenile wood of high specific gravity to improve yields and paper qualities at short rotations.

Advanced Generation Seed Orchards

Second-Generation Orchards

Last year the first selections were made for second-generation orchards. The plan is to make initial selections at year five and hold the selected trees for several more years in clone banks where they are evaluated for



Last year we showed severe damage in the slash pine orchards of the South Carolina Commission of Forestry, resulting from an ice storm. Recovery was dramatic during the past year as shown by (left) a severely damaged graft in which only one small branch remained and (right) a less severely damaged tree in which the top had been broken.

graft compatibility and flowering characteristics. During this time the worth of the selections would be evaluated in the field planting. When ten to twelve years old, the best of the selections would then be placed in production orchards. However, the current heavy demand for additional orchard acreage and added improvement has resulted in use of the better second-generation selections directly in production seed orchards, with the knowledge that some will prove to be inferior and thus must be rogued from the orchard.

A major emphasis on second-generation orchards is on volume growth. Based on results to date, predictions are being made of an additional 20 to 25 percent dry fiber weight yield per acre over the 10 to 20 percent already obtained from the rogued first-generation orchards. Some of the second-generation selections are magnificent. A major problem has been to find trees with desired growth and form that are also disease-free; many otherwise excellent trees have been rejected because of disease infection. Characteristics of the second-generation selections are shown in Table 7.

Table 7. Characteristics of second-generation selections from progeny tests

Source	# Trees Selected	Avg. Ht. of Selections	Avg. Ht. of Plantations	Avg. Ht. of Comm. Check	Superiority over Comm. Check	Superiority over Plantations
Coastal South Carolina	20	12.4	9.7	8.2	51%	28%
Piedmont North Carolina	9	9.9	8.0	7.6	30%	24%
Coastal North Carolina	30	11.5	9.8	8.7	32%	17%
Piedmont South Carolina	15	11.8	9.9	9.5	24%	19%
Piedmont Alabama	11	11.3	8.3	7.5	57%	36%
Total and Avg.	85	11.5	9.4	8.5	35%	22%

Two-Clone Orchards

In a production seed orchard, good general combining clones which produce good progeny irrespective of the other clone with which they are crossed are sought. Additionally clones are found with good specific combining abilities, *i. e.*, progeny from the crossing of two specific clones are outstanding although progeny from the crossing of either parent with other clones might not be particularly good. Such good specific combinations such as 8-33 x 8-31 of Weyerhaeuser can greatly improve production. Weyerhaeuser Company is establishing a North Coastal and a South Coastal loblolly pine two-clone orchard for production of larger quantities of seed of proven performance. It is expected that in the next several years a number of two-clone orchards will be established to produce seed for special problems.

Progeny Testing, Genetic Improvement and Fertilizer Response

Progeny testing is the most laborious and expensive phase of the Tree Improvement Program. It has developed well, and results have enabled us to rogue the older orchards with considerable confidence. The progeny tests also serve as a source of trees for second-generation orchards, for specialty orchards, and for two-clone orchards. Chances for such selection are very large; total lots under test and acreage planted are shown in Table 8.

"Logger, spare that tree." So says Jack Formy-Duval of Riegel Paper Corporation as their loblolly pine seed orchard was being thinned. Such roguing is based on fruitfulness, graft compatibility, and progeny performance of the clone.

Table 8. Control-pollinated progeny field planted in the Tree Improvement Program to June, 1971

	Number of Lots	Acres Planted
Main Tests 1/	3682	516.6
Supplementary Tests 2/	3431	281.1
Totals	7113	797.7

1/ Each cross is planted in six ten-tree row plots for each of three years on land considered representative of the ownership of the cooperator.

2/ Most crosses are planted in three ten-tree row plots for each of three years on areas considerably different from those of the main test.

Difficulties have been encountered in progeny testing. Heavy losses were sustained from fires, with smaller but most aggravating losses from trespass, careless logging, or just plain vandalism. Some tests have not performed well as a result of tip moth and grazing damage or being established on poorly drained sites, and determination of the value of parental clones has been delayed until normal growth has been obtained.

Members of the Cooperative have established plantations which show how fast loblolly pine will grow under good conditions. Results of two such tests are shown in Table 9. The differences in performance among crosses was striking, indicating that the goal of optimal yields will fall far short if the very best seed sources are not employed.

Table 9. Comparison of select crosses vs. commercial checks for height, diameter, and volume in two small four-year-old loblolly pine progeny tests

Organization	Number of Seed Lots	Type of Cross and Percent Superiority	Ht. (ft.)	Diam. (in.)	Vol. (cu.ft.)
International Paper Company Supplementary Test (Georgetown, S. C.)	30	Best 25% Crosses	19.2	3.7	.783
		All Crosses	16.9	3.3	.581
		Commercial Check	16.2	3.3	.513
		Best 25% Crosses to Commercial Check	18.5%	12.1%	52.6%
		All Crosses to Commercial Check	4.3%	0.0%	13.2%
Union Camp Corporation Supplementary Test (Rincon, Georgia)	24	Best 25% Crosses	16.4	2.7	.367
		All Crosses	15.4	2.5	.298
		Commercial Check	14.8	2.5	.292
		Best 25% Crosses to Commercial Check	10.8%	8.9%	25.7%
		All Crosses to Commercial Check	4.1%	0.0%	2.1%

The value of severe roguing is indicated by removal of all but the best 25 percent of the crosses, but leaving the best 25 percent is not the same as a 75 percent roguing of the seed orchard. Because of some inconsistency among the clones, improvement by roguing will be somewhat less than shown, but the depressing effect on overall orchard performance caused by poor clones is obvious.

Genetic Gains

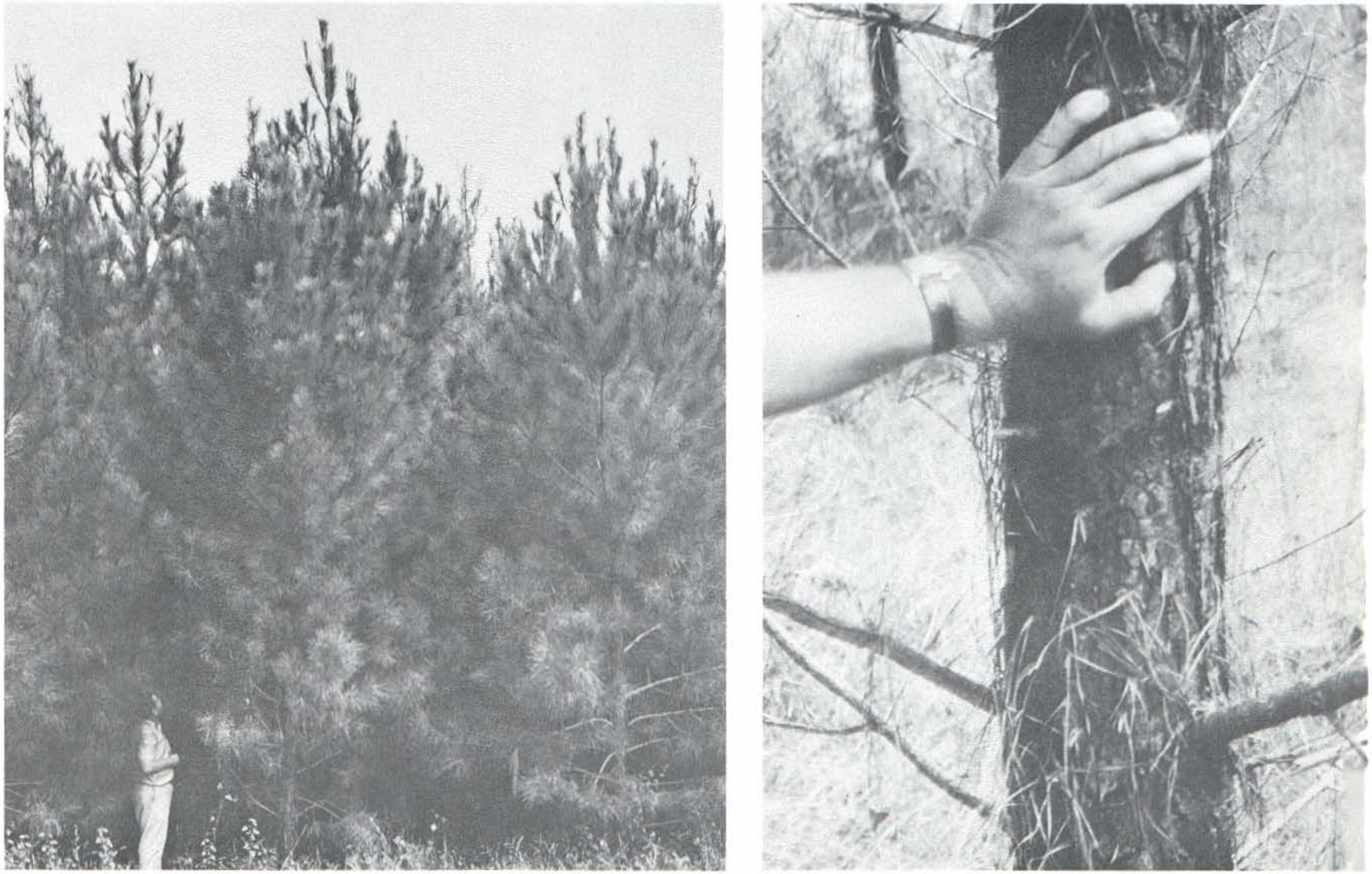
Genetic improvement of economically important traits from the rogued orchards has been good. Trees from seed orchard seed have better form than commercial checks, and improvement in volume growth is usually about 10 to 20 percent but may be greater (Table 9).

Loblolly pine is receiving greater attention in the areas formerly considered as suited only for growing slash pine. This has created a critical demand for loblolly seed from the southern sources. Shown are one-year-old grafts in Georgia-Pacific Corporation's orchard from the vital north central Florida provenance. The orchard being established here is one of the few attempts to obtain genetically improved seeds from these most important provenances.

Table 10. Height growth in feet of the three best and three poorest crosses, fertilized and unfertilized, from several of Weyerhaeuser's 4-year-old progeny tests, compared to commercial checks 1/

Kind of Test	Year Planted	Number Seedlots	Height in Feet: Best 3 Lots	Poorest 3 Lots	Comm. Check	Plantation Average
North Coastal Main - Fertilized	1965	29	8.2	6.7	6.8	7.3
North Coastal Main - Unfertilized	1965	29	8.1	6.5	6.4	7.1
North Coastal Supplemental	1965	19	7.3	6.1	-	6.9
South Coastal Main - Fertilized	1965	35	5.5	4.1	4.3	4.8
South Coastal Main - Unfertilized	1965	35	4.0	2.9	3.2	3.5
South Coastal Supplemental	1965	31	8.0	6.3	-	7.1
South Coastal Main - Fertilized	1964	23	7.1	6.2	6.0	6.5
South Coastal Main - Unfertilized	1964	23	5.4	4.1	4.2	4.6
South Coastal Supplemental	1964	14	10.4	9.4	9.3	9.7
North Coastal Main - Fertilized	1964	22	7.0	5.4	5.3	6.1
North Coastal Main - Unfertilized	1964	22	6.8	5.1	5.9	6.0
North Coastal Supplemental	1964	14	9.3	8.1	8.3	8.7

1/ Some plantations were on good sites, some poor, some fertilized, others not.



Most progeny tests have developed well. Above is one of the best six-year-old tests on lands of International Paper Company, Georgetown, South Carolina. Shown in the insert is the bole of one of the second-generation selections made in the stand.

Comparison of orchard vs. commercial performance obtained over several plantings by one company is shown in Table 10; and a generalized summary of heights from control-pollinated crosses of progeny tests of seven companies, involving several hundred lots, gives the differences shown in Table 11. Note that after four years' growth the poorest three crosses usually are below the commercial checks, but the plantation averages, including the poor crosses, are above the commercials. The benefits from roguing parents producing the poor progeny are obvious, and quality of seed from rogued orchards will be considerably better than from the commercial checks, especially when straightness, crown form, wood qualities, disease resistance, and uniformity of progeny are taken into account.

Table 11. Height in feet of several hundred control-pollinated crosses from unrogued seed orchards. The best, poorest, and commercial values are indicated.

Orchards Tested	Best Three Crosses	Poorest Three Crosses	Commercial Checks	Plantation Average [1/]
Piedmont	9.0	7.6	8.0	8.3
North Coastal	8.2	6.7	7.2	7.4
South Coastal	7.9	6.3	6.5	7.0
All Combined	8.3	6.8	7.1	7.5

1/ Includes all crosses plus all checks

As expected, difficulties are encountered in obtaining gains in several desired characteristics at the same time. For example, clone 11-23 of Westvaco Corporation is a heavy seed producer and its progeny have good growth, form and wood qualities. But most disappointing, its progeny are so susceptible to fusiform rust that they are not usable on much of the forest land in

South Carolina which would be reforested from this orchard. Therefore, it has largely been eliminated from the Westvaco seed orchard; but farther north, out of the range of the bad fusiform area, this clone can well be one of the best. Oppositely, International Paper Company clone 7-56 seems to have most desirable characteristics combined.

The 10- to 12-year-old open-pollinated tests have supplied some very useful data. Growth has been satisfactory to excellent, depending upon site conditions. Two such plantations at Georgetown, South Carolina (one belonging to International Paper Company and the other to Westvaco Corporation) have been thinned twice--once at 7.5 years and again at 11 years of age. Growth, recorded in volume and tons of dry wood, by family, for International's plantation is shown in Table 12.

Westvaco's tests, occupying a good site, were thinned at 7.5 years, measured after the tenth growing season, and thinned during the eleventh year. Following the first thinning, at which time 50 percent of the trees were removed, half the plantation was fertilized, half not fertilized. Overall growth for the 10-year period varied from 2.1 cords/acre/year for the slowest growing family to 2.8 cords/acre/year for the best family (Table 13). Growth for the 2.5 years following thinning varied from a high of 3.6 cords/acre/year to a low of 2.3 cords/acre/year.

Superiority of orchard stock over commercial planting stock is often considerable. Shown is a commercial check (to the left of Jim Hill) and seed orchard crosses in adjacent rows in the Piedmont of Georgia. (Hiwassee Land Company progeny test)

Table 12. Yield in volume and dry weight from 11-year-old open-pollinated progeny tests at second thinning 1/

	Total Growth 2/		Three-Year Growth (1967 - 1970)		DBH (in.)		Height (ft.)		Specific Gravity	
Family	Cords Ac./Yr.	Tons Ac./Yr. 3/	Cords Ac./Yr.	Tons Ac./Yr.	1967	1970	1967	1970	1967	1970
7-2	3.0	3.1	2.4	2.6	5.7	7.6	32	48	.38	.42
7-59	2.8	3.0	2.5	2.7	5.5	7.6	30	49	.39	.44
7-71	2.8	2.9	2.5	2.6	5.6	7.8	32	49	.40	.43
7-56	2.8	2.9	2.1	2.2	5.4	7.4	34	52	.39	.43
7-18	2.7	2.7	2.1	2.1	5.7	7.5	32	47	.38	.41
7-29	2.6	2.6	1.9	1.9	5.4	7.3	32	45	.39	.41
7-34	2.6	2.7	1.9	2.0	5.4	7.2	33	50	.38	.41
7-52	2.6	2.7	2.1	2.3	5.4	7.4	32	49	.39	.43
7-58	2.6	2.6	1.8	1.9	5.4	7.0	31	47	.38	.42
7-33	2.6	2.6	1.9	2.0	5.6	7.3	32	47	.38	.41
7-22	2.5	2.5	2.2	2.3	5.3	7.2	31	48	.38	.41
7-70	2.4	2.5	1.7	1.8	5.3	7.0	30	47	.38	.41
7-67	2.3	2.3	1.7	1.7	5.4	7.0	31	47	.38	.41
7-43	2.2	2.2	1.9	2.0	5.4	7.1	30	47	.36	.41
7-62	2.2	2.3	1.5	1.6	5.0	6.7	30	46	.38	.41
7-72	2.2	2.3	1.6	1.7	5.2	6.8	31	47	.40	.43
Average	2.56	2.62	1.98	2.09	5.44	7.24	31.4	47.8	.384	.420
Diff. in 3.5 years					1.80		16.4		.036	

1/ The first thinning, in 1967, was at age 7.5. Second thinning was fall, 1970, at age 11. Plantation is on lands of International Paper Company, Georgetown, S. C.

2/ Includes thinnings removed 1967, which averaged 6.4 cords per acre.

3/ Tons of dry wood

* Best family was 37% better than poorest family in volume, 39% better in dry weight.

Crosses in progeny tests take on characteristics so clear that they can be picked out without error. Shown are a four-year-old large-limbed progeny and a small-limbed progeny of the same age on lands of Kimberly-Clark Corporation.

Table 13. Growth of 10-year-old open-pollinated progeny following a thinning at 7.5 years of age 1/

Clone	Growth in Cords/Acre/Year Since Thinning at Age 7.5	Total Growth in Cords/Acre/Year Over 10 Years
11-3	3.3	2.8
11-9	3.6	2.8
11-18	3.3	2.7
11-13	3.1	2.6
11-11	3.0	2.6
11-7	2.9	2.5
11-2	3.3	2.5
11-41	2.9	2.4
11-16	2.9	2.4
11-8	3.4	2.4
11-19	2.9	2.3
11-10	3.1	2.3
11-14	3.3	2.3
11-51	3.1	2.1
11-20	2.3	2.1

1/ Westvaco Corporation, Georgetown, South Carolina--
First thinned at age 7.5 and measured again at age 10.

Fertilizer Effects

Operational fertilizer studies are the responsibility of the Fertilizer Cooperative at North Carolina State, but it is the responsibility of Tree Improvement to determine differential response among families. Soil analyses are used by Dr. Charles Davey for recommending optimum levels of macronutrients.

Genotype-x-environment interaction in forest trees grown under normal environments has generally been small. However, fertilizer interactions are sometimes considerable; these were summarized by Zobel[1/] in a paper given at the SAF Biology Symposium at Michigan State University, mimeographed copies of which were sent to members of the Cooperative. In one progeny test of Weyerhaeuser Company (North Carolina) several major changes in family ranking for volume production occurred following fertilization. All families responded to fertilizers with increased tree height, diameter and volume on this moderately good site (Tables 14 and 15), but some responded much more than others.

Table 14. Height and diameter of 6-year-old progeny following fertilization on a wet Coastal Plain site 1/

	Height (ft.)	Diameter (in.)
Fertilized	15.5	2.7
Unfertilized	12.0	2.4
Improvement from fertilization (%)	45.8	12.6

1/ Weyerhaeuser Company test plantings

Important results obtained from this study were:

1. Improvements of 46 percent, 13 percent, and 104 percent for height, diameter, and volume, respectively, were obtained from non-nitrogen fertilization of six-year-old trees.
2. All families responded to fertilization.
3. Usually the faster growing unfertilized family was the faster growing following fertilization. There were some major exceptions which indicated a genotype-x-environment interaction. For example, family 8-31 x 8-53 changed rank from 20 to 6 following fertilizing, and 8-68 x 8-53 dropped from 7 to 21 following fertilizing.

1/ Differential genetic response to fertilizers within tree species

Second-generation selection is going ahead rapidly. Shown is a nice five-year-old loblolly pine from the progeny test of International Paper Company. Over eighty such trees have already been selected.

4. The faster growing families generally responded less to fertilization than did the slower growing ones.

Additional effects of fertilization are shown in Table 10, where response on one site was good but on a wetter site was poor.

Table 15. Ranking by volume of fertilized and unfertilized families of 6-year-old loblolly pine, Weyerhaeuser, N. C. 1/

Cross	Unfertilized Rank	Fertilized Rank	Volume % Increase
8-76 x 8-68	1	3	31.7
8-46 x 8-141	2	4	44.3
8-68 x 8-73	3	12	48.0
8-33 x 8-21	4	9	71.9
8-74 x 8-68	5	2	97.8
8-102 x 8-76	6	1	121.4
8-68 x 8-53	7	21	54.3
Seed Prod. Area	8	23	37.6
8-31 x 8-64	9	7	97.6
8-33 x 8-142	10	18	73.1
8-46 x 8-21	11	22	50.8
8-102 x 8-68	12	5	112.9
8-65 x 8-33	13	14	96.2
8-33 x 8-31	14	8	121.4
Comm. Check	15	10	118.3
8-33 x 8-64	16	19	114.9
8-78 x 8-68	17	11	148.8
8-102 x 8-63	18	16	145.4
8-33 x 8-53	19	17	162.3
8-31 x 8-53	20	6	162.3
8-103 x 8-33	21	13	196.5
8-33 x 8-73	22	20	178.9
Mean			104.2

1/ The planting had minimal site preparation. First fertilization (lime, potash and superphosphate) was made at time of planting; and a second, using the same amendments minus the lime, was used at the beginning of the third growing season.

The Research Program

Any applied program must be backed by suitable basic research. Information is obtained from any source available and we fill in the gaps by faculty or graduate student research. The loss of funds for students has made it difficult to maintain studies necessary for efficient applied activities. The opportunities for needed basic research within the Cooperative are almost unlimited from the standpoint of available plant material. We have several diallels, as well as 800 acres of control crosses planted over 13 states under all kinds of environmental conditions. Some of the progeny are now flowering, making possible more advanced generation breeding. Members of the Cooperative are most generous in use of land and facilities, and the limiting factor for expanded research is manpower and the operating funds to support it.

Heritability Study

The Cooperative International Paper Company-N. C. State Heritability Study continues to generate most valuable information. Basic research information such as is being found on disease resistance, inheritance patterns, population studies, wood studies, etc. is absolutely essential to having efficient applied tree improvement programs, and full use of the genetic material available is being made by graduate students. Annual measurements continue to be made on the control-pollinated male groups. These data, obtained since the start of the study, are now being summarized and analyzed and will be published as a monograph. The paper is in its last stage of review.

Last year, half of the ten-year-old, open-pollinated trees were thinned; the rest will remain unthinned so that quantitative data can be obtained on

Although not yet used commercially, hybrids are being developed for specific problem sites. Shown is a longleaf-x-slash pine cross growing on very deep, droughty sands of Union Camp Corporation in Georgia. Survival and growth of these three-year-old hybrids have been reasonably good under very adverse conditions.

competitive effects. Wood properties, to be summarized in 1971, were measured on the thinned trees. During the thinning, families were separated into crooked large-limbed, straight small-limbed, straight large-limbed, and crooked small-limbed types. Additionally, fusiform-infected and clean trees from the same families were harvested to determine the effect of the disease on wood properties. Pulping tests were done at the research laboratories of International Paper Company. Analyses of the pulping results have not been completed but when this is done a paper will be published showing the pulp and by-products yield and pulp quality from each type of tree.

Fume Damage

It has been reported that concentrations of noxious fumes are great enough to be harmful for certain types of vegetation, within a 30- to 35-mile radius of major cities or centers of manufacturing. Many tree species fall into the sensitive category, and there is growing concern about losses caused by death but also those caused by a reduction in growth and vigor.

A major effort has been initiated this year by members of the Cooperative to determine the magnitude of growth losses from fume damage and to see if strains of pines can be developed that will have high resistance to both sulfur dioxide and ozone. Considerable evidence is already available from studies by the United States Forest Service and other agencies that there is a strong genetic component for resistance in white pine and almost surely in loblolly and Virginia pines. Members of the Cooperative need to categorize and determine the method of resistance to see if special strains can be bred that will grow better in affected areas.

Graduate student Bob Weir has initiated studies on the genetics of fume resistance; he is supported by a Weyerhaeuser fellowship. The Virginia

Division of Forestry has made excellent progress in testing progeny of their seed orchards; they have developed a field inoculation chamber and now determine damage and growth effects from both ozone and sulfur dioxide. As resistant and susceptible families are found they will be outplanted in areas with heavy fume concentration to get an estimate of field performance. The North Carolina Division of Forestry is working with families of white pine and their relative resistance to damage by fumes. Areas have been set aside and plant material obtained for such tests. Work on fume damage has been coordinated with other activities underway by the U. S. Forest Service and Air Pollution Control Office, Environmental Protection Agency. Cooperation has been excellent, and they have loaned members of the Cooperative considerable equipment that would have been otherwise unavailable.

Selfing

An attempt is made to self-pollinate all clones within the Cooperative. This has produced several hundred selfs which range in success from cone abortion to no sound seeds, to fully developed seeds that do not germinate, to seeds that germinate but the seedlings succumb, to seedlings that live but are inferior to outcrossed progeny, and to a few selfs which have as much vigor or more than the outcrossed progeny.

When possible the selfs are put into the regular progeny tests for comparative evaluation. Most of these are suppressed by competition from the other progeny. Therefore, through graduate student Don Rockwood and the good cooperation of Ray Brown, we have established a selfed "holding area" on Hoerner-Waldorf's lands at Tillery, North Carolina. As of now, progeny or grafts from over 100 different selfs have been established from which growth data will be obtained and on which future breeding will be done.

Hybridization

Although the Cooperative has not emphasized the use of hybrids, considerable work has been done with them. Some results are now available, indicating their value for problem areas such as extra wet or dry sites or for disease resistance.

There is nothing magic about the performance of a hybrid but it does allow the breeder to create something new, to bring together gene combinations not previously available. The performance of the new combination cannot always be predicted but usually the hybrids possess characteristics intermediate between the parents. Organizations such as Union Camp Corporation, Westvaco Corporation, American Can Company and others have under test such specially produced hybrids. Their long-term performance is not yet known but early performance is of interest (see Table 16).

Table 16. Growth and survival of young pond-x-loblolly pine hybrids--Westvaco Corporation

Seed Source	Height (ft.)	Survival (%)
After one year in the field on a Piedmont site:		
Commercial check (Piedmont loblolly)	1.0	80
One loblolly parent	1.0	73
Three pond parents	0.9	66
Seven hybrids (Loblolly-x-Pond pine)	1.1	61

	Height	Survival	% Tip Moth Infection	% Needle Cast Infection
After one year in the field on a Coastal Plain site:				
Loblolly parents	1.8	98	78	4
Loblolly-x-Pond hybrids	1.8	98	55	36
Pond parents	1.5	97	36	42

Some grow straight and some grow crooked. Shown are the extremes in sand pine in a four-year-old plantation in Georgia on lands of Union Camp Corporation.

The tip moth and needle cast infection differences between parent and hybrid are of special interest. Such differences between the two species have been observed for many years but the intermediacy of the hybrids is of great importance.

A number of natural hybrids occur in east central Virginia where the ranges of loblolly, pond, pitch and shortleaf pines overlap. These have recently been studied by Dr. Peter Smouse (see publication list). Eleven years ago plantations of hybrids from this area were established in comparison with shortleaf and loblolly pines; these were recently measured by the Virginia Division of Forestry. A summary of results is shown in Table 17; after eleven years the hybrids are "short and fat" while loblolly pine has superior height.

Table 17. Performance of 11-year-old natural hybrids[1/] in a plantation from Spotsylvania County, Virginia, compared to loblolly and shortleaf pines

Species	Height (ft.)	DBH (in.)	Percent Survival
Hybrids	19.2	4.6	97%
Loblolly pine	24.2	4.8	82%
Shortleaf pine	18.5	3.7	91%

1/ Presumably these are pond-x-loblolly hybrids but they also have pitch pine characteristics. The study was made on five replications of 49 tree plots by the Virginia Division of Forestry.

Wood Properties

As in the past, a great amount of activity in the pine cooperative revolves around wood variation and inheritance studies, and the requests for wood information increase each year. Data on wood obtained from the past 15 years' studies are in a technical report now in press.

Top Wood

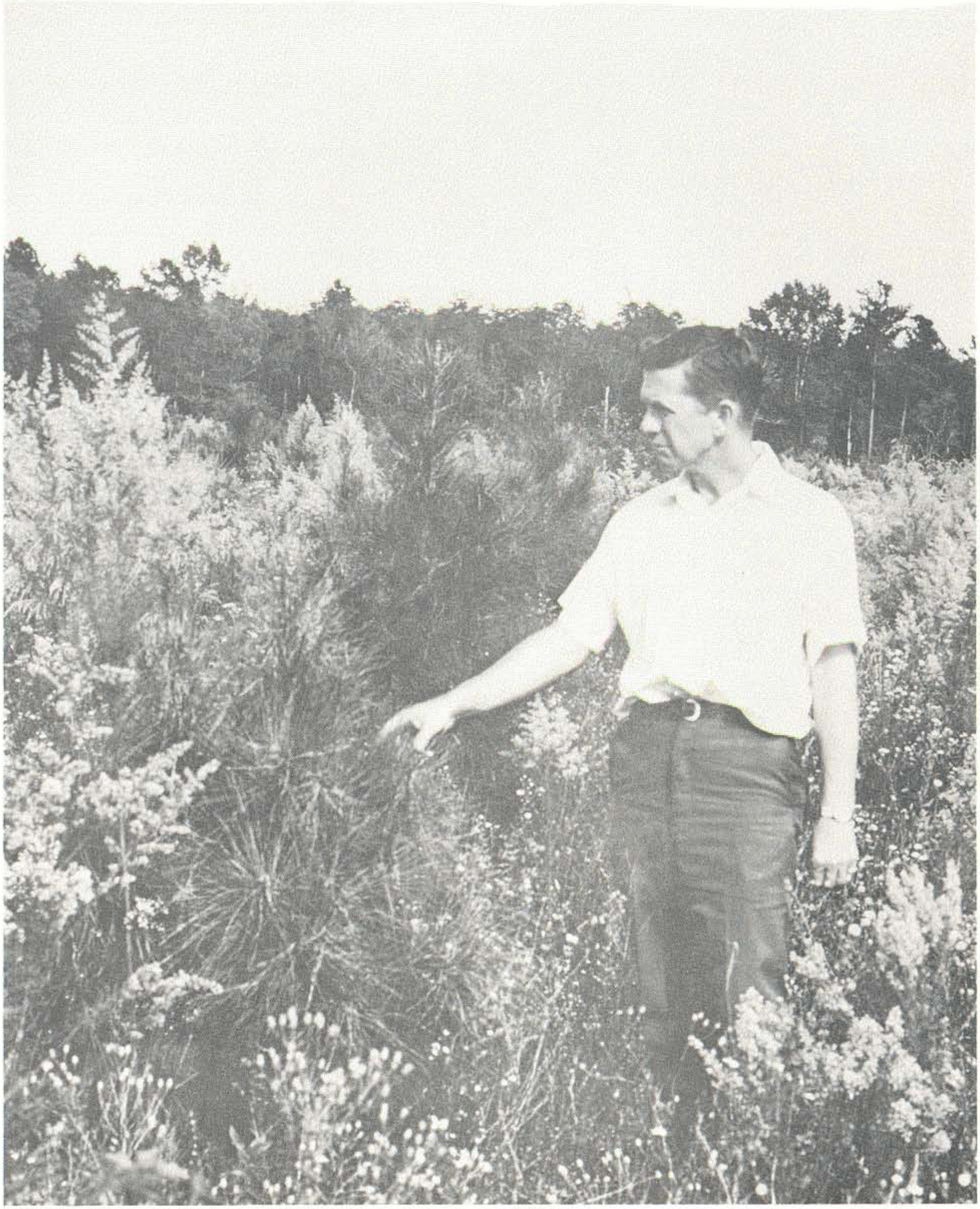
One recurrent request has been for information about wood from the tops of merchantable trees, i. e., top bolts up to and beyond the four-inch merchantable diameter limit. Some data on top wood of loblolly pine were determined by the Department of Wood Sciences but not reported in their publication.[1/] Data they supplied us have been summarized in Table 18 for six individual trees by bolt as well as for all six trees combined. Note that both specific gravity and summerwood percent are low, and that tracheid characters are similar to juvenile wood of young trees, with the exception of tracheid length which is longer.

Juvenile Wood

Several studies have been made on trees of different ages and wood qualities to determine use and value of juvenile pine wood. Some organizations have investigated such wood for possible use as a supplement to their hardwood needs; others are interested to see if properties of juvenile wood can be improved to produce paper with qualities similar enough to that from normal wood so rotation ages can be shortened with minimum change in yield and quality.

One study completed by Hammermill Paper Company is summarized in Table 19. For their product they concluded juvenile wood cannot significantly replace hardwood requirements because of its low opacity. Some rough calculations were made on the effects of juvenile wood on mill production. These will vary, of course, with the age of trees used and the product made. For 12-year-old loblolly pine pulped under Hammermill's conditions, mill production would decrease fifty tons per day because of lower yields per dry wood weight and lower wood density. This calculation is based upon usage of the same volume of wood per digester and use of the same cooking schedule.

1/ The relationship between loblolly pine fiber morphology and kraft paper properties, Tech. Bull. No. 202, N. C. Agri. Expt. Sta.



Poor growth of the trees caused by tip moth attack can be discouraging during early years of a loblolly pine plantation. Shown are severely attacked two-year-old trees of the wide cross study on lands of Continental Can Company in Georgia. It takes an optimist to visualize this as a nice stand three years hence and for the tip moth effects to be hardly noticeable after ten years.

Table 18. Wood qualities of top bolts of loblolly pine from six trees (values are for combined early and latewood)

Tree Number	5-Foot Bolt Number	Diam. O. B. (in.)	Percent Summer-wood	Specific Gravity (Extracted)	Tracheid Length (mm)	Cell Lumen (microns)	Cell Diam. (microns)	Cell Wall (microns)
8-80	12	8.9	39	.43	3.96	31.99	46.84	7.42
	13	8.1	40	.43	3.80	31.70	47.00	7.65
	14	6.9	39	.44	3.59	32.98	47.17	7.10
	15	6.5	39	.43	3.65	30.29	45.18	7.45
	16	2.9	38	.44	2.93	28.77	42.38	6.81
	Avg.	6.7	39	.43	3.59	31.15	45.71	7.29
8-81	9	8.3	26	.36	3.65	36.28	48.18	5.95
	11	5.5	25	.37	3.32	36.25	48.31	6.03
	12	3.5	35	.39	3.04	32.65	43.75	5.55
	13	3.0	19	.33	2.85	33.62	44.28	5.33
	Avg.	5.1	26	.36	3.22	34.70	46.13	5.72
14-25	10	5.1	25	.44	3.85	31.02	45.00	6.99
	11	4.0	24	.42	3.80	31.72	45.31	6.80
	12	2.3	23	.41	3.69	29.84	42.48	6.32
	13	2.2	17	.39	3.38	30.24	41.55	5.66
	Avg.	3.3	22	.42	3.68	30.71	43.59	6.44
6-8	8	6.6	32	.45	3.70	31.16	45.70	7.27
	9	5.2	36	.43	3.49	30.81	44.66	6.92
	10	3.5	36	.42	3.11	29.60	43.87	7.13
	11	3.0	32	.43	3.02	29.41	42.14	6.36
	Avg.	4.6	34	.43	3.33	30.25	44.09	6.92
5-34	11	8.8	25	.35	4.00	35.47	48.29	6.41
	12	8.0	24	.35	4.23	36.02	48.53	6.25
	14	3.6	39	.38	3.48	31.60	45.32	6.86
	15	1.6	26	.36	3.27	33.23	45.36	6.07
	Avg.	5.5	29	.36	3.75	34.08	46.88	6.40
9-6	10	6.9	39	.47	4.32	33.45	49.63	8.09
	11	6.5	41	.46	4.21	34.04	50.43	8.20
	12	6.3	38	.44	4.00	37.28	52.40	7.56
	13	3.2	35	.44	4.06	36.14	49.70	6.78
	14	2.0	41	.46	3.31	28.81	42.88	7.03
	Avg.	5.0	39	.45	3.98	33.94	49.01	7.53
Avg. of 6 trees		5.0	32	.41	3.59	32.47	45.90	6.72

Table 19. Yield and pulp and paper properties of loblolly pine juvenile wood of different densities compared to mill run wood 1/

	Mill Run	Low Gravity	Average Gravity	High Gravity
Number of 12-yr.-old trees	-	6	6	6
Specific Gravity	0.44	0.36	0.40	0.48
Lbs./Cu.Ft.	27.5	22.5	25.0	30.0
Moisture Content 2/	119	142	119	112
Crude Yield (% dry wood)	47.5	44.2	45.7	47.1
Estimated Mill Prod. (TPD)	550	420	500	590
K number	27.5	26.5	28.3	28.4
	At 10-Minute Beating			
Mullen	38	58	49	42
Tear	172	127	138	167
Fold	663	1517	779	646
Opacity	73	74	71	73
Tensile	9.94	12.08	12.04	9.76

1/ Study made by Hammermill Paper Company, Selma, Alabama

One striking result of the Hammermill study is the similarity of paper characteristics and yield of high density juvenile wood to normal mill run wood. Loblolly pine with such high gravity juvenile wood can be obtained by intensive breeding as shown by a long-range study with International Paper Company. Seeds were collected from mother trees with high and low juvenile wood and the trees were grown under normal plantation conditions. After five years, some of the trees were harvested and it was found that the high gravity parents had already developed progeny at five years that had wood 1.5 pounds per cubic foot greater than those from lower gravity parents (Table 20). As the trees become older this difference will increase and it will be possible to develop strains of loblolly pine with higher gravity juvenile wood quite suitable for certain papers.

Table 20. Juvenile wood density of parent loblolly pines and their five-year-old open-pollinated progenies 1/

	14 Families from Parents with High Specific Gravity Juvenile Wood		12 Families from Parents with Low Specific Gravity Juvenile Wood	
	Parent 1/	Five-Year Progeny	Parent 1/	Five-Year Progeny
Sp. Gr.	.492	.339	.400	.316
Lbs./Cu.Ft.	30.8	21.2	25.0	19.7

1/ Nearly 1,000 parent trees were sampled. Cones were collected from those having specific gravity of the juvenile wood similar to the mature wood; it is the five-year-old trees from these seed that were sampled. Comparison was made between the specific gravity of the five-year-old trees and the central, juvenile core (10 rings from the pith) of the parent trees. Study was in cooperation with International Paper Company, Georgetown, South Carolina.

Effect of Age

A number of studies have shown the effects of plantation age or age of stand on wood properties. Most of those have been for loblolly pine in the Atlantic Coastal Plain or in the Piedmont. Additional data were obtained in a recent, preliminary study by Container Corporation for slash pine in the Gulf Coast. Age effects on specific gravity and moisture content were as clear-cut as they have been for loblolly pine (Table 21), showing a trend with age as well as a good correlation between breast height and total tree values. Weighted total tree value differences of six pounds per cubic foot between the younger and older age classes are meaningful, as are moisture content differences from 95 to 151 percent.

One of the newest studies of the Cooperatives deals with determination of growth loss from fume damage and development of strains of trees resistant to fumes of sulfur dioxide and ozone. Shown are fume-damaged and undamaged white pine on the research area of the U. S. Forest Service at Asheville. The Virginia Division of Forestry and the North Carolina Forest Service are actively pursuing such research.

Table 21. The relationship of age to wood specific gravity and moisture content of slash pine from the Gulf Coast 1/

	Breast High Values			Weighted Total Tree Values		
Age	Specific Gravity	Lbs./ Cu.Ft.	Percent Moisture	Specific Gravity	Lbs./ Cu.Ft.	Percent Moisture
10-12	.450	27.6	133	.414	25.7	151
16-21	.506	31.4	97	.471	29.4	115
31-32	.561	35.1	79	.505	31.5	98

1/ Data from a study by Container Corporation, Brewton, Alabama

Wood Properties of Select Trees

We have amassed considerable information on wood from the select trees used in our seed orchard program. Data obtained from breast height sampling are summarized in Table 22. The extremes in specific gravity of loblolly pine are exemplified by the Eastern Shore and the Florida sources. Note the very low specific gravities of spruce and white pines. Tracheid lengths of all species are satisfactory for most products manufactured in the Southeast.

Tree Improvement Short Course

Whenever warranted by the cooperators we hold a tree improvement short course for the benefit of new personnel. This course covers the basics of tree selection, vegetative propagation, orchard establishment, care and maintenance, progeny testing, etc. The purpose of the course is to instruct field men what to do and how to do certain operations and, more importantly, why they are done. Such a short course was held on January 5-7, 1971 at North Carolina State University in Raleigh. The organization of the short course was carried out by the Continuing Education Department at N. C. State University while instruction was done by faculty and staff of the University. There was a total of 25 attendees representing 14 organizations.

Table 22. Wood qualities of seed orchard parent trees by species and physiographic region 1/

	Number Trees	Juvenile Sp. Gr.	Mature Sp. Gr.	Mature Lbs./ Cu.Ft.	Tracheid Length 30th Ring
Coastal Plain					
Gulf and Atlantic Coast Loblolly	711	.45	.54	33.7	4.52
Florida Loblolly	45	.48	.58	36.2	4.12
Eastern Shore Loblolly	39	.42	.51	31.8	4.29
Pond Pine	85	.48	.54	33.7	3.92
Longleaf Pine	194	.51	.57	36.0	4.62
Slash Pine	192	.47	.55	34.3	4.60
Spruce Pine	12	.45	.46	28.7	4.58
Shortleaf (Ala.)	14	.46	.57	35.6	4.57
Piedmont & Mountains					
Loblolly Pine	585	.43	.52	32.5	4.35
White Pine	75	.32	.38	23.7	4.17
Shortleaf Pine	102	.47	.54	33.7	4.55
Pitch Pine	21	.46	.47	29.3	4.52
Virginia Pine	243	.46	.51	31.8	4.08
Total Trees	2,318				

1/ Values from 4.5' above ground; wood not extracted but pitch-soaked samples were discarded.

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.
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, Halifax Timber Div. (formerly Albemarle Paper Company)	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.
Riegel Paper Corporation	N. C., S. 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.

Personnel

It appears that the staff of the Cooperative Programs undergoes changes every other year. This past year was no exception. Bob McElwee resigned after fifteen years with the Cooperative Programs, to accept employment as Associate Professor of Forest Genetics, University of Maine, Orono. He was replaced by Jerry Sprague, a 1970 graduate of N. C. State University's School of Forest Resources. Short on experience but long on determination, Jerry has fitted well into the scheme of things. The next bombshell to hit was the resignation of Jim Roberds, to accept employment with Dr. Gene Namkoong at N. C. State University, where they will be working on a U. S. Forest Service pioneering project. Roberds's replacement is Bob Weir. Weir received his Master's Degree from N. C. State in 1970 and at time of employment was a candidate for the Ph. D. Degree. He assumed duties as statistician for the Cooperative Programs on May 1.

Among the changes of our clerical and laboratory personnel, Mrs. Carolyn Ariail resigned as stenographer to accompany her husband to a new job assignment. She was replaced by Mrs. Barbara Scoggins. In the laboratory Miss Addie Mae Burt has been hired as a research aide. New temporary help includes Mrs. Gladys Bredenberg (clerical) and Mrs. Edith Jones (laboratory).

PUBLICATIONS

Following is a list of publications directly from the Cooperative Programs, as well as other papers by members of the Cooperative. It also includes research results based upon materials made available by the Cooperative.

Adams, W. T. 1970. Competitive relationships among loblolly pine (Pinus taeda L.) seedlings. M. S. Thesis, N. C. State Univ., Raleigh. 57 pp.

Barefoot, A. C., R. G. Hitchings, E. L. Ellwood and E. H. Wilson. 1970. The relationship between loblolly pine fiber morphology and kraft paper properties. Tech. Bull. No. 202, N. C. Agri. Expt. Sta. 89 pp.

Kellison, R. C. 1970. Phenotypic and genotypic variation of yellow-poplar. Ph. D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 112 pp.

Kellison, R. C. 1971. Tree improvement in the southern pines--A decade of progress. La. State Univ. For. Symp. 10 pp.

Kellison, R. C. and B. J. Zobel. 1971. Wood specific gravity and moisture content of five hardwood species of the southern United States. Paper presented at IUFRO Meet., Gainesville, Fla., March. 13 pp. Pap. No. 3408, Jour. Series, N. C. State Univ. Agri. Expt. Sta., Raleigh.

Kellison, R. C. and B. J. Zobel. 1971. Wood and fiber properties of five southern hardwood species. For. Prod. Res. Jour. (In press)

Mallonee, E. H. 1970. Effects of site preparation and fertilization on four tree species planted on a coastal plain wet flat. M. S. Thesis, N. C. State Univ., Raleigh. 83 pp.

McElwee, R. L. 1970. Radioactive tracer techniques for pine pollen flight studies and an analysis of short-range pollen behavior. Ph. D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 97 pp.

McElwee, R. L., R. Tobias, and A. H. Gregory. 1970. Wood characteristics of three southern hardwood species and their relationship to pulping properties. Fifth TAPPI For. Biol. Conf., Raleigh. 21 pp. Tappi 53(10):1882-1886.

Porterfield, R. L. 1970. The financial maturity of certain southern mixed hardwood stands. M. S. Thesis, N. C. State Univ., Raleigh. 71 pp.

Quijada Rosas M. 1970. Drought resistance in eight- and sixteen-week-old loblolly pine seedlings. Ph. D. Thesis, N. C. State Univ., Raleigh. 101 pp.

Publications
Fifteenth Annual Report

Saylor, L. C. and H. A. Simons. 1970. Karyology of Sequoia sempervirens; karyotype and accessory chromosomes. Cytologia 35(2):294-303.

Sheikh, I. 1971. Variation in wood properties of Pinus caribaea var. hondurensis grown under Malaysian conditions. M. S. Thesis, N. C. State Univ., Raleigh.

Smouse, P. E. 1970. Population studies in the genus Pinus L. Ph. D. Thesis, N. C. State Univ., Raleigh. 126 pp.

Weir, R. J. 1970. Open-pollinated sycamore (Platanus occidentalis L.) families on pine sites. M. S. Thesis, N. C. State Univ., Raleigh. 64 pp.

Zobel, B. J. 1970. Developing trees with wood qualities most desirable for paper. Fifth TAPPI For. Biol. Conf., Raleigh. May. 24 pp. Tappi 53(12):2320-2325.

Zobel, B. 1970. Challenge of the seventies--wood for forest industries. Proc., 49th Ann. Meet., Appalachian Sec., SAF. pp. 9-12. Jour. For. 69(4):212-215.

Zobel, B. 1970. Pulpwood mensuration. Chap. 2, Art. 3, Handbook of Pulp and Paper Technology by K. W. Britt. pp. 125-132.

Zobel, B. 1970. The impact of tree improvement on the third forest. Forest Farmer XXX(2):10-11 and 38-39.

Zobel, B. and J. Roberds. 1970. Differential genetic response to fertilizers within tree species. For. Biol. Workshop, SAF, Michigan State Univ., August. 19 pp. Mimeo.

Zobel, B. 1971. Genetic manipulation of wood of the southern pines, including chemical characteristics. Meeting, International Academy of Wood Sciences, Raleigh. March. 25 pp. Wood Science & Technology (In press) Paper No. 3409, Jour. Series, N. C. State Univ. Agri. Expt. Sta., Raleigh.

Zobel, B. 1971. Fast-growing subtropical pines as exotics. 12th Ann. Meet., Society for Economic Botany, Chicago. April. 14 pp.

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Zobel, B. and R. C. Kellison. 1971. Should wood be included in a pine tree improvement program? IUFRO Meeting, Gainesville, Fla. March. 11 pp.

Appendix Table 1
Theses by Graduate Students
Associated With the Cooperative Programs

Adams, W. T. 1970. Competitive relationships among loblolly pine (Pinus taeda L.) seedlings. M. S. Thesis, N. C. State Univ., Raleigh. 57 pp.

Blair, R. L. 1970. Quantitative inheritance of resistance to fusiform rust in loblolly pine. Ph. D. Thesis, N. C. State Univ., Raleigh. 87 pp.

Byrd, V. L. 1964. An investigation of the effect of wood chemical constituents on kraft paper properties of four selected loblolly pines. M. S. Thesis, N. C. State Univ., Raleigh. 113 pp.

Caballero, M. 1966. Comparative study of two species of Mexican pine (Pinus pseudostrobus Lindl. and Pinus Montezumae Lamb.) based on seed and seedling characteristics. M. S. Thesis, N. C. State Univ., Raleigh. 142 pp.

Castillo-Z., J. 1964. Analysis of the yield of some coffee varieties grown in Colombia and Brazil. M. S. Thesis, N. C. State Univ., Raleigh. 84 pp.

Chang, Wei-Min, 1962. The influence of spacing on growth, development, branchiness and wood specific gravity of Virginia pine (Pinus virginiana M.). M. S. Thesis, N. C. State Univ., Raleigh. 79 pp.

Conkle, M. T. 1963. The determination of experimental plot size and shape in loblolly and slash pines. M. S. Thesis, N. C. State Univ., Raleigh. 51 pp.

Franklin, E. C. 1968. Artificial self-pollination and natural inbreeding in Pinus taeda L. Ph. D. Thesis, N. C. State Univ., Raleigh. 127 pp.

Gladstone, W. T. 1968. Responses of earlywood and latewood from loblolly pine to kraft pulping. Ph. D. Thesis, N. C. State Univ., Raleigh. 123 pp.

Goggans, J. F. 1962. The correlation, variation and inheritance of wood properties in loblolly pine (Pinus taeda L.). Ph. D. Thesis, N. C. State Univ., Raleigh. 135 pp.

Gregory, J. D. 1968. The effects of fertilization and irrigation on the flowering and seed production of two loblolly pine (Pinus taeda L.) seed orchards. M. S. Thesis, N. C. State Univ., Raleigh. 128 pp.

Haught, E. A. 1958. An exploratory study of compression wood of loblolly pine (Pinus taeda L.). M. F. Thesis, N. C. State Univ., Raleigh. 65 pp.

Jasso M., J. 1966. Tree improvement program for conifers in Mexico, based on the genus Pinus. M. F. Thesis, N. C. State Univ., Raleigh. 128 pp.

Kang, Ke Won, 1966. Relationship between loblolly (Pinus taeda L.) and pond (Pinus serotina Michx.) pines in North Carolina. Ph. D. Thesis, N. C. State Univ., Raleigh. 135 pp.

Kellison, R. C. 1966. A geographic variation study of yellow-poplar (Liriodendron tulipifera L.) within North Carolina. M. S. Thesis, N. C. State Univ., Raleigh. 70 pp.

Kellison, R. C. 1970. Phenotypic and genotypic variation of yellow-poplar. Ph. D. Thesis, N. C. State Univ., Raleigh. 112 pp.

Kinloch, B. B. 1964. Evaluation of resistance to fusiform rust (Cronartium fusiforme) in loblolly pine (Pinus taeda). M. S. Thesis, N. C. State Univ., Raleigh. 62 pp.

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Kinloch, B. B., Jr. 1968. Genetic variation in susceptibility to fusiform rust in loblolly pine. Ph. D. Thesis, N. C. State Univ., Raleigh. 47 pp.

Land, S. B. 1967. Interspecific variation in sea-water tolerance of loblolly pine (Pinus taeda L.). M. S. Thesis, N. C. State Univ., Raleigh. 97 pp.

Lantz, C. W. 1970. Graft incompatibility in loblolly pine. Ph. D. Thesis, N. C. State Univ., Raleigh. 103 pp.

Ledig, F. T. 1965. Genetic differences in relative growth of shoot and root systems in Pinus taeda L. seedlings as measured by shoot-root ratio and the Allometric formula. M. S. Thesis, N. C. State Univ., Raleigh. 53 pp.

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Salem, M. H. 1961. Measurement and direction of eccentricity in the radial growth of straight-boled post oak (Quercus stellata) trees. M. S. Thesis, N. C. State Univ., Raleigh. 48 pp.

Saylor, L. C. 1960. A karyotypic analysis of selected species of Pinus. M. S. Thesis, N. C. State Univ., Raleigh. 43 pp.

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Saylor, L. C. 1962. Chromosome behavior and morphology in species and interspecific hybrids of Pinus. Ph. D. Thesis, N. C. State Univ., Raleigh. 128 pp.

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Sluder, E. R. 1960. A yellow-poplar seed source study. M. S. Thesis, N. C. State Univ., Raleigh. 39 pp.

Sluder, E. R. 1970. Variation in wood specific gravity of yellow-poplar (Liriodendron tulipifera L.) and its relationship to environmental conditions in the southern Appalachians. Ph. D. Thesis, N. C. State Univ., Raleigh. 68 pp.

Smith, D. 1963. An investigation into the specific gravity relationship between limb sections and the bole of young loblolly pine. M. S. Thesis, N. C. State Univ., Raleigh. 62 pp.

Smouse, P. E. 1970. Population studies in the Genus Pinus L. Ph. D. Thesis, N. C. State Univ., Raleigh. 126 pp.

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Taft, K. A. 1965. An investigation of the genetics of seedling characteristics of yellow-poplar (Liriodendron tulipifera L.) by means of a diallel crossing scheme. Ph. D. Thesis, N. C. State Univ., Raleigh. 57 pp.

Taras, M. A. 1965. Some wood properties of slash pine (Pinus elliottii Engelm.) and their relationship to age and height within the stem. Ph. D. Thesis, N. C. State Univ., Raleigh. 157 pp.

Taylor, F. 1965. A study of the natural variation of certain properties of the wood of yellow-poplar (Liriodendron tulipifera) within trees, between trees, and between geographic areas. Ph. D. Thesis, N. C. State Univ., Raleigh. 190 pp.

Thorbjornsen, E. 1960. Variation in loblolly pine (Pinus taeda L.). Ph. D. Thesis, N. C. State Univ., Raleigh. 188 pp.

Webb, C. D. 1960. Field grafting loblolly pine. M. S. Thesis, N. C. State Univ., Raleigh. 33 pp.

App. Table 1
Theses

Webb, C. D. 1965. Natural variation in specific gravity, fiber length and interlocked grain of sweetgum (Liquidambar styraciflua L.) within trees, among trees, and among geographic areas in the South Atlantic States. Ph. D. Thesis, N. C. State Univ., Raleigh. 125 pp.

Weir, R. J. 1970. Open-pollinated sycamore (Platanus occidentalis L.) families on pine sites. M. S. Thesis, N. C. State Univ., Raleigh. 64 pp.

Woessner, R. A. 1965. Evaluation of growth, form and disease resistance in four-year-old control- and five-year-old open-pollinated progeny of loblolly pine (Pinus taeda L.) selected for seed orchards. M. S. Thesis, N. C. State Univ., Raleigh. 135 pp.

Woessner, R. A. 1968. A juvenile assessment of wide crosses of loblolly pine select trees indigenous to different geographical areas. Ph. D. Thesis, N. C. State Univ., Raleigh. 148 pp.