SEVENTEENTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

June, 1973

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FOREWORD

Now that the forest economy is improving we already are experiencing an upsurge of activities in both Cooperatives; this is especially true in hardwoods, where more interest is evident than in the past three years. The widespread "short-term" thinking that has been common in the industry the past several years is being gradually transformed into a renewed concern for a continuing supply of quality raw material. Although the concern has dealt primarily with pines, where the course of action is clear, long-range planning in hardwood management is increasing as stumpage prices rise.

During the past year, the Cooperatives have been at top operating efficiency. Despite small changes in the laboratory, all personnel are now well established in their jobs and have been efficiently carrying out their responsibilities. We are sometimes questioned as to "who is responsible for hardwoods" and "who do I see to discuss progeny designs." Insofar as possible we have not specialized. Although each member of the Cooperative staff has major responsibilities, each is obligated to familiarize others of all that has transpired. Therefore, all staff members have a working knowledge of all the Cooperative's activities.

The widespread change of personnel that has taken place within each cooperating organization since the Program was initiated in 1956 was especially evident at the last Advisory Committee Meeting in Atlanta. Only a few of the "old-timers" are still active. Such changes cause inefficiencies but they are a fact of life. We have learned to reduce the impact of the inefficiencies by maintaining continuous orientation and training programs. Some orientation has been accomplished by short courses, such as the recent one dealing with hardwoods, but most is done through direct personal contact by staff members of the Cooperative. Also it is realized that some personnel changes enhance rather than detract from the Cooperatives. A most valuable "spin-off" has resulted when persons once directly associated with Cooperative activities have advanced aministratively. Their knowledge of the objectives sought has allowed administrative decisions beneficial to all concerned.

THE COOPERATIVE TREE IMPROVEMENT PROGRAM--PINE

Introduction

Although most activities related to the Pine Cooperative are operational, basic and developmental studies continue. In some ways fundamental information is now needed more than ever because of the level that the program has achieved. Initially, major activities centered around determination of the variation patterns within the species of importance, and from these we designed programs to utilize "what nature has already produced." This approach resulted in the highly successful selection programs and establishment of seed orchards. The major objective was to obtain as much genetic improvement as possible in the shortest period of time. This phase of the program has matured rapidly. Enough seed were collected from seed orchards to plant 120 million trees in 1972, and within five years all foreseeable seed requirements of members of the Cooperative should be filled with genetically improved seed.

We are now well into the second phase of the long-range program to maximize genetic gains. The activities associated with this phase require more planning and a higher degree of technical competence than did the selection phase but greater gains will result. It is a real challenge to achieve quick gains from advanced-generation breeding of forest trees. It keeps the staff in Raleigh and members of the Cooperative "jumping" to make the necessary crosses, designs and tests.

One of the most pleasant, and to us most significant, occurrences of the past several years has been the widespread request by operational foresters for genetically improved stock for their regeneration needs, with reluctant acceptance or refusal to plant unimproved trees. Such spontaneous recognition of the value of seed orchard seedlings by operational foresters makes one feel that the Program has "arrived." Also, private landowners are increasingly expressing their desire for genetically improved seedlings.

Long-Range Developmental Plans

The Cooperative has developed to the point that a reassessment of past activities and future long-range plans need to be refined. Following a series of staff meetings, discussion with members of the Cooperative and with other scientists, we are mapping the course of the future. The plans, summarized in Figure 1, show what has been accomplished, where we now stand, and where we are headed. In summary, the various steps of the chart indicate:

1. The initial genetic stock was comprised of select trees from wild stands kept separate by geographic areas.
2. The "boxes" surrounded by heavy lines are the production seed orchards. They represent an increase in genetic improvement from top to bottom

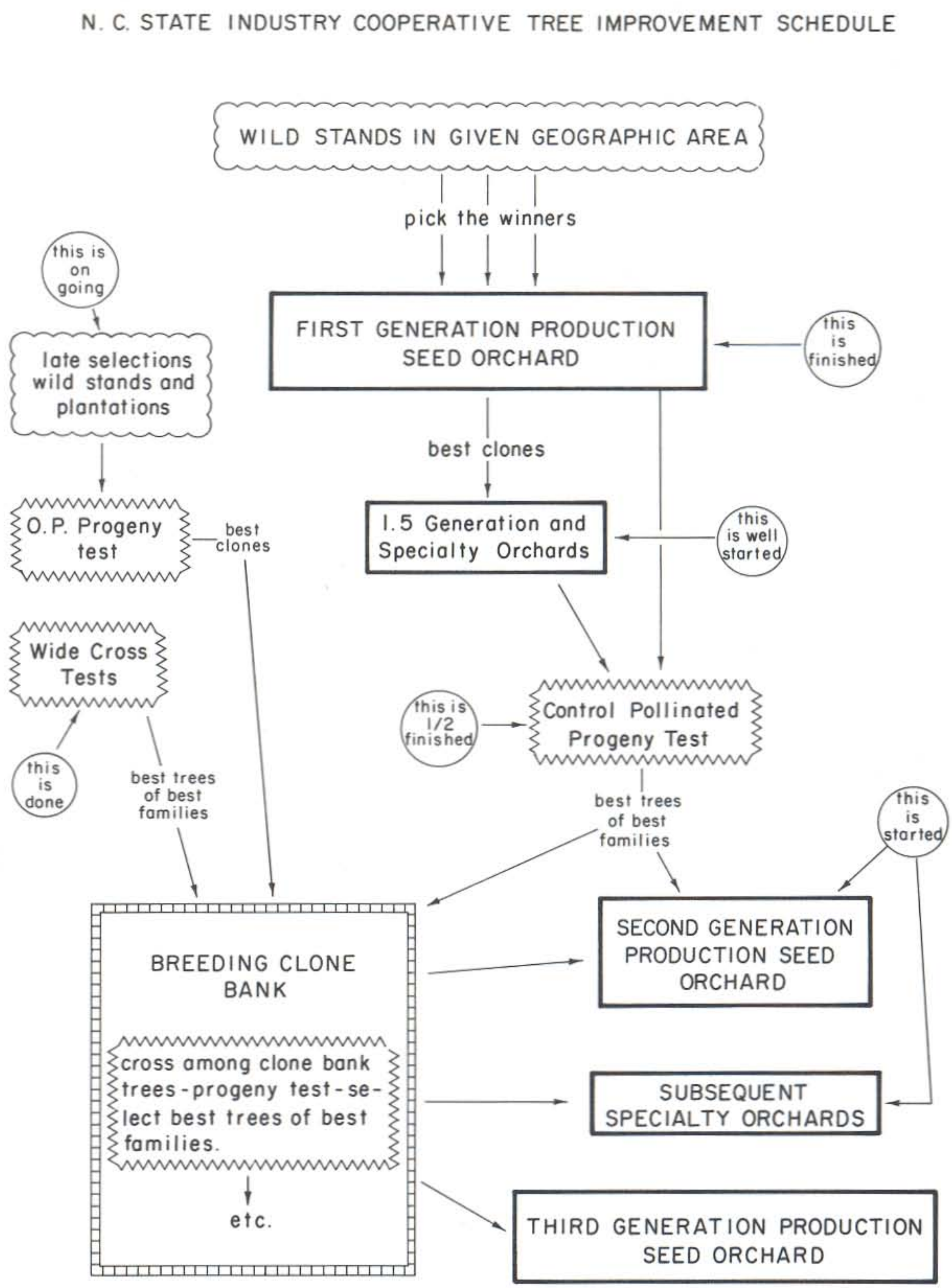


Figure 1. Plans and developmental steps of the Pine Tree Improvement Program. Boxes to the right indicate production orchards; to the left, methods to broaden the genetic base.

of the page. Not shown is an intermediate stage of improvement between the first- and 1.5-generation[1] orchard, which is the improved first-generation orchard that has been rogued of poor clones based upon orchard and progeny performance.

3. For the long term, the box labeled "Breeding Clone Bank" is of key importance. It is through such clone banks that the broad genetic base necessary for gains in succeeding generations is maintained. Each member of the Cooperative will establish a clone bank which will include genotypes of every source from which genetic improvement might be expected. Crosses among these genotypes will follow a comprehensive design to be developed by the staff of the Cooperative. Pollen will be stored at Raleigh and sent to the cooperator at the time the crosses are to be made.

4. The boxes on the left side of the figure indicate new genetic material that will enhance the required broad genetic base. This important activity is well advanced. Many late selections from plantations and from natural stands which are not included in the first-generation production seed orchards are being preserved and progeny tested. Additionally, selections from the five-year-old wide-cross study and from other special studies will be included in breeding clone banks starting this year.

1/ There is correct criticism of our use of the term "1.5-generation" orchards. Technically these orchards are greatly improved first-generation orchards which combine only the most outstanding clones from a number of different seed orchards within the Cooperative. No additional generations are involved. We continue to use this term because it is generally understood by members of the Cooperative.

Problems are always encountered in seed orchard programs, one of which is ice storms. Despite numerous ice storms throughout the Southeast last winter, only the seed orchard of International Paper Company, Georgetown, South Carolina, was hard hit. At top left, a 5-year-old progeny test is weighted down by ice; at top right is a graft with bad limb breakage; and at bottom, smudge pots (salamanders) are used to prevent more severe breakage.

If the operations outlined in Figure 1 are to be effective, much basic research remains to be done. Of prime importance is the determination of the relatedness that can be tolerated in a production seed orchard. Bob Weir was awarded a small grant by the Faculty Professional Development Fund, N. C. State University, to initiate such a study. It will require crossing among full-sibs, half-sibs, backcrosses, selfs and other combinations.

Genetic Improvement in Growth

From Seed Orchards

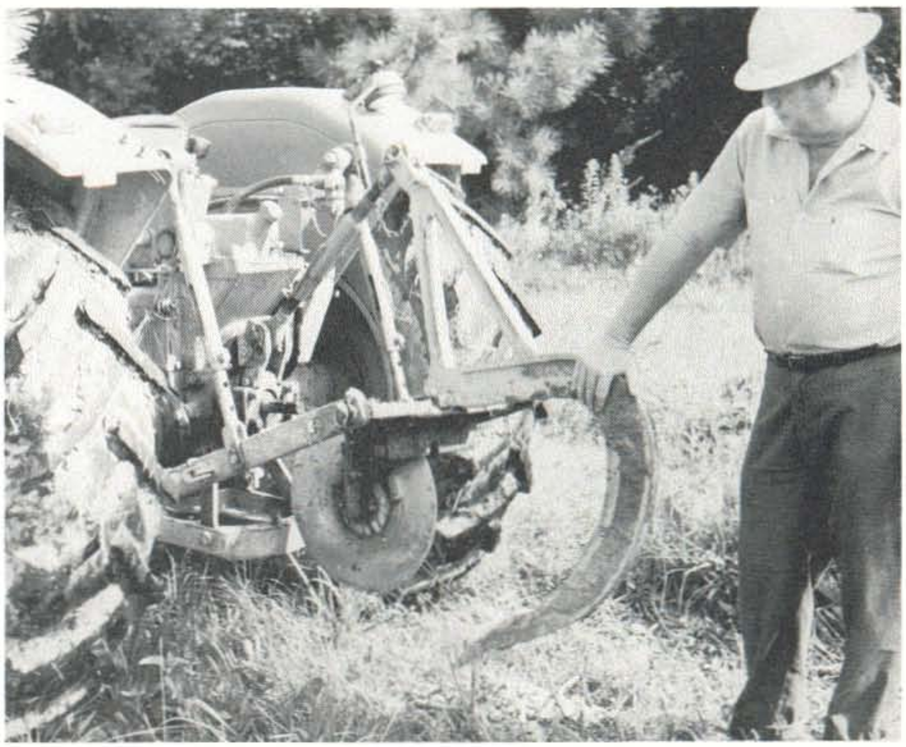
The objective of the genetic program is to improve yield and quality. Volume improvement is of key importance and, even though it was not strongly emphasized in the initial selections relative to quality, gains have been surprisingly good. Recent reports from a number of different sources all show height growth from unrogued orchards to be about 10 to 20 percent better than from commercial checks. More limited reports for volume and dry weight production show gains from unrogued orchards over commercial checks to be up to 30 percent or even greater. However, since these volumes were obtained from trees just attaining merchantability, we will use the 10 to 20 percent improvement figure until it is proven to be too conservative.

With roguing the orchard is upgraded, resulting in even greater gains. Additional improvement will be obtained from 1.5-generation, specialty, and second-generation orchards. Although data are limited, we now predict the following:

Kind of Orchard	Volume Growth and Quality Improvement Over Current Planting Stock
1. Unrogued first-generation orchard	10 - 20%
2. Heavily rogued orchard	15 - 25%
3. Newly established, improved first-generation orchard from the best general combiners (1.5-generation orchard)	20 - 30%
4. Specialty orchard (disease resistance, adaptability, etc.) for specified problem areas	30+%
5. Second-generation orchard	35 - 45%

In future years it will be possible to compare the actual improvement with the predicted gains. Certainly the values will vary by orchard and commercial check used; for example, one member of the Cooperative is finding only about 7.5 percent improvement in volume of the seed orchard stock over the commercial check in the Piedmont, while from their Coastal Plain seed orchard the gain is over 20 percent.

The estimates must be accepted with caution because they are based upon results from young trees in control-pollinated progeny tests which may not represent the same degree of improvement as that to be derived from a wind-pollinated, operational seed orchard. Another consideration is that the commercial checks may vary widely from lot to lot. It was an initial oversight to use a single commercial check; now, all tests will include more than one check, resulting in a more reliable estimate of the differences between orchard and commercial seed. The true estimate of gain will come only from operational plantings from the rogued seed orchards compared to normal commercial planting stock. Because most orchards are only now being rogued, such studies are in the process of being established.



Subsoiling and management of the forest floor is very important in a properly managed seed orchard. Shown above is a rototilled section of Hoerner-Waldorf's seed orchard in North Carolina. One very successful type of subsoiler as used by Hoerner-Waldorf is shown in the bottom photo.

We already have some data comparing unrogued seed orchard performance to commercial planting stock. In a summary of twelve paired, 5- and 6-year-old improved and commercial slash pine plantations located throughout the holdings of Union Camp Corporation's Savannah Division, the improved material was superior in volume production in all but one of the twelve plantations. The improved trees averaged 14 percent greater volume over all plantations and were decidedly better in stem and crown form than the commercial run-of-the-mill comparison plantings. The only characteristic of the orchard stock which was inferior was disease resistance. Initial selection intensity against rust was low, and several of the heaviest seed-producing clones in the seed orchard produced very disease-susceptible progeny. Disease resistance will show marked improvement following orchard roguing. The special report prepared by Union Camp Corporation concludes with the following paragraph:

"The superiority of improved slash pine in growth rate, straightness, and crown form reported here demonstrates the gains that have been made so far. Additional gains will be made by roguing and by selection, testing and establishment of advanced-generation orchards. Emphasis must now be placed on developing rust resistance in slash pine."

Additional comparisons between unrogued orchard stock and regular stock from adjacent operational plantations are available from Kimberly-Clark Corporation's lands in Alabama (Table 1).

Table 1. Comparison of growth of 9-year-old and 6-year-old loblolly pine plantations from seed orchard and standard commercial stock. The plantations are located in the Piedmont of Alabama and belong to Kimberly-Clark Corporation.

Type of Plantation	DBH (in.)	Height (ft.)	Volume (cu.ft.)	% Fusiform Infection
1964 - Seed orchard	4.5	23.1	1.35	13.0
1964 - Regular	3.4	19.2	0.70	38.0
Superiority of seed orchard stock	32%	20%	93%	--
1967 - Seed orchard	2.1	12.0	0.17	13.0
1967 - Regular	1.5	10.0	0.08	25.0
Superiority of seed orchard stock	40%	20%	--	--

The plantations in the two different years cannot be directly compared because they are on different sites and are of a different age. However, the differences in heights and diameters are distinct and appear to be increasing with time. In contrast to the slash pine results reported by Union Camp Corporation, rust infection of the orchard stock is considerably less than that of the regular stock.

In another study, open-pollinated families of two select trees from the Kimberly-Clark seed orchard were compared to the commercial check eleven years after field establishment. Even with only a selected mother and unknown father, the progeny have some superiority in growth rate and greatly improved form relative to the commercial check.

Source	Cords/Acre	Cords/Acre/Year
Clone 12-10	27.5	2.5
Clone 12-13	25.0	2.3
Commercial Check	23.5	2.1

Differences between orchard and commercial stock are usually greater when both parents are select phenotypes. However, all good-looking parents do not produce good progeny, and we find 10 to 15 percent of the original selections performing below desired levels, sometimes even being inferior to the commercial check. Removal of the poor trees by roguing the orchard results in a significant genetic improvement.

Results such as these from commercial plantings of Kimberly-Clark and Union Camp give us confidence that we have made progress. The magnitude and value of the gains from an economist's viewpoint will be available upon the completion of the Ph. D. research by Dick Porterfield, who is currently studying at Yale University. He is making a thorough and detailed analysis of the economics of tree improvement, using data from the Cooperative and the literature to bolster the in-depth information he has obtained from two members of the Cooperative.

From Advanced-Generation Breeding

Much to our surprise and delight, the movement into advanced-generation breeding has been much more rapid and vigorous than anticipated. Our planned "leisurely" approach has had to be abandoned in favor of a speeded-up effort to put into use the improved material now available. Such a speedup results in sacrificing some efficiency in order to gain time. Nearly every member of the Cooperative who has control-pollinated progeny tests old enough has started a second-generation seed orchard. Establishment of second-generation production orchards is done on a limited scale each year because we are annually obtaining an increasing number of outstanding selections.

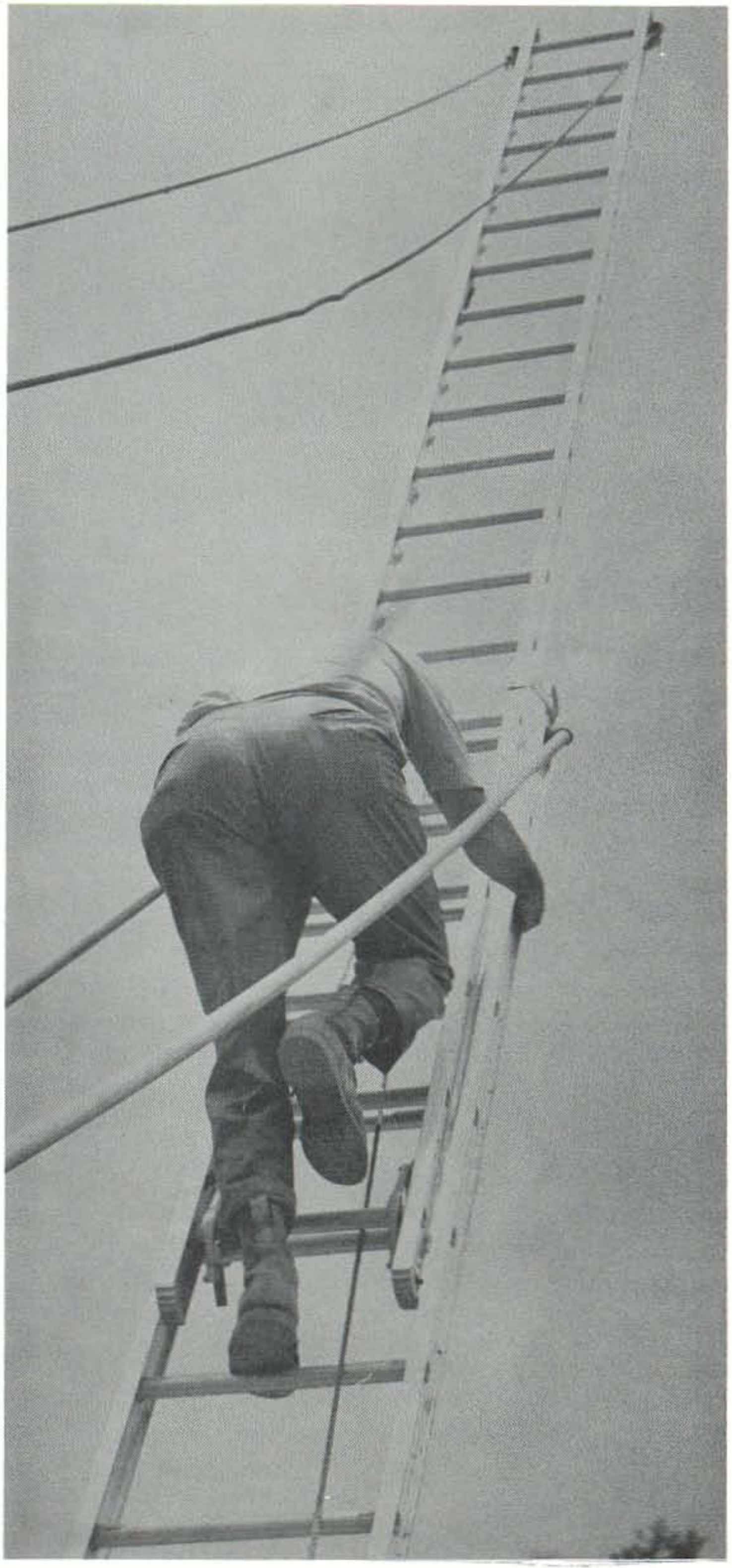
The relationship between fifth- and ninth-year second-generation selections has been about as expected. In some plantations the superiority of several of the early (fifth-year) selections did not carry through to the ninth year, while in others nearly all did. Some of the earliest second-generation selections were chosen by criteria less rigid than those now used. Bob Weir and Alice Hatcher have developed a computer program to select the best individuals of the best families. Following computer identification, the trees are field graded and the best are used in the second-generation orchards. In addition, a few really outstanding individuals from poorer families are included in the clone banks for breeding purposes and possible later use. These will be included in a production seed orchard only after progeny testing has proven them to be genetically desirable.

In the process of obtaining second-generation selections we discovered that from one to four clones in every seed orchard are very strong general combiners. This is wonderful for immediate gains in operational orchards but has a major influence on suitable methodology for advanced-generation breeding, if inbreeding is to be avoided. The parents that are strong general combiners within a seed orchard appear in the majority of the second-generation selections. If a pollen mix or open-pollinated seed are used, most second-generation selections will have either a common mother or father and many will have both parents in common. Such relatedness greatly restricts the utility of advanced-generation selections from operational plantations or from progeny tests originating from pollen mixes, or open-pollinations from a seed orchard. If the effects of the strong general combiners are ignored, serious inbreeding problems may result. Therefore, selections for advanced-generations are made only from progenies in which both parents are known or in which there is no possibility of relatedness.

Because of the importance of this, two papers have been prepared by members of the Cooperative to summarize and document the tendency for certain individuals to be strong general combiners. The first, given at the TAPPI meeting in Wisconsin,[2/] showed that 65 percent of the second-generation selections from the South Carolina Coastal Plain had one parent in common and 36 percent had both parents in common. A more comprehensive paper,[3/] presented at the Working Party on Progeny Testing of IUFRO in Macon, Georgia (October, 1972), discussed the information summarized in Table 2. From these results it is evident that certain parents are highly superior and produce more than their share of outstanding offspring.

[2/] Zobel, B. J., Weir, J. R., and Jett, J. B. 1972. Breeding methods to produce progeny for advanced-generation selection and to evaluate parent trees. Presented at the TAPPI Forest Biology Comm. Meet., Appleton, Wis. Published in Canadian Jour. of For. Res. 2(3):339-345.

[3/] Weir, R. J. and Zobel, B. J. 1972. Outstanding general combiners and their influence on breeding programs. Presented at the Working Party on Progeny Testing, IUFRO, Macon, Georgia.



One sees all sorts of views in a seed orchard, as exemplified by this superbly engineered piece of equipment. Despite the practicality of the ladder, it has been replaced by a "cherry-picker" for purposes of safety and logistics.

Table 2. Clones from nine loblolly pine seed orchards, illustrating how progeny from outstanding general combiners were selected a greater number of times than would be expected from their frequency in the progeny test; the relationship is expressed as a disproportionality ratio 1/

Clone	A - Percent of second-generation selections with clone as one parent	B - Percent of crosses in the progeny test with clone as one parent	Disproportionality Ratio (A/B)
7-33 T/	50.0	14.3	3.50
7-56*	70.0	23.2	3.02
4-18	41.3	17.9	2.30
1-66	29.4	12.9	2.28
6-8	25.0	13.1	1.90
10-39	38.5	20.3	1.90
11-2	34.2	20.0	1.71
6-20 T/	45.0	26.3	1.71
4-4	31.0	18.8	1.64
10-14	38.5	23.4	1.64
7-56*	31.5	20.0	1.58
12-12	37.7	25.0	1.51
5-33 T/	53.5	36.2	1.48
1-60	23.5	16.1	1.46
14-10 T/	50.0	35.2	1.42
4-6	34.4	26.4	1.30

*Clone 7-56 occurs in the seed orchards of several cooperators, including those of Westvaco Corporation and International Paper Company, for which test data have been summarized. In all orchards in which it occurs, it shows outstanding general combining ability just as for the two analyzed in the above table.

T/ Clone used as a tester. Many of the testers demonstrate outstanding GCA.

1/ From Weir, R. J. and Zobel, B. J. 1972. Outstanding general combiners and their influence on breeding programs. Presented at meeting of Working Party on Progeny Testing, IUFRO, Macon, Georgia.

We now have over 500 second-generation selections ranging from five to nine years of age, which were chosen from performance data obtained at age four. A few of the selections have been reevaluated at age nine from data obtained following the eighth growing season. The 332 selections summarized in Table 3 are superior in height to the averages of the plantations (32%) and to the commercial checks (42%). With heritability of height being reported as 0.3 to 0.5, it is evident that large height gains will be obtained from the second-generation selections.

Table 3. Heights of four-year-old second-generation selections compared to average heights of the plantations and of the commercial checks

Geographic Area	Number of Selections	Avg. Hgt. of Selections (feet)	Avg. Hgt. of Plantations (feet)	Avg. Hgt. Comm.Cks. (feet)	Superiority over Plantations(%)	Superiority over Comm. Ck. (%)
Coastal Virginia	43	11.1	8.7	8.2	27.4	35.0
Coastal N. Carolina	67	11.6	8.4	8.1	38.7	44.0
Coastal S. Carolina	44	12.7	9.9	9.1	28.7	39.2
Coastal Georgia	13	14.9	11.4	10.8	30.7	38.6
Piedmont N. Carolina	38	10.6	8.3	7.1	26.5	48.2
Piedmont S. Carolina	24	11.3	8.7	7.1	29.9	58.5
Piedmont Georgia	50	11.6	8.7	8.2	32.3	40.8
Piedmont Alabama	53	10.6	7.9	7.7	33.6	34.6
Totals and Weighted Average	332	11.5	8.7	8.1	32.2	42.0

Progeny Test Results

Approximately 1400 acres of control-pollinated progeny tests have been established by members of the Cooperative, as summarized by source and type of test in Table 4. In 1972, eighth-year measurements were obtained from the control-pollinated progeny tests of two cooperators and from several more tests and cooperators in 1973.

Table 4. Acreages and number of lots in control-pollinated progeny tests in the Tree Improvement Cooperative

Species and Geographic Location	Total Seed Lots Planted	Acreage Planted through 1972	Acreage Planted in 1973	Total Acreage Planted
Loblolly pine--Coastal Plain		542.8	158.7	701.5
Loblolly pine--Piedmont		370.4	111.5	481.9
Virginia pine		33.0	14.1	47.1
Slash pine		89.7	21.0	110.7
Pond pine		32.7	6.6	39.3
Shortleaf pine		6.3	6.4	12.7
Hybrid pines		6.7	4.7	11.4
Total Acreage		1081.6	323.0	1404.6
Main Tests	6,148	666.4	194.5	860.9
Supplemental Tests	6,326	388.2	128.5	516.7
Special Tests	84	27.0	000.0	27.0
Totals	12,558	1081.6	323.0	1404.6

Measurements from the approximately 75 crosses assessed in 1972 show the trends that are developing for height and volume (Table 5). Data have been arranged to indicate the best one-fourth and best one-half of the crosses, and the superiority of the best one-fourth over the commercial checks and plantation averages. Values shown are for volume in cubic feet per tree, height in feet, and percentage superiority.

On the wet but otherwise good coastal sites in North Carolina, the use of fertilizers increased the plantation volume production 135 percent in the north coastal and 30 percent in the south coastal tests. Height growth was also increased. Because of the high ground water table common to these sites and because site preparation was by harrowing only, the trees are just now beginning to show their growth potential. Under these conditions it is

Table 5. Volume in cubic feet and height in feet of eight-year-old progeny tests in the Carolinas, based on approximately 75 crosses

Source and Kind	Best 25% Vol.	Best 25% Ht.	Best 50% Vol.	Best 50% Ht.	Plantation Average Vol.	Plantation Average Ht.	Commercial Check Vol.	Commercial Check Ht.	Best 25% over Plantation Average Vol.	Best 25% over Plantation Average Ht.	Best 25% over Commercial Check Vol.	Best 25% over Commercial Check Ht.
	cu.ft.	ft.	cu.ft.	ft.	cu.ft.	ft.	cu.ft.	ft.	cu.ft.	ft.	cu.ft.	ft.
N. Coastal Main (North Carolina)												
Unfertilized	.476	15.2	.428	14.3	.338	13.2	.251	12.2	40.8	15.2	89.6	24.6
Fertilized	1.028	19.9	.913	19.4	.795	18.4	.797	17.9	29.3	8.2	29.0	11.2
S. Coastal Main (North Carolina)												
Unfertilized	.631	17.5	.593	16.9	.499	15.9	.476	15.5	26.4	10.0	32.6	12.9
Fertilized	.834	18.7	.749	18.1	.644	16.9	.627	15.6	29.5	10.6	33.0	19.9
Supplemental (North Carolina)[1/]	1.399	24.9	1.343	24.5	1.236	23.8	1.289	23.5	13.2	4.6	8.5[1/]	6.0
Coastal Main (South Carolina)												
Unfertilized	1.689	25.9	1.627	25.4	1.335	23.5	1.238	21.3	26.5	10.2	36.4	21.6
Coastal Supplemental (South Carolina)												
Unfertilized	1.553	24.5	1.413	23.8	1.350	23.4	1.354	23.2	15.1	4.7	14.7	5.5

[1/] The commercial check from North Carolina performed especially well in the supplemental test; it was from the same seed lots as the commercial checks of both the N. Coastal and S. Coastal main tests, which performed poorly.

interesting to note the magnitude of volume superiority in relation to height superiority. Many estimates of genetic gain have been reported only as height gain but it is clear that volume of wood production is underestimated using height only.

In a special study of a fast-grown loblolly pine test, Union Camp Corporation made measurements after six years in the field, with results shown in Table 6.

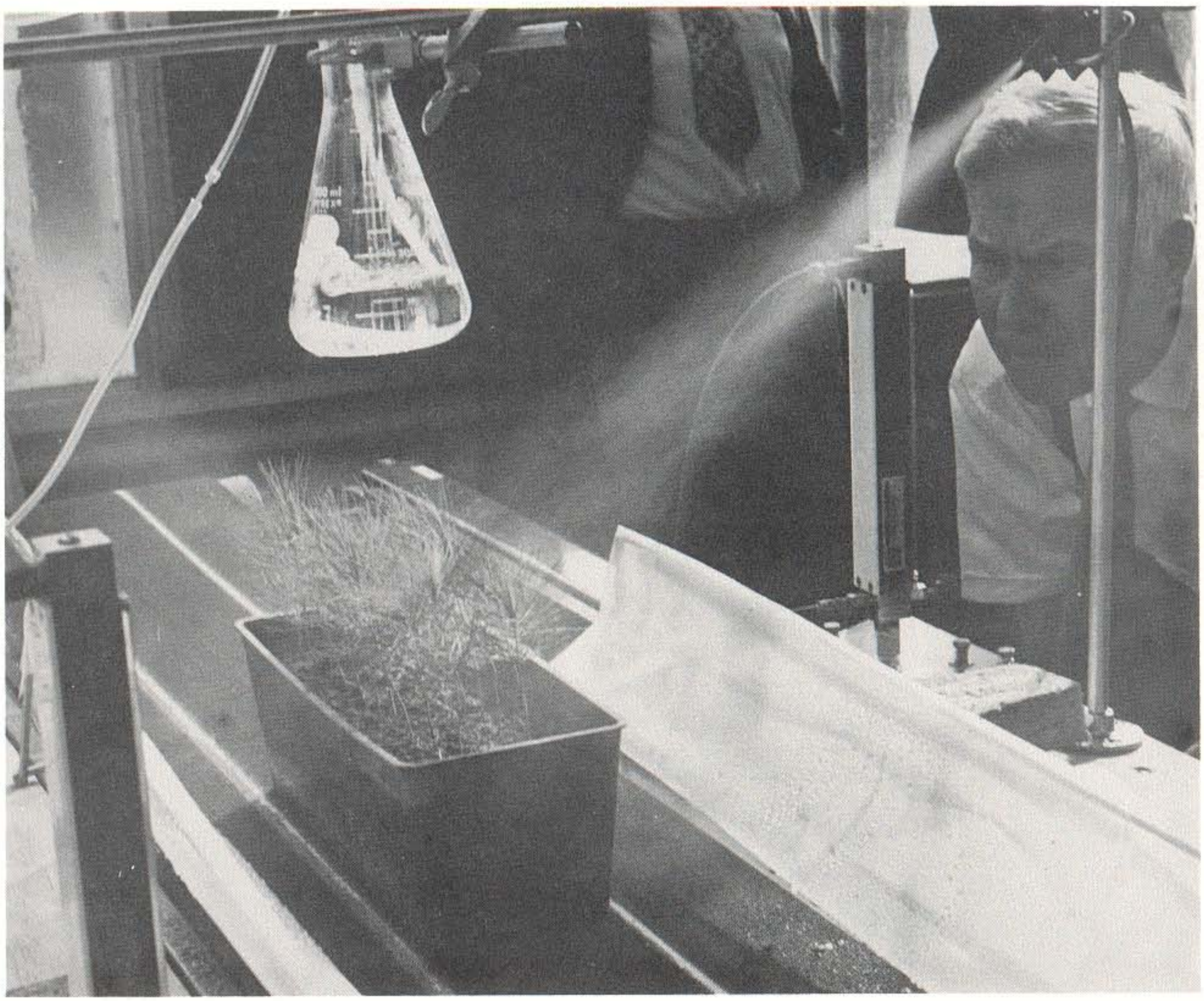
Table 6. Growth, disease and survival of a 6-year-old progeny test of loblolly pine established by Union Camp Corporation near Savannah, Georgia

Type of Material	Height (ft.)	Diameter (in.)	Volume/ Tree (cu.ft.)	Sur- vival (%)	% of Trees having rust infection on boles	Volume/ Acre (cu.ft.)[1]
All crosses from the seed orchard	26.0	4.3	1.48	92	47	989
Best 50% of crosses	26.6	4.5	1.62	95	51	1111
Poorest 50% of crosses	25.5	4.1	1.34	88	44	851
Avg., Comm. Ck. and SPA [2]	24.2	4.2	1.26	93	62	895

[1] Based on growth and survival. Acreage volumes should be interpreted with caution because they are based on small plots.

[2] Seed production area

Compared to the commercial check, average volume superiority of all crosses and of the best 50 percent of the crosses is 18 percent and 30 percent, respectively, while volume production of the poorest 50 percent of the crosses is comparable to that of the commercial check. In comparison to the



The United States Forest Service has set up a fusiform rust test center at Asheville, N. C. The facility is now in operation; mechanization, such as the inoculation procedure shown here, assures constant and repeatable conditions.

other groups, a greater proportion of the commercial check trees had fusiform galls. Stem gall infection, by family, ranged from 18 to 79 percent. Since two of the most severely rust-infected families were also the poorest volume producers, considerable genetic improvement could be expected by roguing these clones from the seed orchard.

Cone and Seed Production and Seed Quality

The major objective of a seed orchard is to produce large quantities of genetically improved seed as quickly as possible. Quality and size of crop are affected by freezing weather, ice damage, insects, diseases and inbreeding among seed orchard parents. In years of small or average cone crops, percentage losses due to pests often become very large, exceeding 30 percent or more of the viable seed. Unexplained annual fluctuations occur in the number of flowers and cones set, and certain sites consistently produce more seeds than do others, even when the same clones are present in both. Ecological effects on seed production are exceedingly complex; graduate student Carlos Gallegos has started a study to try and categorize what constitutes a good seed orchard site.

Several times we have been asked about the value of seed losses with the further logical question about how much can economically be spent to curtail such losses. When this question was posed, Dick Porterfield calculated the economic consequences if 20 percent of the seed were lost. He made the following realistic assumptions:

Plantation spacing - 8' x 10'

Rotation age - 25 years

Stumpage value - $10/cord

Yield from regular plantation - 50 cords

Yield from improved plantation - 56.25 cords (2.25 cords/ac./yr. or 12.5% more than the regular plantation)

Interest rate - 8%

Plantable seedlings/lb. of seed - 8,000

Orchard 50 ac. in size, with a production of 40 lbs. of seed/ac./yr.

The reduction in forest earnings caused by a loss of 20 percent of the orchard seed which would result in planting fewer acres with improved seed had a discounted present value = $48,207, or nearly $1,000 for every acre of seed orchard. This shockingly large value loss resulting from destruction of only 20 percent of the seed indicates that a considerable expenditure can be made to protect seed yields by better seed orchard management operations and pest control.

Seed Yields

Growing concern has been expressed the past three years regarding poor yields and quality of seed from seed orchards. Slash pine has given the greatest problems, but there have also been occasional reports of poor yields and germination from loblolly pine orchards. To determine the pattern of seed yields and germination necessary to identify the cause of poor yields, the U. S. Forest Service initiated S.O.S. (Seed Orchard Survey) in 1971 and has supplemented this with S.O.S.E.T. (Seed Orchard Survey Evaluation Test) in 1972. Results from the SOS studies indicate that 1971 was generally a good year for yields and germination for both loblolly and slash pine, especially in the Midsouth where heavy cone crops occurred. A summary from data of 18 members of the Cooperative prepared by J. B. Jett (Table 7) indicates that differences for several seed and cone characteristics are greater among clones within orchards than among orchards. Insect damage to slash and loblolly pine cones and seed is comparable although the range of damage on different orchards for loblolly greatly exceeds that for slash pine.

Table 7. Summary of S.O.S. results for loblolly and slash pine in the N. C. State Cooperative Tree Improvement Program[1/]

	Cones/ Bushel	Total Seed/ Cone	Number Seed/ Lb.	Lbs./ Bushel	% Full Seed	% Full Seed Germ.	% Insect- Damaged Seed	% Insect- Damaged Cones
				Loblolly Pine				
Mean	254	74.6	14,031	1.34	75.5	94.4	7.55	6.4
Range	141 - 407	48 - 94	12,473 - 15,764	0.75 - 2.16	49.6 - 87.0	85.6 - 98.8	1.8 - 17.8	0.1 - 26.6
				Slash Pine				
Mean	165	80	10,890	1.21	76.9	82.9	8.3	6.0
Range	146 - 181	64 - 96	10,365 - 11,407	1.00 - 1.38	68.6 - 83.3	66.7 - 88.6	6.3 - 11.3	2.8 - 12.4

[1/] Based upon results furnished by U. S. Forest Service Seed Laboratory, Macon, Georgia, for 18 members of the Cooperative Tree Improvement Program who participated in the Seed Orchard Survey (S.O.S.)

Sometimes the results from the S.O.S. tests are surprising; one company found that their "prize-producing" clone, which contributed 48 percent of the volume of cones from their orchard, produced only six sound seed per cone. The problem appears to be that this clone flowers earlier than any others, resulting primarily in selfed seed. A clone of another cooperator which contributes over 50 percent of the seed from their orchard had over 130 sound and viable seed per cone.

The cone crop was generally poor in 1972 relative to 1971; in the Cooperative we collected only 8,729 bushels of cones (Table 8) compared to 10,647 bushels in 1971. Slash pine yields fell sharply in 1972. The exception to the poor crop was loblolly pine in the Atlantic Coastal area, where cone and seed yields in 1972 were good. In the Piedmont and Gulf Coast areas the crop was nearly a failure. In years of small cone crops, there is a consistent pattern that yields of seed per bushel and seed germination percentage are greatly reduced.

Table 8. Cone and seed yields in 1972 from pine seed orchards of the Cooperative, compared to the good year 1971

Species	Bushels of Cones	Pounds of Seed	Pounds of Seed/ Bushel of Cones (1972)	Pounds of Seed/ Bushel of Cones (1971)
Coastal Source Loblolly Pine	4212	4483	1.06	1.18
Piedmont and Mountain Source Loblolly Pine	2595	2189	.84	1.09
Slash Pine	1684	1014	.60	0.80
Virginia Pine	152	74	.49	0.58
Pond Pine	0	0	0	0.39
White Pine	54	13	.24	0.36
Shortleaf Pine	32	24	.75	0.53
Totals	8729	7797	-	-

Differences in seed yield between good and poor years are illustrated by data from two of Weyerhaeuser Company's orchards (Table 9).

Table 9. Effect of year on seed yield and quality in two loblolly pine seed orchards of Weyerhaeuser Company, Washington, N. C.

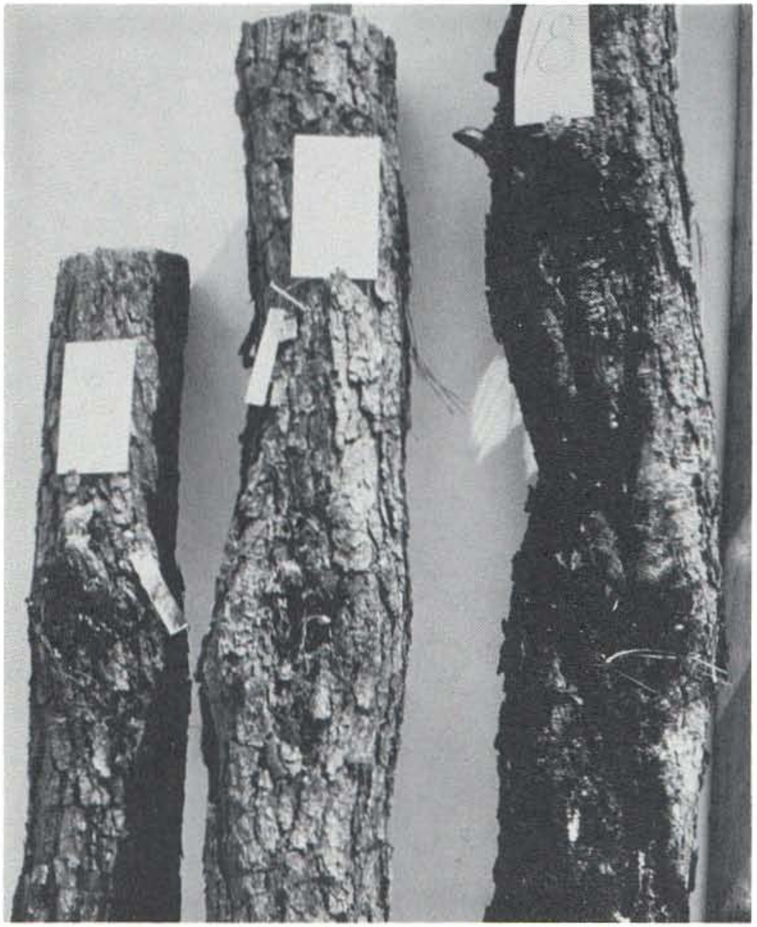
	North Coastal High Density			South Coastal High Density		
Year	Lbs. Seed	Seed/ Lb.	Percent Germination	Lbs. Seed	Seed/ Lb.	Percent Germination
1970	1042	13,464	76	1353	14,992	83
1971	145	13,089	64	330	13,667	66

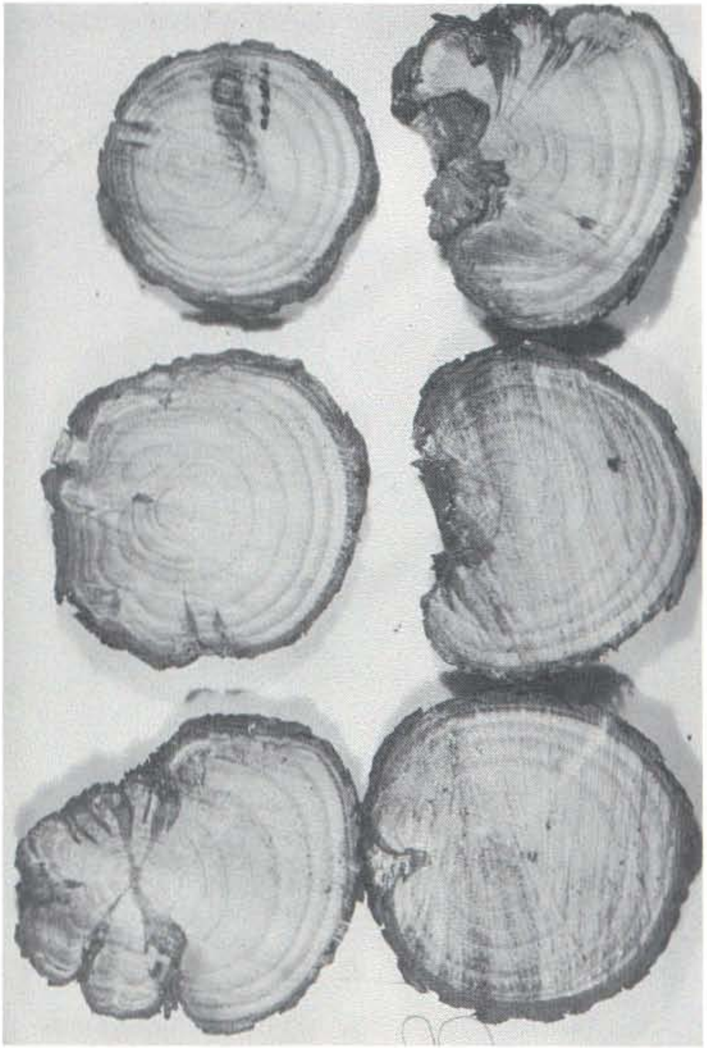
Weyerhaeuser Company also found considerable difference in germination based on seed size, with small seeds often showing strikingly poorer germination (Table 10).

Table 10. Effect of size on germination of loblolly pine seed from two years' tests made by Weyerhaeuser Company from two of their seed orchards at Washington, N. C.

	North Coastal High Density				South Coastal High Density			
	1970		1971		1970		1971	
Seed Size	Seed/ Lb.	% Germ.	Seed/ Lb.	% Germ.	Seed/ Lb.	% Germ.	Seed/ Lb.	% Germ.
Small	18,290	45	19,220	46	18,670	84	19,890	50
Medium	13,980	75	14,090	60	14,730	80	13,700	59
Large	11,990	84	11,660	70	13,220	88	12,550	79

Effect of seed size is not always consistent and, opposite to the Weyerhaeuser results, reports have been made showing the poorest germination from the largest seed. Generally, however, the smallest seed come from the base and tip of the cone and these usually do not germinate well.





Fusiform rust causes damage through mortality and growth loss. Shown left are three categories of galls on young loblolly pine; and, right, cross-sections through a badly infected tree depict the amount of infected wood. A pulping study has been designed to determine the yields and quality of paper from galled wood.

Fertilization, Irrigation, Subsoiling

Past results indicate that for nearly all orchards, fertilization is essential for maximum seed production and that for many orchards, irrigation applied at the appropriate time is very beneficial. Studies are in progress to verify whether or not seed production is increased by subsoiling as visual observation would indicate. Information needed is the time, method and quantity of fertilization, irrigation, and perhaps subsoiling to reach the optimal level for economical seed production. Preliminary assessments made by Dr. Charles Davey indicate that a conservative payoff on most good producing, well-kept seed orchards is about $5 of seed for each $1 of fertilizer. On some orchards the ratio is closer to $8 to $1.

Chuck Davey and Jerry Sprague maintain detailed records of fertilization treatments for each seed orchard. Their strategy is to apply nutrients during the later years to maintain health and vigor of the trees while improving seed production. Their records show that it takes about three years to build up a "threshold nutrient level" in the older trees and in the soil. After this level is reached, the amount of fertilization required annually may remain constant or even decrease. Studies are now in progress within the Cooperative to determine optimal fertilization levels for orchards in different environments.

Catawba Timber Company, Catawba, South Carolina, maintains the only study in the Cooperative where irrigation and fertilization have been applied throughout the life of the orchard. Positive results from the study, some of which are shown in Table 11, are responsible for the recent decision by the company to install a permanent irrigation system for their entire loblolly pine production seed orchard.

Table 11. Effect of fertilization and irrigation on cone production during a normal year (1971) and during a year of above normal rainfall (1972) in Catawba Timber Company's loblolly pine seed orchard

Year	Cones: Check	Cones: Fertilizer Only	Cones: Irrigation Only	Cones: Fertilizer + Irrigation
1971 - tree count	15	20	27	38
1972 - tree count	24	45	33	48
	Flowers			
1972 - branch count[1/]	60	109	96	126

[1/] Flowers per sample that will be mature in 1973, based on branch count. The branch facing the river on third, fourth and fifth whorl from top of tree had the flowers tagged and cones counted for the study.

One clone which produced nearly 50 percent of the cones in 1971 and 25 percent in 1972 seems to be especially responsive to fertilization; therefore the values are biased by this responsive clone.

The N. C. Forest Service's longleaf seed orchard has produced abundant flowers for the past three years, but a majority of the conelets abort during the first year, both from open- and control-pollinations. The problem is serious. In 1971 only 19 percent of the control-pollinated conelets survived, of which 5 percent matured. Results were even worse in 1972, in which only 6 percent of the yearlings from 2,364 pollinated flowers survived. Efforts have been made to control and determine the cause of the loss but to no avail. Therefore, starting in spring 1973, an all-out effort to control cone loss has been started by the N. C. Forest Service in conjunction with the Cooperative. Since we know from previous tests that the loss apparently is not due to insects or diseases, we are trying to reduce conelet abortions through altering the physiology of the tree. Treatments being tried include various fertilizer and irrigation combinations. Based upon results, a more intensive test will be undertaken in 1974 to see how much the conelet loss can be reduced.

Control of Seed and Cone Insects

A major activity of the Cooperative has been the attempt to improve seed yields by controlling cone worms, seed worms, and seed bugs. Many different insecticides have been tried with varying degrees of success. Because of the importance of this problem, a Seed Protection Committee was established at the 1972 Advisory Committee Meeting in Atlanta. This group, chaired by Norman Johnson of Weyerhaeuser Company, has been very active and has already achieved some notable results such as getting thimet labeled for use for tip moth in seed orchards. The objectives of the committee are:

1. To collect, analyze and dispense data on insect control methods.
2. To generate new data on cone and seed insect control methods.
3. To exert pressure on governmental research organizations to intensify research on cone and seed insects.
4. To work with chemical companies on new and potentially useful chemicals.
5. To help in obtaining labels for useful chemicals.
6. To define and recommend policy on insect control for the Cooperative.

The committee, coordinating activities of the Cooperative through Bob Weir, outlined a Cooperative study that was installed in spring 1973 to evaluate thimet and gardona. The latter is a new, relatively safe, chemical tested for the past two years by the Virginia Division of Forestry and for the past year by Weyerhaeuser Company. It appears to be very effective when used as a 0.5 percent spray applied to the point of run-off. Weyerhaeuser Company reported 8 percent insect damage when gardona was used, compared to 38 percent for the unsprayed control. The Virginia Division of Forestry has found gardona to be good for tip moth as well as for cone insects.

In an attempt to determine the most efficient control methods, 14 special tests were established by members of the Cooperative in 1973. Orchards from throughout the geographic range are being tested; based upon the results, we hope to make positive recommendations as to the best insecticide for cone and seed insect control in seed orchards.

Thimet has been used very successfully for tip moth control for many years. However, it is highly toxic and, as a result, had not been registered for forestry use. Through American Cyanamid Company, and with the influence of the Cooperative behind the request, an application for use of thimet for young trees (up to 8 feet tall) was approved by the Environmental Protection Agency, effective December 21, 1972. Further attempts are being made to have the chemical approved for use on seed orchard trees of all sizes.

Cone and Seed Harvesting and Seedling Production

A continuing problem is the best method to collect seeds from the seed orchards. As cone crops become heavier, the makeshift ladders and towers now in use are found to be inadequate, inefficient, and sometimes not safe. These makeshift devices have largely been replaced by "cherry-pickers" and other similar pieces of equipment because of safety, ease of operation, and relative efficiency.

Nearly 2,000 bushels of cones were collected by International Paper Company, Georgetown, S. C., in 1972 using three "cherry-pickers." The job was done with dispatch and in plenty of time to avoid seed losses from cone opening. The key to such an operation is to collect from the earliest maturing clones first and hold the late maturing clones until last; this extends the collection season two weeks or more. In addition, companies such as Hoerner-Waldorf Corporation started collection from their earliest maturing clones about ten days before cone maturity. The cones harvested were then placed in shade under wet burlap for a period of maturation. Such a system works well, with good seed yields and germination.

We are concerned with the methods and costs of cone and seed collection. Cost varies widely by orchard age and size and by equipment used, but most influential is the size of the cone crop. Costs per pound of seed have been reported from a low of \$2.50 to \$15.00.

Based on detailed records for a six-day period during the height of the 1971 (heavy) cone collection season, Kimberly-Clark Corporation found that with one cherry-picker and a supporting crew, 8.88 bushels of cones were collected and loaded in the dry kiln per man for an 8-hour day. Similar records for Virginia pine showed 2.82 bushels per 8-hour man-day for the seven best days and 2.20 bushels/8-hour man-day for the season.

The Seed Harvest Committee has been very active and has contracted with Bowie Machine Works, Bowie, Texas, to develop a reasonably priced mechanical harvester to collect seed from the ground. Early field trials made in Weyerhaeuser Company's North Carolina Piedmont seed orchard indicate: (1) pick-up of seed was not as good as desired; (2) speed of pick-up needs improvement; (3) separation of seed from trash was not satisfactory, requiring some major modifications of the machine; and (4) shaking of seed from open cones on the trees was readily accomplished without apparent harm to the tree. Results of these tests and modifications now being made indicate that the harvester should be operational by fall 1974.

The number of plantable seedlings that will be obtained from a pound of seed from the seed orchards will vary with seed-bed densities and a host of other factors, including geographic source and seed size. From their orchard in North Carolina, Hoerner-Waldorf Corporation observed a range for loblolly pine from about 5,000 to about 6,500 seedlings per pound of seed from their 1971 seed orchard crop (Table 12). In contrast, commercial collections yielded from 7,500 to about 10,000 seedlings per pound of seed.

Table 12. Seedling production per pound of seed for Hoerner-Waldorf Corporation in 1971

Source of Seed	Pounds of Seed Collected	Number of Seedlings Produced	Number of Seedlings/ Lb. of Seed
S. Coastal Plain (commercial)	624	4,691,000	7,520
N. Coastal Plain (commercial)	209	2,060,500	9,860
Coastal Plain (seed orchard)	103	674,000	6,540
Piedmont (seed orchard)	58	290,500	5,010

Disease Studies

Locating and Developing Resistant Parents

Emphasis on breeding for resistance to disease, primarily fusiform rust, has resulted in outstanding cooperation by industry, university and governmental organizations in conducting field and basic research studies. A

Before and after! Our oldest progeny test, by Westvaco Corporation, is shown at age 11, just prior to (above) and following the second thinning (below). Progeny in this test are growing rapidly, with several families averaging over 3 cords/acre/year.

Disease Test Center has been established by the U. S. Forest Service at Asheville, N. C. to screen seed orchard clones or potential parents for the susceptibility of their progeny to fusiform rust. Trial runs in 1972-73 are being conducted in preparation for operational testing in 1973-74. The critical question not yet fully answered relates to how well greenhouse tests such as those of the Disease Test Center compare to the results obtained from field tests.

Several members of the Cooperative have selected rust-free trees with good growth and form from plantations having in excess of 90 to 95 percent fusiform rust infection. The efficiency of this practice has been questioned but early results are encouraging. Seed of seven such slash pine trees selected in cooperation with Union Camp Corporation were tested in the greenhouse by Dr. Harry Powers of the U. S. Forest Service. Progeny of three of the selections had low rust infection, three had high infection, and one was intermediate (Table 13). If this ratio of success can be maintained, the practice of selecting from diseased plantations would be very rewarding.

Table 13. Infection percent of progeny from fusiform-free slash pine parents from badly infected plantations and from normal seed orchard parents. Tests were conducted in the greenhouse. 1/

Source of Seed Parents	Percentage Infection of the Progeny in the Greenhouse
7 trees from diseased stands:	
3 trees (good resistance)	39%
1 tree (intermediate resistance)	66%
3 trees (no evident resistance)	82%
10 seed orchard parent trees:	
2 most resistant clones	42%
1 intermediate clone	63%
7 with poor resistance	91%

1/ Tests made by Harry Powers, U. S. Forest Service, Athens, Georgia; tests are part of Union Camp Corporation's tree improvement program.

Many benefits have been derived from a knowledge of the inheritance of fusiform rust. Most directly, seven members of the Cooperative have established specialty disease resistance orchards, some of which are now beginning to produce cones. Out of approximately 1,000 clones screened, we have six rated as very good, 15 as good, and 10 above average. These clones produce disease-resistant progeny that also have outstanding growth and form. Establishment of such orchards is possible only through a cooperative where the clones are progeny tested over a series of years and at a number of locations where the disease is prevalent. As results become available each year, new clones are added to the list and occasionally an inconsistent clone is deleted. The 31 disease-resistant clones now used have come from the following members of the Cooperative (Table 14):

Table 14. Clones that produce disease-resistant progeny come from several members of the Cooperative.

Organization Supplying the Disease-Resistant Clone	Number of clones found to have good disease resistance
Champion International	9
Hiwassee Land Company	3
Kimberly-Clark Corporation	4
International Paper Company	3
Union Camp Corporation	4
Continental Can Company, Inc.	3
Westvaco Corporation	4
Federal Paper Board Company, Inc.	1
Total	31

In addition to establishing the specialty orchards, the seven members have joined together in making a half-diallel test cross of all clones used. These crosses will generate an additional base from which to select second-generation trees and will provide data for further study of the inheritance pattern of this disease.

Gains Using Rust-Resistant Parents

Based upon values obtained from the Heritability Study and from other tests, Roger Blair and Bruce Zobel calculated the gains that can be achieved by breeding for rust resistance. Results showed substantial variation in resistance to rust infection. Heritabilities, on an individual tree basis, ranged from 0.02 to 0.39; three methods of assessing infection were used and predicted gains are indicated in Table 15.

Table 15. Predictions of gain using three methods of selection and three indices of susceptibility for two different years 1/

	Predicted Gain as Percent of Mean	
	1963	1964
Mass selection		
Gall counts	56	9
C-score 2/	24	3
Percent infected (as threshold trait)	16	9
Mass selection and progeny testing		
Gall counts	91	25
C-score	47	12
Percent infected	36	18
Family and within-family selections		
Gall counts	98	46
C-score	30	17

1/ Blair, R. L. and Zobel, B. J. 1971. Predictions of expected gains in resistance to fusiform rust in loblolly pine. Proc., 11th South. For. Tree Impr. Conf., Atlanta, Ga. pp. 52 - 66.

2/ Based upon an index which reflects the potential economic and biological impact as well as the incidence of the disease

Even if the lower values for 1964 are used it is evident that useful gains can be achieved by breeding for fusiform rust resistance.

In a progress report on growth and rust infection of slash pine in Georgia, Marvin Zoerb of Union Camp Corporation related disease infection to growth rate. He states: "Just as we found in loblolly pine tests, in slash pine the best-growing plantations also show the highest rust infection. However, when rust infection is plotted by individual families it is quite apparent that there is no cause and effect relationship between growth rate and infection rate. If anything, the slowest-growing families tend to show the highest infection rate. It is possible that the average growth rate is being retarded in the badly infected families. Similar trends were found in loblolly pine progeny tests."

Comandra Rust

Several years ago a rather heavy infection of comandra rust became evident on certain of Hiwassee Land Company's loblolly plantations in the Cumberland Plateau. Damage was so severe that in some areas the plantations were destroyed. The U. S. Forest Service made studies of the infected stands and Hiwassee established a progeny test which contained 43 crosses in each of eight replications from their own and from Kimberly-Clark Corporation's seed orchard on the site of the heavy kill. Trees in four of the replications were heavily fertilized. After two growing seasons the infection rate for fusiform and comandra rusts combined was only 1.2 percent. At these low infection rates it is not possible to determine resistance or susceptibility of loblolly to comandra rust. For fusiform rust we usually find that overall infection must exceed 15 percent before reliable family differences can be detected. Although not related to rust infection, it was clearly evident that several of the loblolly pine crosses from the lower elevation and more southerly sources did not survive or grow as well on the Cumberland Plateau as did those from more northern sources.

Wood Studies

As in the past, a major activity of the Cooperative relates to wood and wood qualities. It appears there sometimes is the belief that we in the Cooperative are concentrating only on the development of high specific gravity trees. This is incorrect and for several members we are working toward maintaining average gravity while others prefer low gravity wood. Each seed orchard has been developed for special wood types dependent on the end product desired.

Young Wood

With the greater use of young wood and wood residues, interest has rapidly increased in the characteristics and value of the wood of young trees. Several mills have made special runs using all or part young wood for several days to determine the yields and quality of paper produced and thus the financial effect of using young or residue wood. Results are often classified but, in general, pine trees younger than 15 years produce 6 to 15 percent less pulp when based on a volume or a green weight basis than do 30-year-old trees. Additionally, certain paper properties are considerably altered compared to older wood. One study by Hammermill Paper Company showed that the total cost of producing pulp from 12-year-old loblolly pine was 65 percent greater than from 30-year-old trees[4/] when

4/ Kirk, D. G., Breeman, L. G. and Zobel, B. J. 1972. A pulping evaluation of juvenile loblolly pine. Tappi 55(11):1600 - 1604.

the young trees were from plantation thinnings. Pulp yields of the 12-year-old trees were 9 percent lower on a volume basis than were the yields of the older trees. The young wood exhibited higher tensile, burst, fold, smoothness, and apparent density, but lower opacity and tear than did mature wood.

Similar results from other pulping studies show increased costs from the pulping of young wood because there is 25 to 50 percent more juvenile wood from the younger, smaller trees than from larger, older trees. The conclusion is that young wood gives different yields and qualities than does the normal furnish but can be most desirable for certain papers if handled separately.

From a special study of high and low gravity trees of different ages, Brunswick Pulp and Paper Company made available some valuable data which have contributed to our knowledge of the variation in wood properties (Table 16).

Table 16. Wood qualities of high and low specific gravity slash pine trees of different ages [1]

	15-Year Age Class			21- to 25-Year Age Class		
	High Gravity	Average Gravity	Low Gravity	High Gravity	Average Gravity	Low Gravity
Moisture content[2]	85.0	99.7	117.0	77.5	91.3	89.5
Unextracted Sp. Gr.	.565	.497	.455	.565	.536	.500
Extracted Sp. Gr.	.550	.485	.435	.545	.510	.475
Percent extractives[2]	2.5	2.8	4.7	4.1	3.5	4.0
Tracheid length (mm)	4.10	3.93	4.10	4.65	3.77	4.00
Single wall thickness (microns)	11.25	9.83	11.15	11.95	11.20	8.60
Lumen size (microns)	15.55	15.80	17.20	14.40	15.53	17.15
Cell diameter (microns)	38.00	35.48	39.45	38.20	37.73	34.25
% Yield, dry basis	45.20	46.27	45.27	45.04	46.31	46.09
% Yield, wet basis	24.29	22.52	20.61	26.30	24.04	23.74

[1] Results are only general because of the very large sampling errors due to tree-to-tree differences within a class where only two to four trees were sampled. Values are simple averages for cross-sectional samples taken at the 5- and 15-foot levels above the stump. From a study by Brunswick Pulp and Paper Company in Georgia.

[2] Based on dry weight of wood

In addition to the large fluctuations caused by tree-to-tree variation, some apparent anomalies exist in the data. Cell wall thickness of the average gravity trees of the 15-year age class is considerably less than the low gravity trees of the same age group. One explanation for this is that the average gravity trees had considerably more summerwood even through the cell walls of the summerwood are thinner than the lower gravity trees. As expected, the older trees had low moisture content and high specific gravities; the low gravity trees tended to have larger cell lumens and a greater amount of extractives. Tracheid length is independent of gravity and varies widely, depending on the individual trees involved. Yield of pulp on a wet wood basis was greater for the high density and older trees.

Effect of Fusiform Rust on Wood Properties

We have been working closely with Southlands Experiment Forest, International Paper Company, to determine the effect of fusiform infection on plantation yields. To assess the total effect of this destructive disease it is necessary to determine how pulp yields and quality from wood of infected trees compare to those from uninfected trees. Results from a preliminary test indicate that the disease has a major effect on pulp yields and quality (Table 17). Based on these findings, a major study has been initiated on the pulping of trees infected with fusiform rust.

Effect of Stocking and Site Preparation on Wood Qualities

Wood qualities are known to remain relatively stable at normal stocking densities (6' x 6' to 12' x 12'), but the effect of different intensities of site preparation on wood qualities has, until recently, been unknown. From two large studies to determine the effect of different site preparations and stocking on wood yields of slash pine, Brunswick Pulp and Paper Company obtained wood samples which were analyzed at Raleigh (Table 18).

Table 17. Wood and pulp properties from fusiform-infected and nondiseased wood obtained from approximately the same location within the same trees 1/

Characteristic	Clean Wood (noninfected)	Diseased Wood (fusiform-infected)
Unextracted specific gravity	.437	.507
Extracted specific gravity	.424	.424
Percent resin	3.1	19.4
Pulp yields 2/	52%	26%
Fold	209	78
Tear	157	150
Tensile	4300	3600
Burst	32	26
Brightness	15	21
Total carbohydrates 3/	73.7	50.0
Alpha cellulose 3/	40.7	25.8
Hemicellulose 3/	28.6	19.1
Lignin 3/	21.7	22.2

1/ A preliminary test based on 10 trees by members of the Wood Sciences Department, N. C. State University

2/ Based on dry weight of wood

3/ From Rowan, S. J. 1970. Fusiform rust gall formation and cellulose, lignin and other wood constituents of loblolly pine. Phytopathology 60:1216-1220.

Table 18. Effect of stocking and site preparation on wood specific gravity of 14-year-old plantations of slash pine 1/

Spacing (ft.)	Site Preparation: Control	Burn, Scalp	Burn, Harrow	Burn, Double Harrow	Average by Spacing
6' x 6'	.490	.498	.487	.495	.492
6' x 12'	.498	.489	.489	.481	.489
8' x 12'	.496	.486	.490	.486	.489
12' x 12'	.488	.494	.501	.489	.493
Average by Treatment	.493	.491	.492	.487	

1/ The study by Brunswick Pulp and Paper Company was replicated four times at six locations in South Georgia.

It is evident from the results that neither site preparation nor stocking had a major effect on wood specific gravity.

From a similar 8-year-old study of slash pine established at six locations in South Georgia to evaluate four intensities of site preparation planted at a constant spacing of 6' x 10', Brunswick found little relationship between wood specific gravity and cultural practice (Table 19). Based on these two large, well designed studies, it is evident that wood specific gravity of slash pine is not affected by differing site preparations or normal stocking densities.

Table 19. Effect of site preparation on wood specific gravity of 8-year-old slash pine 1/

Site Preparation	Specific Gravity
Control	.415
Bedded only	.424
Harrowed only	.422
Harrowed and bedded	.426

1/ Study by Brunswick Pulp and Paper Company, with four replications at each of six locations in South Georgia

Tolerance to Droughty and Wet Sites

Several cooperators have tested drought-resistant sources of loblolly pine or their hybrids on deep sands or in other droughty environments. Studies by Westvaco Corporation, Union Camp Corporation, and Georgia Kraft Company have shown this material to have two special attributes: (1) It can survive and grow satisfactorily under conditions of severe, intermittent drought on inherently droughty soils, and (2) it has strong resistance to fusiform rust infection. Results from a plantation established in March, 1955 by Westvaco Corporation, Georgetown, South Carolina from seed of select trees or groups of trees from east Texas and southwestern Louisiana[5] are shown in Table 20.

Table 20. Comparative 10-year performance of drought-tolerant loblolly pine to a local source on deep sands in coastal South Carolina[1]

Source[2]	Percent Survival	Height (ft.)	Diameter (in.)	Percent Fusiform Infection
Bastrop County, Texas #4	79	13.2	2.1	9
Bastrop County, Texas #2	88	16.6	2.8	17
Bastrop County, Texas #5	91	16.9	2.8	21
Fayette County, Texas #4	82	13.8	2.2	19
Fayette County, Texas #3	88	15.5	2.4	26
Leon County, Texas #3	53	19.0	3.2	7
Louisiana #2	64	17.1	2.8	49
Westvaco Seed Production Area, Georgetown, S. C.	69	17.7	3.0	62

[1] Data obtained from a study by Westvaco Corporation, Georgetown, South Carolina

[2] Bastrop #5 was from an individual select tree, Bastrop #2 and #4 were from bulk collections. All other lots were bulk collections from three or more trees, except Leon #3 which was from a single tree in the post oak belt in east Texas. The Louisiana source was from southwestern Louisiana.

The "Lost Pines" sources from Bastrop and Fayette Counties were superior in survival and disease to the local check and to the Louisiana source; however, individual trees from the local source were larger than their counterparts from the "Lost Pines" sources. The potential usefulness of selected sources such as Bastrop #5, either for direct planting or to provide genes to combine with the best local material, is evident.

[5] Seed for this study were obtained from studies by the Texas Forest Service sent by Zobel prior to 1956 or by van Buijtenen after 1956. The Texas Forest Service has been most cooperative in supplying test material.

In June, 1965 the drought-resistant test plantation was thinned and fertilized and the best trees were crossed with four of the best clones from Westvaco's seed orchard in South Carolina. First progeny were outplanted in 1970. These hybrid plantings are still too young for a definite assessment of performance but they look very promising through the third year in the field.

Early performance of several potential drought-resistant hybrids from a study by Union Camp Corporation was reported in Table 33, page 78, of the Sixteenth Annual Report. In this study, the slash-x-Texas loblolly cross is growing very well. Both Federal Paper Board Company and Catawba Timber Company have established good-sized, well-designed tests in the dry, sandy areas of the Carolinas. Both have included several species and sources within species, including sand pine, to see how it will grow under the cooler conditions in the Carolinas.

There are millions of acres in the coastal areas too wet to grow loblolly pine using normal management procedures. Some of this area has mineral soil and originally supported fine mixed stands of hardwood and pine. Following logging and site preparation, such sites often become excessively wet, preventing reasonable survival or growth of new plantations during their early years. Other wet sites are the deep peats or mucks, which are characterized by organic soils sometimes exceeding 15 feet in depth. Such areas normally support pond pine, although occasional, scattered stands of loblolly pine can be found there. A special seed orchard was established by Westvaco Corporation from loblolly pine in North Carolina, growing on no less than four feet of peat. Clones from this orchard have been well tested, both on the organic and wet mineral soils, and performance has been surprisingly good.

Studies are not restricted to the southern pines. Plantings were made in Florida from seed collections of P. caribaea in the Bahamas. Growth has not been spectacular, but differences among progenies are great.

Comparative performance of selected wet site, average wet site, and commercial check loblolly and pond pine on wet mineral soils is shown in Table 21. The wet site seed orchard stock performed well; the seed orchard pond pine had remarkably good growth and form.

Problems are evident on wet site planting, even when bedding is practiced. For example, Marty Fox of Federal Paper Board reports a "phase-out" in which loblolly planted in the Green Swamp of southeastern North Carolina sickens and dies after about five years in the field. The condition worsens with distance from the drainage canals. Young plantations of the "wet site" source loblolly have grown very well under such circumstances and it now appears the "phase-out" problem may be partially solved. Most wet lands are very productive after the trees capture the site.

Because of the encouraging results with the wet site loblolly pine selections, both Federal Paper Board Company and Weyerhaeuser Company have established "wet site" loblolly seed orchards to produce seed for planting under conditions described above. Their new selections, combined with those already tested by Westvaco Corporation, make available a good genetic base within the Cooperative for this special wet site strain of loblolly to overcome a special and very serious regeneration problem. The wet site selections have proven to be very vigorous although somewhat poorer in form than improved loblolly that grows on mineral soils nearby.

Table 21. Height of 4-year-old seed orchard wet-site loblolly, local check wet-site loblolly, commercial check loblolly, and pond pine grown on wet, heavy clay soils in Virginia 1/

Source of Seed	Year Planted	Height (ft.)	Cronartium 2/ Score	Crown 3/ Score	Straightness 3/ Score
Seed orchard loblolly (wet-site source)	1966	8.50	1.00	3.6	3.0
	1967	8.64	1.00	3.4	3.3
	Avg.	8.57	1.00	3.50	3.15
Local, wet-site loblolly check	1966	7.52	1.07	3.7	3.6
	1967	7.93	1.20	3.3	3.4
	Avg.	7.72	1.13	3.50	3.50
Commercial Check	1966	7.41	1.23	3.9	3.7
	1967	7.53	1.02	3.4	3.6
	Avg.	7.47	1.12	3.65	3.65
Seed orchard pond pine	1966	7.47	1.06	3.6	3.0
	1967	8.07	1.00	3.0	3.3
	Avg.	7.77	1.03	3.30	3.15

1/ Tests on lands of Union Camp Corporation, Franklin, Virginia

2/ A score of 1.0 indicates no infection; the higher the value, the greater the infection.

3/ The higher index values indicate the heavier-crowned and more crooked trees.

Miscellaneous

"Minor" Species

It is necessary to work with one or more major species and several minor species in a region when unusual environments are common or where large climatic and edaphic differences occur. Because of this need for species diversity, Virginia, pond, longleaf, white and spruce pines all have been investigated by members of the Cooperative. Genetic gains have been particularly good in Virginia and pond pines, and already a few second-generation selections have been made in these two species.

Sand pine has received considerable attention by the more southerly companies because of its very good performance when planted on droughty, deep sands. A special seminar on sand pine was held in Florida in 1972 by the U. S. Forest Service, in which various aspects of growth, development and wood of the species were reported and discussed. This species appears to have real potential on droughty sites in the warmer areas.

Spruce pine is an intriguing species growing amongst hardwoods and successfully competing with them. It usually occurs as an isolated tree although it is occasionally found in pure stands. Under natural conditions it grows very rapidly on the best sites; when planted on dry sites it is very susceptible to tip moth and forms a rough tree with a crooked bole and heavy limbs. Results from one small study established by Georgia-Pacific Corporation compares the performance of spruce pine to that of loblolly and slash pines, with and without the use of fertilizers (Table 22). Survival of all species ranged from 92 to 100 percent. Also, all species responded to fertilization and none was especially hard hit by tip moth. Spruce pine ranks third in height growth but there are indications that the differential is being reduced.

Table 22. Height of spruce, slash, and loblolly pines after three years in the field in Georgia 1/

Pine Species	Fertilized (ht. in ft.)	Unfertilized (ht. in ft.)	Combined
Loblolly	12.5	10.1	11.3
Slash	11.6	9.3	10.4
Spruce	9.8	8.1	8.8
Mean, All Species	11.3	9.2	

1/ Study by Georgia-Pacific Corporation

Although loblolly and slash pines have the greatest commercial importance of the pines in the Southeast, it is necessary to have other species available for special problems or special conditions. As foresters better learn to handle minor species in the nursery and in field planting, greater use will be made of them.

Fume Damage

Intensive studies have been initiated to determine the sensitivity of pines to fumes, especially to ozone and sulfur dioxide. The primary objective has been to determine the growth losses associated with fume damage, with less emphasis being placed on mortality caused by the pollutants.

The Virginia Division of Forestry, North Carolina Forest Service, and N. C. State (Bob Weir's Ph. D. thesis project) are coordinating efforts in this important area of study. The field test chamber built by Billy Apperson and Ron Wasser of the Virginia Division of Forestry has worked well. However, early test results have been somewhat confusing, because of differences in response to fumes related to temperature, time of day and time of year, and in methods of assessing damage as well as shifts in ranking of families from one year to the next. Hopefully, a solid pattern of genetic response will develop so that it will be possible to breed for strains of trees that are sufficiently resistant to the pollutants to minimize growth losses.

Preliminary results from the Virginia Division of Forestry indicated a narrow-sense heritability of 0.33 and 0.41 for susceptibility of loblolly pine to ozone. This study was too small for reliable data, but these initial results do indicate that genetic resistance of loblolly pine to fumes may be great enough to respond to genetic manipulation.

Movement of Seed

As more information is obtained and outstanding clones are located there is a strong tendency to use seed outside its geographic area. Such movement can be beneficial but it also can be most dangerous. Even though the moved source may grow well for one to several years, a peculiar combination of environments can wipe out the plantation. Without reducing the enthusiasm that is building up to use the best material over large areas, it is necessary to have sound tests before major seed movements are made. Our approach is conservative, i. e., use the seed that is known to be well adapted, even if other, less well adapted sources might grow a little faster.

The "proof of the pudding" is in the testing. Therefore, as decided at the Contact Men's Meeting, work plans have been developed to test how far the best clones can be moved. We have recommended that outstanding sources, such as Livingston Parish, Louisiana, Marion County, Florida, Gulf Hammock, Florida and others, be incorporated as commercial checks in the regular progeny tests. This enables testing the suitability of these potentially valuable sources at the same time and against stock adapted to the area.

A number of tests are already underway in the Cooperative. Weyerhaeuser has 5-year-old tests of North Carolina loblolly growing in central Alabama and Mississippi. Both Coastal and Piedmont loblolly from North Carolina have grown reasonably well. In West Virginia, Fred Trew of Westvaco reports the following heights of 5-year-old loblolly pine from different sources when grown at Parkersburg, West Virginia:

E. Tennessee	- 9.0 feet
N. Alabama	- 8.25 feet
Virginia Piedmont	- 8.0 feet
Maryland	- 7.0 feet

In a more comprehensive study in Tennessee, Henry Barbour found that sources from the South Carolina, Virginia and North Carolina Piedmont varied from 1.87 feet to 2.60 feet by mother tree after one year in the field. A Kentucky commercial check was only 1.85 feet in height.

Another Pest

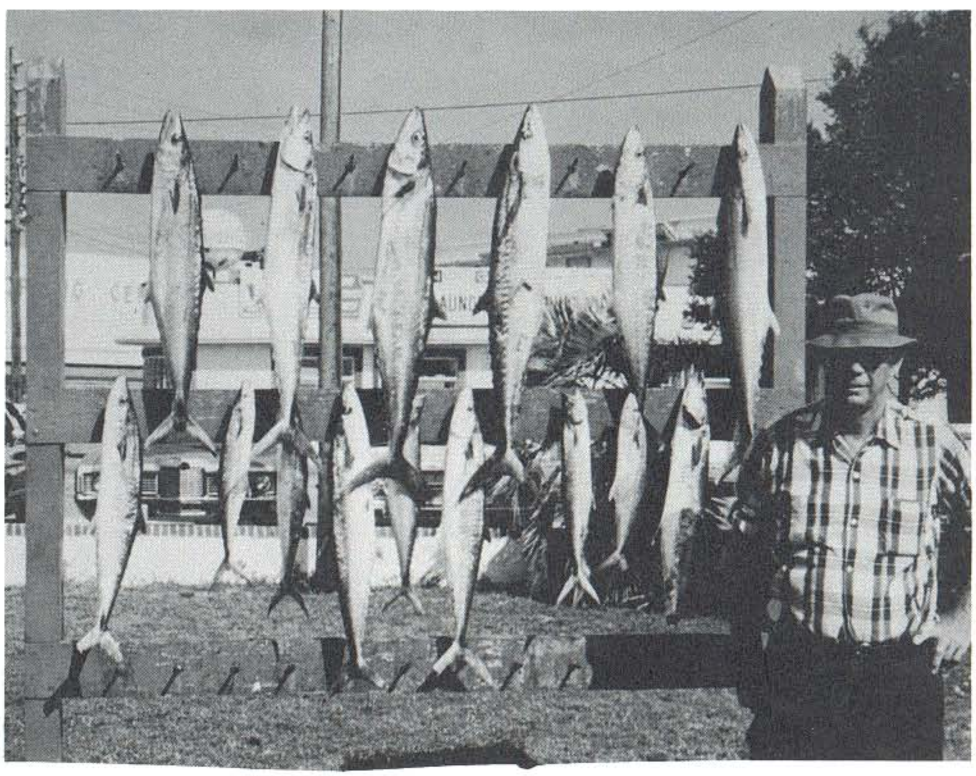
A couple of years ago a parasitic weed (*Seymeria cassiodes*) was reported on pine in west Florida. Since then a number of foresters have been on the lookout for this weed. Jack Mocha of Westvaco Corporation has now noted it attacking both loblolly and slash pines as far north as South Carolina. Some plantations three to five years of age have had considerable mortality, and trees of older ages are yellow and sickly, as if they have a nutrient deficiency. The original description was:

Mann, W. F., Grelen, H. E. and Williamson, B. C. 1969. *Seymeria cassiodes*, a parasitic weed on slash pine. *For. Sci. 15(3): 318-319.*

Other organizations such as Brunswick Corporation are studying the extent and losses from *Seymeria*. Obvious severe growth loss as well as mortality result from attacks by this parasite.

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.
Champion International	Alabama Div.--Ala., Tenn. Carolina Div., S. C., N. C., 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.
St. Regis Paper Company	Ala., Miss. and W. Fla.
Tennessee River Pulp and Paper Company	Tenn., Ala., Miss.
Union Camp Corporation	Savannah Div.--Ga., S. C., Ala. Franklin Div.--N. C., Va.
Virginia Division of Forestry	Va.
Westvaco Corporation	South--N. C., S. C. North--Va., West Va., Ohio
Weyerhaeuser Company	N. C. Div.--N. C., Va. Miss.-Ala. Operations--Miss., Ala.



People have different methods of enjoying themselves. This is illustrated by Bob Kellison and Bruce Zobel on a fishing outing with personnel of St. Regis Paper Company.

Membership

Based on action taken at the Advisory Committee Meeting last year, the Hardwood Research Council headquartered at Statesville, N. C. joined the Cooperative Hardwood Research Program on October 1, 1972. Although the Council owns no land on which to do research, they can be effective in initiating and supporting research on the broad scale. They can also be effective in initiating practices for better utilization of the timber available.

St. Regis Paper Company, Jacksonville, Florida, was accepted into the Tree Improvement Program on January 1, 1973. The major area of activity for St. Regis will be Alabama and Mississippi, working on loblolly pine. St. Regis has been a member of the Cooperative Hardwood Program for several years, with one working unit in the Georgia-Florida area and a second unit in the Alabama-Mississippi area. Since there has been very little activity with hardwoods in the Alabama-Mississippi area, the company will, by mutual consent, drop participation of that unit, effective July 1, 1973. The base unit in Georgia-Florida will remain intact, thus giving St. Regis a base working unit in each of the Cooperative Programs.

As a result of their purchase of about 75,000 acres of land in the Piedmont of South Carolina and Georgia, Brunswick Pulp and Paper Company, Brunswick, Georgia, will become a member of the Tree Improvement Cooperative on July 1, 1973. The area of activity will be restricted to genetic improvement of loblolly pine.

Personnel

The low point of the year occurred October 4, 1972 when Mrs. Lanora Goss succumbed to complications resulting from heart disease. Mrs. Goss had been a faithful employee in our laboratory since 1964. She was the lady with the patience of Job who labored over the microscope for hours at a time, determining pollen germinability and tracheid and fiber dimensions. She was also the lady with the amiable disposition, a trait too many of us do not have or have lost. She is missed!

To fill the slot created by the death of Mrs. Goss, Mrs. Edith Jones has been elevated from Research Aide to Research Technician. Due to redefinition of duties, we do not plan to fill the vacant position at this time.

Except for the changes noted above, the remainder of our staff remains intact, as shown:

Mrs. Martha Holland	- Administrative Secretary
Miss Susan Bigbee	- Stenographer
Mrs. Norma Bergeron	- Stenographer
Mrs. Martha Matthias	- Research Technician II
Mrs. Addie Byrd	- Research Technician I
Mrs. Edith Jones	- Research Technician I
Mrs. Alice Hatcher	- Computer Programmer
Mr. Vernon Johnson	- Agricultural Research Technician

The faculty members associated with the Cooperatives also remained intact the past year. Each of us has certain responsibilities, and since we have been together as a team for several years we feel that we are about as efficient as we can possibly be under the circumstances of the wide-ranging programs.

One change in personnel to occur next year is that Bob Kellison will be taking a one year's leave of absence, beginning July 1, 1973, to work with the New Zealand Forest Research Institute, Rotorua, New Zealand. Kellison has been wanting to gain experience in forestry research in another part of the world for some time, and this opportunity looked so good that he could not turn it down. Don Smith, a Ph. D. candidate who has worked closely with the Hardwood Growth and Yield Study and other hardwood and pine projects, will be taking over many of Kellison's duties for the year.

Graduate Students

The graduate training program is proceeding as planned. A "high point" was achieved during the past year in number of students completing their degrees (Table 12). The trend toward an imbalance of foreign and United States students has abated and, thanks to Cooperative support, we were able to award four new assistantships during the past year to replace those lost through graduation.

The 15 to 20 graduate students associated with the Cooperative Programs continue to make a major contribution to both basic and applied research. Stated plainly, the "payoff" has been outstandingly good; use of funds to support graduate research is the best investment that the Cooperative can make. Fields of research covered are very diverse, and the contributions from the greater than 40 Ph. D. and Master's Degrees graduated via the Cooperative are very outstanding, with many former students holding key jobs throughout the world. The efficiency and productivity of the graduate students become greater each year, as the inventory of plant material on which studies can be made increases. We are able to do studies now not dreamed of ten years ago.

Table 12. Graduate students associated with the Cooperative who have recently completed, or nearly completed, their studies. Research project and home of the student are listed.

Name of Student	Home of Student	Research Project
1. James Barker	Florida	Effect of environment on heritability estimates and gain predictions
2. Lert Chuntanaparb	Thailand	Inheritance of wood properties
3. Donald Cole	Georgia	Differences within and between sources of loblolly and slash pine
4. Jim Deines	New York	Production of quality hardwood seedlings
5. Neville Denison	South Africa	Analysis of *Pinus patula* progeny
6. John Drew	Australia	Variation in photorespiration and photosynthesis
7. Ibrahim Sheikh	Malaysia	Variation in wood of *P. caribaea*
8. Jay Kitzmiller	West Virginia	Response of sycamore to fertilizers
9. John Kundt	Virginia	Diallel analysis of Virginia pine
10. Sam Land	Virginia	Sea-water flood tolerance of pine
11. Ralph Lewis	West Virginia	Biochemical indicators for fusiform rust resistance
12. Alan Long	California	Variation and response of loblolly pine to mycorrhizae
13. Dick Porterfield (Degree at Yale)	Ohio	Economics of tree improvement
14. Don Rockwood	Illinois	Monoterpenes in loblolly pine
15. Vichien Sumantakul	Thailand	Genetic variation in sycamore
16. Steve Webster	Oregon	Nutrition in seed orchards
17. Michael Wilcox	New Zealand	Brightness in loblolly pine

Publications

We have prepared a list of publications related to the Cooperative complete to March, 1973, available upon request. The list has become rather formidable; the supply of reprints of many publications has been exhausted.

Following is a list of publications of interest to members of the Cooperative during the past year or articles that have been submitted for publication and will be out soon:

Adams, T., Roberds, J. and Zobel, B. 1972. Intergeneric interactions among seedling families of loblolly pine (*Pinus taeda* L.). Theoretical and Applied Genetics. 15 pp.

Barker, J. A. 1972. Location effects on heritability estimates and gain predictions for ten-year-old loblolly pine. Ph. D. Thesis. N. C. State Univ., Raleigh. 107 pp.

Blair, R. L. and Cowling, E. B. 1972. Influence of site, vertical position, age, and fertilization on the susceptibility of loblolly pine to fusiform rust. N. C. State Univ., Agri. Expt. Sta., Raleigh. 16 pp.

Chuntanaparb, L. 1973. Inheritance of wood and growth characteristics and their relationships in loblolly pine (*Pinus taeda* L.). Ph. D. Thesis. N. C. State Univ., Raleigh. 119 pp.

Cole, D. E. 1972. Differences between species and within populations of slash and loblolly pine; a seed source study. Ph. D. Thesis. N. C. State Univ., Raleigh. 155 pp.

Dorman, K. W. and Zobel, B. J. 1973. Genetics of loblolly pine. For. Ser. Res. Paper, U.S.D.A. (In press--mimeo 69 pp)

Drew, T. J. 1973. Magnitude and variation of photorespiration and oxygen inhibition of photosynthesis in seedlings of select loblolly pine (*Pinus taeda* L.). Ph. D. Thesis. N. C. State Univ., Raleigh. 62 pp.

Duffield, J. W. 1972. Biological and technical problems in American seed orchard development. Repr., For. Tree Impr. (4), Symp. in honor of C. Syrach-Larsen. Hørsholm., Oct., 1968. 39 pp.

Ibrahim, S. 1972. Variation of wood properties of *Pinus caribaea* var. *hondurensis* grown in West Malaysia. M. S. Thesis, N. C. State Univ., Raleigh. 73 pp.

Kasile, J. D. 1971. Optimization of cluster sampling through empirical investigation of computer simulated forests. Ph. D. Thesis, N. C. State Univ., Dept. of Exper. Stat., Raleigh. 316 pp.

Kellison, R. C. 1972. Cone and seed collections from seed orchards. Nurserymen's Conf., Wilmington, N. C. June. 6 pp.

Kellison, R. C. and Zobel, B. 1972. Genetics of Virginia pine. (In press--Mimeo report 17 pp)

Kirk, D. G., Breeman, L. G. and Zobel, B. J. 1972. A pulping evaluation of juvenile loblolly pine. TAPPI For. Biol. Meet., Appleton, Wis. May 2-3. Tappi 55(11):1600-1604.

Kuhlman, E. G. 1972. Susceptibility of loblolly and slash pine progeny to Fomes annosus. USDA For. Ser. Res. Note SE-176. 7 pp.

Land, S. B., Jr. 1972. Sea-water flood tolerance of some southern pines. Ph. D. Thesis. N. C. State Univ., Raleigh. 169 pp.

Lee, C. 1972. Natural variation in wood of American sycamore (Platanus occidentalis L.). Ph. D. Thesis. N. C. State Univ., Raleigh. 91 pp.

Lewis, R. A. 1973. An investigation of possible biochemical indicators for resistance to fusiform rust in loblolly pine. Ph. D. Thesis. N. C. State Univ., Raleigh. 74 pp.

Long, A. 1973. Genotypic variation and response to mycorrhizal formation on loblolly pine seedlings. Ph. D. Thesis. N. C. State Univ., Raleigh.

Maki, T. E. 1972. Clearcutting and soil depletion. Talk given at the APA 1972 Ann. Meet., Atlanta, Ga., Mar. 28, 1972. 16 pp.

Maki, T. E. 1972. Dependence of forest and wood production on fertilizers. Comm. I of the Seventh World Forestry Congress, Buenos Aires, Argentina. Oct. 6. 11 pp.

Miller, W. D. and Zobel, B. 1972. Abstracts of Japanese literature in forest genetics and related fields. Authored by Ryookiti Toda, Govt. For. Expt. Sta., Vol. 1, Part A, 236 pp. For. Sci. 18(2):150.

Saylor, L. C. and Zobel, B. J. 1972. Interspecific hybridization involving sand pines--past attempts and future potential. Paper No. 3911, Jour. Series, N. C. State Univ. Agri. Expt. Sta., Raleigh. 15 pp.

Smith, D. 1973. Decision-making under uncertainty: should hardwood plantations be established? Tech. Rept. No. 49, School of Forest Resources, N. C. State Univ., Raleigh. (In press--approx. 65 pp.)

Smouse, P. E. 1972. The canonical analysis of multiple species hybridization. Biometrics 28:361-371.

Stonecypher, R. W., Zobel, B. J. and Blair, R. L. 1972. Inheritance patterns of loblolly pine from an unselected natural population. Tech. Bull., N. C. State Univ. Agri. Expt. Sta., Raleigh. (In press)

Webster, S. R. 1972. Nutrition of seed orchard pine in Virginia. Ph. D. Thesis. N. C. State Univ., Raleigh. 173 pp.

Weir, R. J. and Zobel, B. J. 1972. Outstanding general combiners and their influence on breeding programs. IUFRO Progeny Testing Working Group, Macon, Ga. 17 pp.

Wilcox, M. D. 1973. Brightness in loblolly pine. Ph. D. Thesis, N. C. State Univ., Raleigh. 114 pp.

Woessner, R. A. 1972. Crossing among loblolly pines indigenous to different areas as a means of genetic improvement. Sil. Gen. 21(1-2):35-39.

Zobel, B. J. and Kellison, R. C., Matthias, M. and Hatcher, A. 1972. Wood density of southern pines. Tech. Bull. No. 208, N. C. State Univ. Agri. Expt. Sta., Raleigh. 56 pp.

Zobel, B. J. and Kellison, R. C. 1972. Short-rotation forestry in the Southeast. Tappi 55(8):1205-1208. August.

Zobel, B. J., Weir, R. J. and Jett, J. B. 1972. Breeding methods to produce progeny for advanced-generation selection and to evaluate parent trees. TAPPI For. Biol. Comm., Appleton, Wis., May. Canadian Journal of Forest Research 2(3):339-345.

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

Zobel, B. J. 1972. Genetic implications of even-aged forest management. Presented at the Second North American Forest Biol. Workshop, Corvallis, Ore. August. 6 pp.

Zobel, B. J. 1972. The three-ring-per-inch dense southern pine--can it be developed? Jour For. 70(6):333-336.

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

Zobel, B. 1972. Genetic implications of monoculture in forest management. Oregon State For. Biol. Meet., Second North American For. Biol. Workshop. 10 pp.

Zobel, B. 1972. The search for super trees. Talk given at American For. Assn. Meet., October 23, New Orleans, La. (In press)

Zobel, B. and Kellison, R. C. 1972. Forest tree improvement--promises and problems. Talk given at 1972 SAF Nat'l. Conv., Hot Springs, Ark. October. 5 pp.