TWENTY-SECOND ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

June, 1978

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INTRODUCTION

It is difficult to summarize trends for the recent year because activities have been so mixed. Markets for certain paper products softened substantially but stumpage prices for top-quality pine logs have been at an all-time high. Particularly disconcerting are the rather gloomy predictions for the paper industry made by Wall Street. Yet the importance of forest land productivity, timber inventories, and investments in intensive forest management are being recognized as never before by top-level corporate managers. The continued increase in the cost of energy has been troublesome, and the industry has begun to seriously consider the opportunities of "Energy Plantations." Once again snow, ice, and wet winter weather have seriously hampered efforts to supply wood to the mills.

Seed orchards and progeny tests have been affected by two of the coldest winters on record and one of the hottest, driest summers ever. These two factors have caused both test and operational plantations to fail or to have only marginal survival. Yet despite these environmental extremes, the Cooperative harvested the largest cone and seed crop ever. "Pay-off" day is in fact here! The Cooperative harvested 32.8 tons of pine seed during the fall of 1977. Enough seed was harvested to more than plant the annual needs of the Cooperative members (440,000 acres or 334,000,000 seedlings). Some companies have an excess of seed in storage while others with young orchards have not yet produced their needs.

Through this period of mixed activity, support for the Cooperative Tree Improvement Program has continued to be excellent. Tree improvement is firmly accepted as a proven way to increase land productivity, and the effect on intensive forest management investments is clear. Activity in the advanced-generation improvement program has intensified. Second-generation orchards are developing at a rapid pace and many are nearing the goal of locating 100 new plantation selections. We will begin breeding and testing second-generation selections in a year. Final breeding plans are being formalized by the Cooperative staff as this report is being written.

During the past year, the Cooperative ranks have grown. We are happy to welcome Scott Paper Company to membership, effective January 1, 1978. Scott has made a major shift to loblolly planting for their Alabama and Mississippi lands. We anticipate a long and mutually beneficial association with Scott.

The Cooperative has always had a most active student training program and has carried on many special studies to enhance our overall understanding of forest tree improvement. These efforts continue at an almost hectic pace and have been highlighted in two special sections of this annual report. We thought the magnitude of effort and the substantial contribution to the Cooperative from these special activities would be of interest to the membership.

In summary, it has been a year of ups and downs. However, with good support, record cone harvests, active student programs, and expanding efforts on special research projects, we have on balance enjoyed a most productive year.

CONE AND SEED PRODUCTION

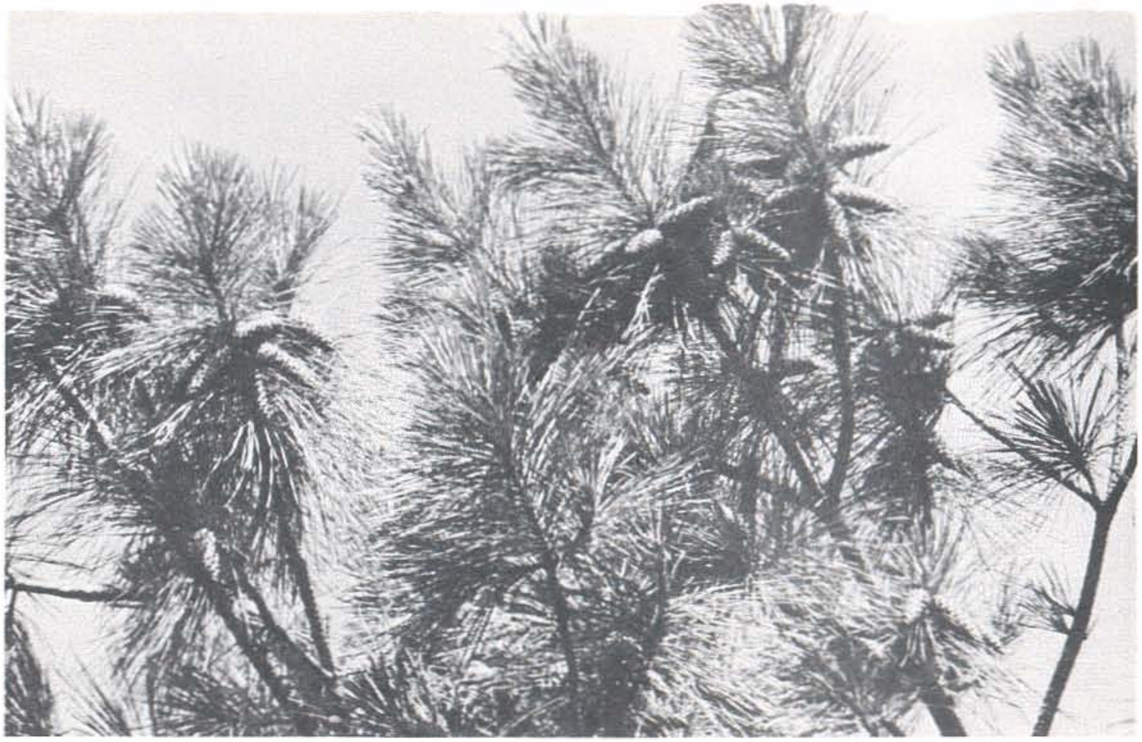
Yields

The Cooperative is an applied tree improvement program with the major goal being the production of genetically improved seed for operational planting. In 1977 the "payoff" year arrived! The overall cone crop harvested during the past year was the largest ever encountered by members of the Cooperative. In years such as 1972, 1974, and to some extent 1976, the heavy flower crop was seriously damaged by late spring freezes which resulted in smaller cone crops because newly emerging flowers were killed. However, all went just right for the 1977 crop. Note the size of crop and yields compared to earlier years in Table 1, where Cooperative production data are shown for the last nine years.

Table 1. Cone and seed yields within the Cooperative over the past eight years

	Loblolly		Slash	
Year	Bushels of Cones	Lbs. Seed/ Bushel	Bushels of Cones	Lbs. Seed/ Bushel
1969	1769	1.10	317	0.42
1970	5146	1.36	1744	0.88
1971 1/	6478	1.14	3795	0.80
1972	6807	0.98	1684	0.60
1973 1/	11853	1.09	2779	0.58
1974	8816	0 99	4088	0.74
1975	16348	1.31	5516	0.93
1976	14656	1.21	5233	0.79
1977	32152	1.54	12880	1.17

1/ Loblolly flower crops were severely damaged by freezing weather in 1971 and 1973.



The "payoff," production of improved seed, is shown by the heavy cone crop (top) in Weyerhaeuser's North Carolina orchard. The 1977 cone and seed crop was the largest ever for the Cooperative.
We expect another very good year in 1978 when the current conelet crop (bottom) matures.

Last year Bruce Zobel wrote that "predictions are risky but at least a 50% increase in seed production is expected for the 1977 crop." Once again Bruce's prediction has proven to be conservative. The increases are due to three factors, (1) ideal weather conditions, (2) vastly improved insect control, thanks to the availability of Furadan, and (3) better seed extraction procedures by most organizations.

In Table 2 a comparison of the relatively good cone production year (1975) and the best of all (1977) is shown. The differences are overwhelming.

Table 2. Comparison of the cone and seed yields for the good year 1975 and the best year ever, 1977 1/

	Bushels of Cones		Pounds of Seed		Pounds of Seed/ Bushel of Cones	
	1975	1977	1975	1977	1975	1977
Loblolly Pine-- Coastal Source	9284	22769	12384	36692	1.33	1.61
Loblolly Pine-- Piedmont and Mountain Source	7064	9383	9032	12947	1.28	1.38
Slash Pine	5516	12880	5146	15024	0.93	1.17
Virginia Pine	324	321	314	292	0.97	0.91
Shortleaf Pine	86	22	58	14	0.67	0.64
White Pine	72	60	26	9	0.36	0.15
Pond Pine	23	18	21	11	0.92	0.61
Longleaf Pine	0	588	0	622	0	1.06
Total	22369	46041	26981	65611		

1/ There should be an automatic increase in cones each year because of the new seed orchard acreage coming into production.

The good news is that the 1977 flower crop was excellent and we expect the 1978 cone crop to be on a par with it. The 1977 cone and seed crop was theoretically large enough to more than meet the Cooperatives' entire planting program needs. However, the uneven distribution of seed production prevents this from being reality. Some organizations produced much more seed than needed and were able to put into storage a 3- to 5-year inventory as insurance against those lean years which will inevitably come. Only those organizations with young orchards or those few with orchards on the northern extreme of the range which were again hurt by freezes do not have enough genetically improved seed for their regeneration programs.

So much slash pine seed was harvested in 1977 that there is virtually a "glut on the market." The few sales of improved slash seed that have taken place were at prices well below the true value of the seed because of the oversupply. Improved loblolly seed is still in relatively short supply and very few sales have taken place or are anticipated in the near future. Several organizations with ample seed inventory are planning to group their clones into classes based on genetic quality. They will pick and extract seed separately according to groups of good, average and relatively poor parents. The intent is to plant just the seed from the best clones and lower quality seed will be stored or sold. This is an excellent way to capture the greatest possible genetic improvement.

One negative note on this year's bumper crop relates to the extremely hot and dry summer of 1977. As this is being written it is too early to determine germination rates but they are expected to be somewhat lower as a direct result of heat. Germination data for the few organizations which have reported tend to confirm this suspicion.

Harvesting

Although the huge cone crops are indeed a welcome realization, they present incredible challenges to those persons charged with the task of cone harvest. It is particularly difficult to harvest large crops of loblolly pine where cones must be individually picked. A serious problem has developed resulting from a shortage of aerial lift equipment needed to harvest the cone crops. Some orders for rental equipment could not be filled, resulting in a very serious and most exasperating situation, especially for those who placed orders to lease lift equipment as early as January, 1977. One organization in North Carolina rented lift trucks from as far away as Florida, Chicago, and one even from Germany. Those organizations with older orchards now approaching 75 feet in height found the bigger lift trucks were nearly impossible to lease.

Work continues on the "debugging" of the vacuum harvester, primarily by Union Camp and the U. S. Forest Service. The machine will pick up the seed but the large volume of debris continues to be a problem. Plans are to modify the machine to only pick up the seed and associated debris--separation of the seed and debris will be a distinct operation outside the confines of the vacuum machine. Some cooperators are testing the ground-cloth system employed by the Georgia Forestry Commission.

It becomes increasingly important to accurately predict the size of the harvest so that equipment and manpower can be planned well in advance. Tom Dierauf and Ron Wasser of the Virginia Division of Forestry have examined the reliability of several sampling schemes in predicting cone crops. Three methods of sampling during the summer were tried:

1. Cone counts on the top 4 whorls of branches from a bucket truck.

Harvesting large cone crops is a monumental task. The shortage of rental lift trucks such as the one shown above in Catawba's orchard is a serious concern. Alternative harvesting systems are being considered that do not require hand-picking of each cone.

2. Cone counts on the top 8 whorls of branches from a bucket truck.

3. Binocular counts on the south side of the tree from a distance of one chain.

The average time required per tree for the three methods was 4, 12 and 2 minutes, respectively. After relating these counts to total-tree counts by linear regression analysis it was found that the binocular counts were not only quickest but also the most reliable method for predicting the total cone crop. The procedure was surprisingly good for prediction purposes. An example for Virginia's Piedmont block 2 is shown in Figure 1. Different prediction equations may be needed for large trees and small trees, also for small cone crops and large cone crops. Dierauf and Wasser's system has considerable promise; all that may be required are modifications as mentioned above.

Cone Storage and Extraction

Extremely large cone crops put pressures on extraction facilities. Several organizations produced cone crops far in excess of their extractory capacity. Cone storage then becomes more critical. Several methods of cone storage are being used; one commonly suggested is the large bulk crates or boxes. Recently St. Regis compared the bulk storage method with the standard burlap sack system. Homer Gresham collected two bushels of slash cones from each of several ramets of numerous clones. One bushel from each ramet was placed in a burlap bag and the other placed in a 20-bushel cone box. Eighty bushels of cones were collected and stored by each method. The resulting and quite dramatic differences in seed yields from the two methods after storage to the first week of December are shown in Table 3. Cones stored in sacks had 30% greater seed yield and the required opening time was reduced by 40%.

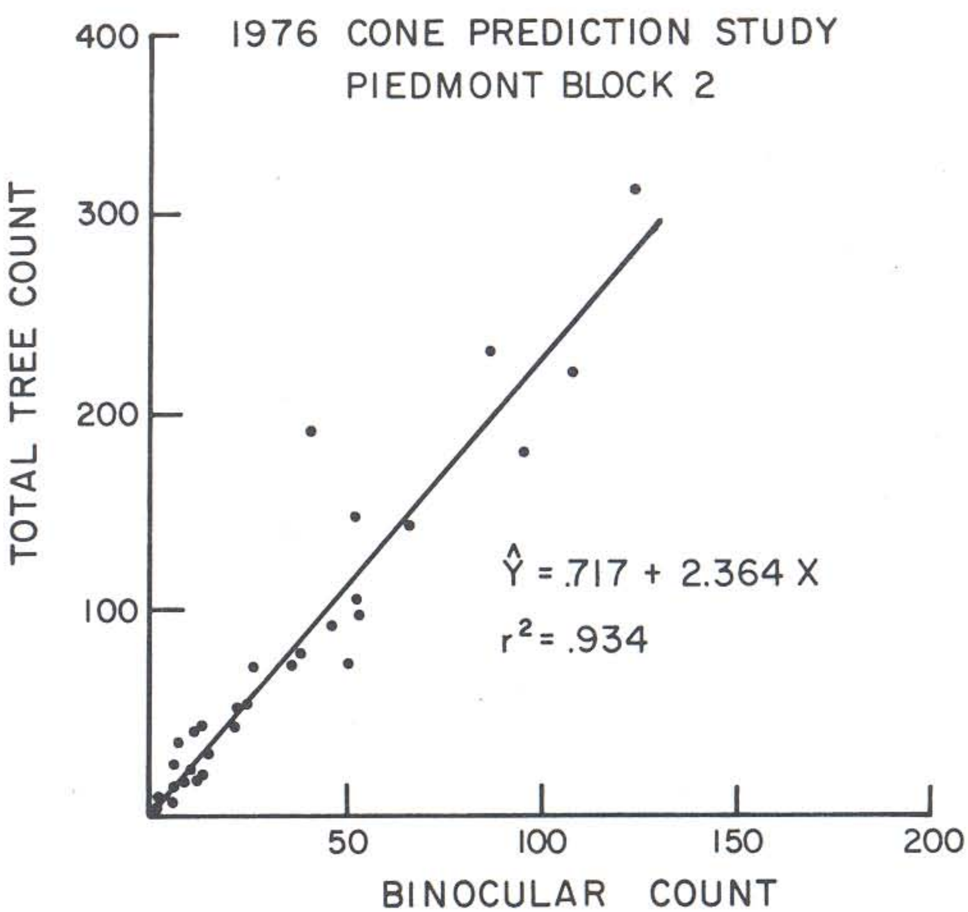


Figure 1. Results of a cone crop prediction study conducted by the Virginia Division of Forestry. Binocular counts were made during the summer prior to harvest, with relative ease and speed.

Table 3. Comparison of yields from cones stored in bulk and burlap containers by St. Regis

Number of Bushels	Type of Container	Time To Open 1/	Lbs. of Seed per Bushel
80	20 bu./crate	13-1/2 hrs.	1.04
80	1 bu./bag	8 hrs.	1.35

1/ Extraction was done in their new seed plant.

Homer reported that 5% of the cones in crates were case-hardened while virtually no case-hardening was observed among cones stored in sacks.

Processing the cones through the drying kilns and tumblers a second or third time sometimes provides meaningful increases in seed yield. The seed from follow-up runs is sometimes of lower quality, with lower germination percentages, but the increased overall yield of up to 15% can be of great value. Significant quantities of high-value seed can be lost if care is not taken in the cone storage and seed extraction.

Cone Analysis

Cone analysis as a tool to evaluate seed orchard management and efficiency of seed production is gaining wide acceptance with orchard managers. Not only does the technique provide a means of evaluating productivity but it also allows the determination and quantification of seed losses during the various stages of seed development. A complete look at the data available through cone analysis cannot be presented here, but condensed results obtained by the North Carolina Forest Service are indicative of the information provided (Table 4).

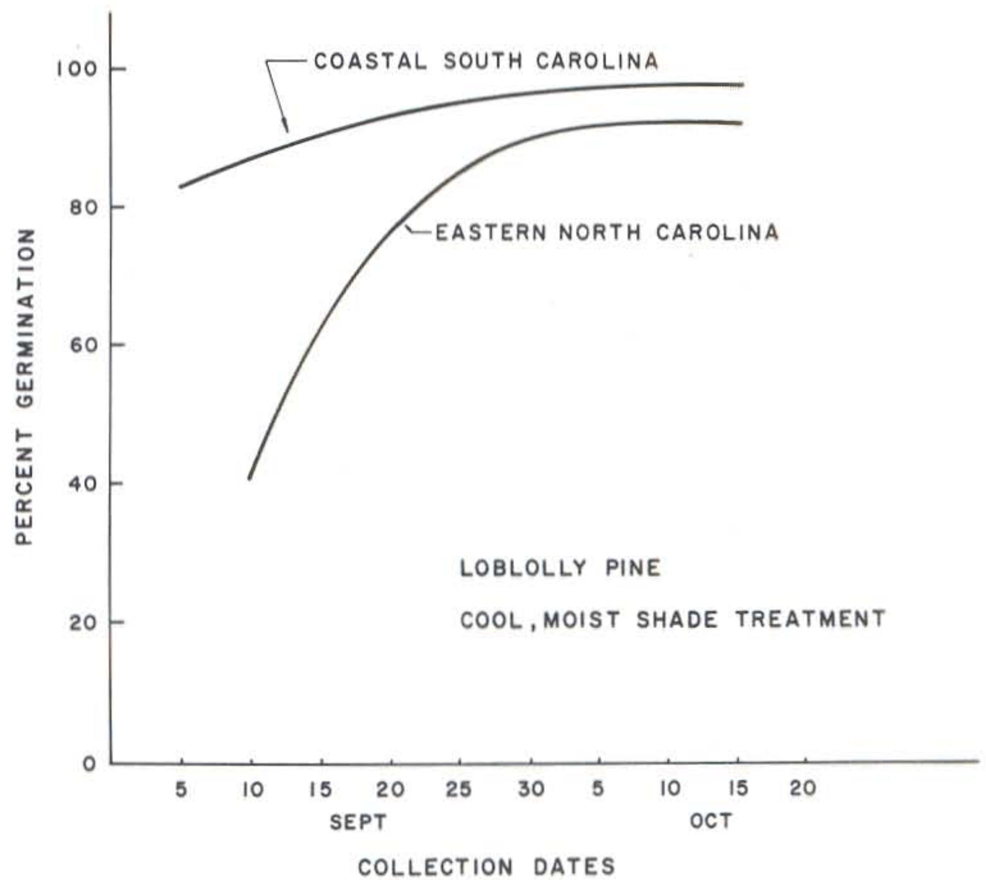
Table 4. Two years of cone analysis service* results for three clones in the Piedmont loblolly pine seed orchard of the North Carolina Forest Service

	------------Percent of Production Potential---------------							
	First-Year Ovule Abortion		Second-Year Ovule Abortion		Insect-Damaged Seed		Seed Production Efficiency	
Clone	1975	1976	1975	1976	1975	1976	1975	1976
16-20	44	10	4	0	2	0	36	75
16-164	49	14	2	1	2	0	42	78
16-58	52	13	4	0	0	0	31	75
Weighted Mean	49	12	3	0.4	1.1	0	36	76

*Available from the Eastern Tree Seed Laboratory, Macon, Georgia

Grady Harris attributes the improvement from 1975 to 1976 to a combination of improved insect control from Furadan as well as weather conditions more conducive to complete pollination. The doubling of seed production efficiency is particularly striking and the 1976 results represent a rather high level of efficiency rarely achieved. The entire collection from the N. C. Forest Service Piedmont orchard had seed yields of 2.04 lbs./bu. of cones in fall, 1976, for a collection in excess of 200 bushels. Such yields were not even dreamed of a few years ago. The year-to-year variations that have been observed in cone analysis results graphically point out the importance of maintaining accurate weather and management records for each orchard. Only with complete information can an orchard manager evaluate management strategies and maintain high production. Ideally, cone analysis data should be obtained for each clone in an orchard over a period of time. This is particularly important for clones in the improved first-generation orchards, commonly known as 1.5-generation orchards.

STRATIFIED SEED GERMINATION BY COLLECTION DATE



The cone harvest season can be lengthened if cones are picked early and stored moist in a cool, shaded area. However, care must be taken not to reduce the germination of extracted seed by picking too early. Results of a study done by the Cooperative in 1968-69 are shown above.

Although the cone analysis service is available at cost through the Eastern Tree Seed Laboratory at Macon, Georgia, it is entirely feasible for the work to be done by personnel at each orchard. Detailed instructions have been published in a booklet entitled "Cone Analysis of Southern Pines—A Guidebook," available from the Seed Laboratory.

Orchard Roguing

Most first-generation orchards in the Cooperative have been rogued at least once and many have experienced or are approaching their second or third roguing. Since information on the genetic quality of clones in young orchards is generally unavailable, the first roguing is designed to remove diseased, incompatible and poor-producing trees and also to open the good trees up to full sunlight. During the early roguing a concentrated effort is made to correct spacing problems resulting from violation of the "90' Rule" necessary to reduce inbreeding. Little effort is made in the initial marking to change the clonal distribution in the orchard. In subsequent roguings, the primary goal becomes the modification of the clonal disbribution to maximize the genetic quality of the orchard.

Procedures whereby the orchard is marked in narrow bands of three rows at a time reduced the likelihood that the desired goals would be achieved. The effect of removal of a given graft could only be judged in relation to other trees generally within the boundaries of the orchard segment under consideration on any one pass. It is impossible to determine the effect of any given decision on the entire orchard. While substantial upgrading occurred, maximizing the genetic quality in each segmented section did not always result in maximum upgrading for the entire orchard.

In an effort to eliminate the problems associated with segmented markings, a study was initiated to determine the feasibility of computer assistance in roguing. During several orchard markings, detailed information was recorded to determine the inputs required by a computer program designed to rogue an orchard. Once these basic requirements were established, several additional orchards were "rogued" on paper, utilizing the system of the intended orchard marking program.

The Piedmont loblolly orchard of Continental Forest Industries was marked using this method. As shown in Table 5, the effect of the marking on the clonal distribution in the orchard was good. Prior to orchard marking, clones rated as good (based on progeny information and cone production) accounted for only 46% of the ramets in the orchards. Following marking, 63% of the ramets in the orchard were rated as good. The three clones rated as poor were virtually eliminated from the orchard. Since clone 5-41 is a tester, enough ramets were retained to complete the necessary control-pollinations. In addition to tremendously upgrading the quality of the orchard, the marking successfully accomplished the elimination of essentially all spacing problems and achieved the required crown release. The paper marking was found to be very adaptable for field use and a considerable reduction in field marking time was realized. Cooperators were pleased with the speed and accuracy of marking with the computer assistance. The information required to rogue an orchard in this manner is available without additional data collection. The following are required:

1. An up-to-date map of the seed orchard.
2. The evaluation of the genetic quality of the clones from the progeny test program.
3. A cone production rating for each clone.
4. An estimate of the minimum requirement for crown release.

The "computer markings" are not intended as a replacement for the on-the-ground marking, but it is intended as an aid to the persons doing the marking, so maximum improvement and proper spacing can be quickly and accurately achieved. The final computer program development is underway and hopefully will be complete for use on a broad scale in 1978.

Table 5. Results of computer-assisted marking of Continental Can's Piedmont loblolly orchard

Clone	Overall Rating	% of Orchard Before Roguing	% of Orchard After Roguing	% of Ramets Removed
5-5	Good+	7.1	9.8	31.3
1-64	Good+	5.4	7.7	28.0
5-33	Good+	4.5	6.2	31.7
1-531	Good	3.1	4.9	20.9
5-21	Good	5.8	7.0	38.8
10-28	Good	5.2	7.9	23.6
15-1	Good	4.8	7.5	22.4
1-523	Good-	5.6	6.7	39.7
1-14	Good-	5.0	4.9	50.1
1-11	Avg+	5.8	6.6	42.5
1-516	Avg+	5.9	7.6	35.4
5-19	Avg+	5.8	5.3	54.3
3-21	Avg	4.6	3.9	57.8
5-63	Avg	1.7	1.0	70.8
5-52	Avg	5.8	4.2	63.8
5-61	Avg	6.0	6.5	45.8
5-47	Avg	3.8	2.0	73.1
7-77	Poor+	5.8	0.0	100.0
5-41	Poor	4.7	0.04	95.4
5-15	Poor-	3.5	0.0	100.0

Large cone crops are possible with good orchard management practices such as irrigation. Shown is the irrigation pond for Catawba's new, permanent irrigation system. The pond is filled from four deep wells.

PROGENY TESTING

Progress to Date

The progeny test program began in 1964 with six plantings. After 15 years, the Cooperative has 933 progeny tests established on over 3400 acres (Table 6). Test plantings have been completely finished for thirteen orchards, and seed are available to complete progeny test establishment for another seven orchards. These progeny tests provide the information to determine the genetic worth of clones and to provide a new base population from which selections can be obtained for an advanced-generation breeding. An evaluation of clonal genetic worth enables upgrading of the genetic quality of the orchards through roguing and provides information about the best parents for 1.5-generation and specialty orchards. The data base from which evaluations are made is growing annually as more tests reach measurement age. As of May, 1978, age 4 data are available on approximately 70% of the tests established, with both age 4 and age 8 data available on over 30% of the tests. Measurement status for the Coastal and Piedmont loblolly tests is shown in Table 7. We are currently receiving measurements on approximately 200 tests each year and anticipate that this will increase to over 300 in the next couple of years.

Although not reflected in the tables, a number of tests have been thinned and have been assessed a third time. When considering progeny test thinnings, some concern was expressed that differences between families and checks might be reduced as a result of thinning. As illustrated in Table 8, this has not been the case. The average volume per tree for every family has increased substantially, but the difference between the best and poorest family has changed by only .1 cu.ft. and the thinning has caused only minor and insignificant changes in family ranks (Table 8). Some change would be expected since the more variable families are upgraded more from thinning than families having relatively uniform trees, but the best families before thinning have remained the best after thinning.

Table 6. Acreages planted and number of progeny tests by species or type test in the N. C. State Cooperative as of May 1, 1978

Species or Type Test	Acreage	Number of Tests
Coastal Loblolly	1225	356
Piedmont Loblolly	814	247
Slash Pine	485	91
Virginia Pine	214	65
Shortleaf Pine	33	9
Pond Pine	34	12
Other (Mountain, Longleaf, Hybrids, etc.)	124	45
Good General Combiner	360	80
Disease Diallel	113	28
Total	3402	933

Table 7. Measurement status of Coastal and Piedmont loblolly tests as of May 1, 1978

	Number of Tests	
	Piedmont	Coastal
Not measured to date	77	102
Fourth-year measurements only	101	143
Eight-year measurements completed	69	111
Total	247	356

For most tests, measurement at the time of thinning will be the final assessment. However, to verify the validity of selection at near half-rotation a few tests will be maintained and measured on a regular basis through the entire rotation. Probably no more than 50 tests will be assessed in this detailed manner in the whole Cooperative.

Table 8. Results from thinning Union Camp's 1966 Lower Coastal loblolly main test

Family	Average Cu.Ft. Volume Per Tree (Family Rank)		
	Before Thinning	After Thinning	Cut Trees
10-8 x 10-5	3.85 (1)	4.23 (2)	3.19 (2)
10-2 x 10-25	3.78 (2)	4.15 (4)	2.94 (9)
10-14 x 10-8	3.73 (3)	3.94 (7)	3.38 (1)
10-13 x 10-39	3.71 (4)	4.30 (1)	2.92 (10) 1/
10-18 x 10-39	3.71 (4)	4.17 (3)	2.99 (7)
10-14 x 10-25	3.62 (5)	3.99 (5)	3.07 (4)
10-12 x 10-8	3.60 (6)	3.94 (6)	3.02 (5)
10-14 x 10-39	3.52 (7)	3.73 (13)	3.16 (3)
10-5 x 10-25	3.51 (8)	3.91 (8)	2.92 (10) 1/
10-13 x 10-8	3.46 (9)	3.78 (12)	3.00 (6)
CC	3.44 (10)	3.87 (9)	2.55 (15)
10-18 x 10-8	3.40 (11)	3.68 (14)	2.71 (13)
10-16 x 10-37	3.32 (12)	3.51 (16)	2.95 (8)
10-18 x 10-25	3.29 (13)	3.80 (11)	2.51 (16)
10-16 x 10-8	3.28 (14)	3.61 (15)	2.84 (11)
10-8 x 10-39	3.27 (15)	3.82 (10)	1.97 (18)
10-14 x 10-37	3.26 (16)	3.61 (15)	2.83 (12)
10-39 x 10-6	3.09 (17)	3.29 (20)	2.55 (15)
10-6 x 10-37	3.05 (18)	3.33 (18)	2.64 (14)
10-16 x 10-25	3.04 (19)	3.46 (17)	2.38 (17)
10-5 x 10-8	3.01 (20)	3.32 (19)	1.86 (19)
SPA	2.22 (21)	2.58 (21)	1.47 (20)
Test Average	3.39	3.73	2.78

1/ Same average volume per tree; therefore the same rank is assigned.

Progeny test results are often dramatic. Measurements are not needed to see that the growth rate of rows flanking Billy Arnold are different. Parents of the poor family on the right will be removed from the orchard.

Time Means $ $ $

How quickly can the control-crossing and progeny testing of a seed orchard be completed? This question can now be answered after observing more than 20 member organizations conducting control-pollinations over the past 15 years. The speed and efficiency of progeny testing depends on several environmental factors such as weather and insects but also depends on the quality of care exercised in pollen collection and storage and in making control-pollinations. Some organizations have put little emphasis on this phase of the program, and therefore 12 years after establishment of their first progeny test they still have not completed them. Others have done much better; three organizations planted their first tests in 1971 and will complete their testing in 1979. Their efforts have been consistent year after year. An outstanding example of speed and efficiency has been the efforts of the Weyerhaeuser Alabama-Mississippi program; control-pollinations in Weyerhaeuser's Upper Coastal orchard were started in 1972-73, even though flower production was very limited in the young orchard. Once the orchard started producing heavily, the bulk of the crossing was done in three years. Provided that the 1979 test survives well, they will have completed progeny for one orchard in essentially three years, a record that will be hard to break. This was accomplished by planting two large main tests in 1977 and then one large test in 1978 and one planned for 1979.

We have experienced the extremes, from 12-plus years to 3 years for testing. In tree breeding, time means money. The sooner progeny testing is completed, the sooner the gains from rogued first-generation seed orchards and advanced-generation orchards will be obtained.

Our experience over many years indicates the following factors are important to efficient and speedy progeny testing:

1. Support from upper management so that manpower with suitable training is not a limiting factor.
2. Taking advantage of bumper crops by making more pollinations than called for.
3. Making an all-out effort on control-pollinations every spring.
4. Using proper collection, extraction and storage of pollen and proper pollination techniques.
5. Controlling insects to protect flowers and developing cones.
6. Having properly prepared land available when the progeny seedlings are ready for planting.
7. Care of tests to prevent loss from fire or other things.

Longleaf Pine

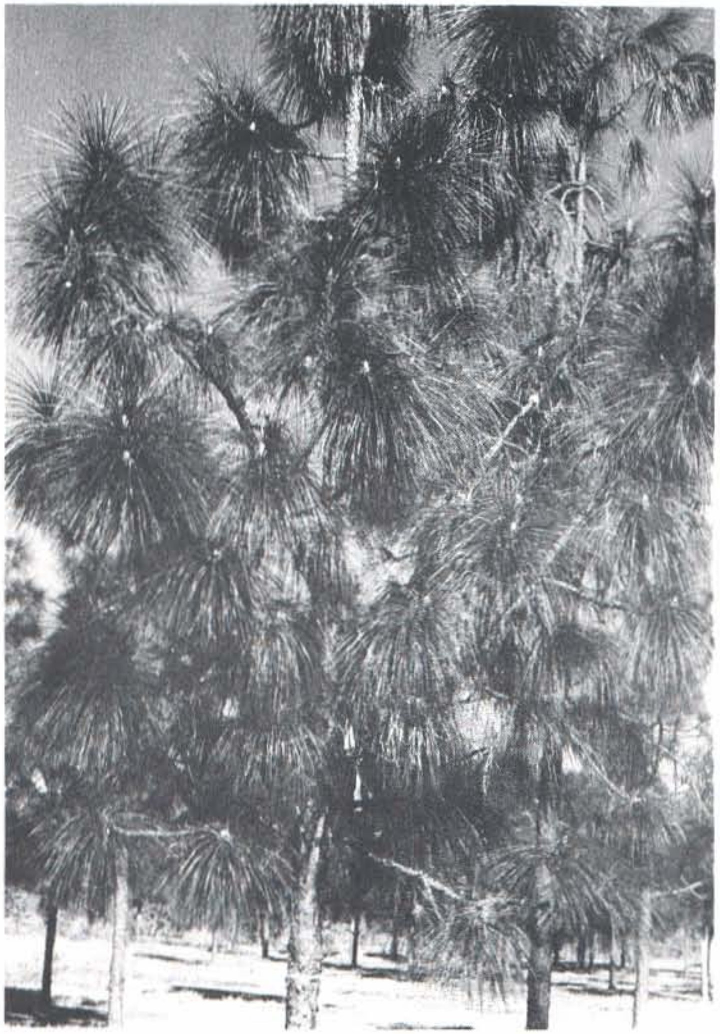
A renewed interest in longleaf pine for regenerating droughty high rust hazard sites is becoming evident. Recently the North Carolina Forest Service assessed two plantings of longleaf pine after two growing seasons in the field to determine the percentage of trees that had passed the grass stage. The results of this special assessment are reported in Table 9.

Table 9. Percentage of longleaf pines having initiated height growth after two growing seasons in the field

Family	Height Growth Begun--Percent Main Test Good Site	 Supplemental Test Sandy Site
16-118	84	-
16-119	70	-
16-131	52	-
16-134	-	14
16-135	70	-
16-144	68	14
16-146	62	-
16-146P	45	8
16-156	36	4
16-157	52	0
16-158	69	-
16-161	-	8
16-200	19	-
16-216	50	7
16-218	60	-
16-219	68	8
16-224	74	21
CC-1	42	-
CC-2	42	4
Progeny Average	60	9
Check Average	42	4

Dash (-) indicates not planted in the test.

It is clear that the difference between the good site and the relatively poor sterile sandy site had a major effect on how fast the grass stage was overcome. Marked family differences occur for this characteristic; a clone such as 16-200 produces progeny that are extremely slow to initiate height growth. However, the key to quickly overcoming the grass stage is nursery culture. Longleaf seedlings must be grown at a very low nursery bed density (8 to 10 per square foot) if a vigorous, healthy seedling having large root-collar diameter is to be produced. Family differences in seed size are suspected to influence germination speed and vigor in the nursery. If this effect is pronounced, it may subsequently influence the



Programs to improve "minor" species are particularly active with the three state members. Such are in addition to the major effort in loblolly improvement. The Fraser fir (left) is in North Carolina's seedling seed orchard and is producing seed for Christmas trees. The longleaf orchard (right) also belongs to the North Carolina Forest Service and is beginning to produce heavily.

speed with which the grass stage is overcome. Certainly in the Deep South where brown spot disease is a concern, family differences in resistance will be associated with the ability to quickly initiate height growth.

General Combiner Tests

Approximately 80 good general combiner tests, composed of the best clones in the Cooperative, have been established in the United States and an additional 10 locations planted overseas. Many of the tests are in their fourth year in the field; in 1978-79 extensive 4-year data will be obtained. These tests were designed to (1) indicate which of the best clones could be moved outside their natural range and still have superior performance, (2) determine genotype-x-environmental interaction, (3) obtain a better handle on the relationship of pine genotype and source of rust, (4) locate clones that will be particularly suitable for planting overseas.

John Talbert has elected to do a detailed study of the 1975 good general combiner plantings for his Ph. D. research. Most published interaction studies of loblolly pine covering large geographic regions have utilized data from provenance tests of unimproved stock. It is hypothesized that genetically superior seed could be moved farther than unimproved stock because of improved adaptability resulting from selection and breeding. John's research will concentrate on (1) assessing the extent of genotype-environment interaction, including the identification of those families contributing most to any observed interaction, (2) identifying environmental factors associated with any observed interaction, and (3) determining if certain good general combiner families can be moved farther from their place of origin than provenance test results have previously indicated. If the answer to the last question is yes, it will have the effect of broadening our genetic base and lowering our program costs since more parent trees will be usable in any given area.

The overseas good general combiner plantings were established both in areas where P. taeda grows well and in marginal areas. During a recent visit to Mogi Guaçu, State of São Paulo, Brazil, Bruce Zobel obtained measurements from a planting made by Champion Celulosa. The area is marginal for southern pines; they often grow rapidly but have very poor form. The study for which data were obtained had grown reasonably well, with great differences in form being evident. Only height measurements were taken at this young age (22 months from planting). At the regular measurement age, form will be assessed.

At 22 months of age the average height was approximately four feet, with the best source being about 7 feet. The tallest tree was about 10 feet, the smallest 1.3 feet. The pattern of height growth generally followed the expected trend of southern sources, being fast-growing, northern sources slow-growing. The six fastest- and six slowest-growing sources or clones are indicated in Table 10.

Table 10. Heights in feet and range in heights for the six fastest- and six slowest-growing lots in a general combiner test in the State of São Paulo, Brazil, on a site not considered good for P. taeda. Trees are 22 months from planting.

Source	Average Height (feet)	Range in Height (feet)
Best 6 Lots		
Marion Co., Fla. (bulk lot)	7.48	4.55 - 10.73
Coastal Georgia (10-5, Union Camp)	6.96	4.23 - 9.75
Coastal South Carolina (11-16, Westvaco)	6.79	4.23 - 9.43
Coastal South Carolina (7-34, International Paper Company	6.66	3.58 - 9.75
Coastal South Carolina (7-56, International Paper Company	6.53	3.25 - 10.08
Coastal Georgia (10-6, Union Camp)	6.50	3.90 - 8.78
Poorest 6 Lots		
Eastern Shore, Va. (bulk lot)	3.80	1.30 - 6.50
Coastal Virginia (2-8, Union Camp)	4.45	1.95 - 7.15
Coastal Virginia (4-6, Chesapeake Corp.)	4.65	2.28 - 7.80
Coastal Virginia (4-18, Chesapeake Corp.)	4.68	2.60 - 7.48
Piedmont, South Carolina (3-36, Champion International)	4.78	2.60 - 7.15
Coastal Virginia (2-40, Union Camp)	4.81	1.63 - 8.78

First Test Clear-cut

In 1960 Westvaco established an open-pollinated loblolly pine progeny test on a good old-field site in the Coastal Plain of South Carolina. The stand has had a checkered history beginning with a severe Fomes attack following the second thinning in 1972, despite the use of borax to prevent this. Because of the importance of this study, intensive measures were taken to contain the Fomes outbreak. Infected areas were outlined and the soil treated with methyl bromide to form a barrier preventing escape of the fungus. These measures failed to contain the disease and trees continued to die. This past year, drought triggered an insect attack and fear for the healthy trees in surrounding tests prompted a decision to clear-cut the test.

An aerial shot of Weyerhaeuser's main progeny test growing in a phosphorus-deficient soil in the Coastal Plain of North Carolina. Phosphorus was added to replications 4 and 6 (left and right) but no fertilizer was applied to replication 5 (center of picture), where trees are barely visible after 10 years in the field. Even with such a dramatic response to fertilizer, no family-by-fertilizer interaction was detectable.

The test had been thinned twice with a combined yield of 17.7 cords per acre. Weight tickets showed that 28.6 cords per acre were harvested in the final cut of the 17-year-old test. The total production, including thinnings, was 46.3 cords per acre or 2.72 cords per acre per year! As Bill Hammond, Westvaco research forester, said, "That's not bad for a bunch of sick trees."

Fusiform Rust

The outplantings for the disease diallel have been completed with 28 tests established. The first measurements from these tests will be made in the winter of 78-79.

In 1975, ten cooperators established operational plantings of the Livingston Parish, Louisiana provenance of loblolly pine. The material was planted in over 30 locations in the states of Alabama, Mississippi, Georgia, North Carolina, South Carolina, Tennessee and Oklahoma. A work plan has been developed to utilize these plantings in comparing the performance of the Livingston Parish source to local sources in operational plantings. The study has been designed to:

1. Determine if the Livingston Parish, La. provenance of loblolly pine has a greater resistance to infection by fusiform rust than local provenance loblolly.
2. Compare the growth rate of the Livingston Parish material to local source loblolly pine.
3. To determine how far the Livingston Parish provenance can be established and grow satisfactorily from its native Louisiana.

The field plots are currently being established with the first measurements scheduled for the winter of 1979-80.

MSI--Measurement Training Sessions

The MSI data collection system continues to serve our needs well. We have occasionally encountered difficulty when new people try to use the system without proper training. For this reason we are planning additional training sessions in the next year. This will allow an opportunity for new personnel to learn procedures for measurement, machine operation, and data entry. It will also be an excellent refresher course for anyone experiencing difficulty in using the system. Notification of locations and dates for these regional sessions will be made.

ADVANCED-GENERATION PROGRAM

The Cooperative has progressed well in advanced-generation development. Breeding and testing for future generations of improvement are being emphasized in three major areas:

1. Breeding and testing second-generation selections.
2. Breeding and testing good general combiners.
3. Plantation selection and breeding.

Each phase will be developed to make immediate and maximum use of the best available genetic resources in production orchards and to insure the maintenance of a broad genetic base for future generations.

Second Generation

Twenty-three cooperators are now actively involved in the establishment of second-generation production orchards. Through 1977, 252 acres have been established. An additional 123 acres are planned for establishment in spring, 1978. Some of the first orchards established (1972-73) are now beginning to produce flowers with some regularity. Cone harvesting in these young orchards is just a year or two away. Genetic improvement in second-generation orchards is conservatively predicted to be 20% greater than first-generation orchards.

To date we have recommended that a rather methodical pace of development be maintained in orchard establishment. The deliberate pace plus the close spacing (145 trees/acre) were both recommended since we realized that some of the selections established in the early years would subsequently be rejected and new and better selections would become available. There is some inefficiency in this procedure since some trees are grafted, later rejected, and subsequently rogued from the orchard. However, time is gained and time is money in orchard development. The quicker the orchard can be established, the sooner the payoff (improved seed production) can be realized.

The 5- to 9-year-old second-generation selections are reassessed on a regular and frequent basis. A selection is rejected if superiority in growth, form or rust resistance is not maintained over time. We had expected an overall rejection rate of about 25% but have been extremely pleased that only 17% of the selections recommended for use in the orchard have been rejected. Our gamble to gain time by early selection is paying off well.

In the near future we will be recommending that organizations in areas where the majority of the selections are age 8 or older complete their needed second-generation orchard acreage. Ultimately each member should plan for sustained seed production from their second-generation orchard sufficient to meet all regeneration needs. When this expanded establishment phase is reached, 100 orchard trees per acre will be recommended. First-generation pollen parents will continue to be utilized until we have sufficient information from the early blocks to determine if the young grafts are producing an adequate pollen crop.

Approximately 175 new second-generation selections are being graded by the Cooperative each year. Shown is a prime candidate for selection in one of Masonite's 3-year-old progeny tests. The vigor of this individual tree is superb.

Table 11. Summary of second-generation orchard clonal recommendations and rejection rates, 1972 - 1978

	Number of Clones Recommended for Orchard	Percent Rejected
Hiwassee	52	17.3
Catawba	80	25.0
Union Camp (Va.)	78	25.6
Champion	86	34.9
Chesapeake	70	31.4
Continental Forest Industries (Ga.)	57	21.1
Champion International--		
Eastern Carolina Division		
Coastal	41	9.8
Piedmont	40	2.5
International Paper		
Coastal	62	19.4
Piedmont	32	0.0
Weyerhaeuser		
N. C. Coastal	104	26.0
Federal--Coastal	48	10.4
Piedmont	90	35.6
Union Camp (Ga.)	78	24.4
Westvaco	70	24.3
Kimberly-Clark	51	29.4
Continental Forest Industries (Va.)	51	8.5
Georgia Kraft	36	0.0
American Can	51	7.8
South Carolina Commission of Forestry	53	7.5
Tennessee River	54	13.0
Georgia-Pacific	52	11.5
Masonite	39	2.6
Container	35	5.7
Rayonier	47	12.8
Brunswick	41	2.6

Overall rejection rate of 17.0%

Selection of new second-generation trees from progeny tests continues at a steady pace. We currently have over 1600 selections in the Cooperative with an increase of approximately 175 selections annually. The majority of the second-generation selections (1357) are loblolly.

The initial rejection rate of 30% reported a couple of years ago has declined to 22.3% (Table 12). This decline is the result of increased experience in selection of second-generation trees. Also we are now able to select more trees from tests that are eight years old or more. The likelihood of a performance reversal with older selections is much reduced. About the same rejection rate due to late fusiform rust infection is still being encountered. A number of trees appear to be rust-free when selected but later show infection and must be discarded when reassessed.

Table 12. Current status of all second-generation selections of loblolly pine in the Cooperative

	Number of Selections	% of Selections Rejected
Hiwassee	119	24.4
Catawba	35	0.0
Union Camp (Va.)	65	9.2
Champion--Western Carolina Division	55	41.8
Chesapeake	85	24.7
Continental Forest Industries (Ga.)	71	33.8
Champion--Eastern Carolina Division	94	16.0
International Paper	78	26.9
Weyerhaeuser (N. C.)	137	32.8
Weyerhaeuser (Miss.-Ala.)	26	3.8
Federal	80	33.8
Union Camp (Ga.)--Loblolly Only	42	23.8
Westvaco	110	20.0
Kimberly-Clark	109	30.3
Continental Forest Industries (Va.)	64	31.3
Georgia Kraft	44	2.3
American Can	29	3.4
S. C. Commission of Forestry	29	10.3
Tennessee River	47	0.0
Virginia Division of Forestry	30	0.0
Georgia-Pacific	7	0.0
Masonite	1	0.0
	1357	22.3

Breeding plans for the second-generation selections are now being finalized. Pollen collection for the pollen bank was made this year and the first crossing will begin in the spring of 1979.

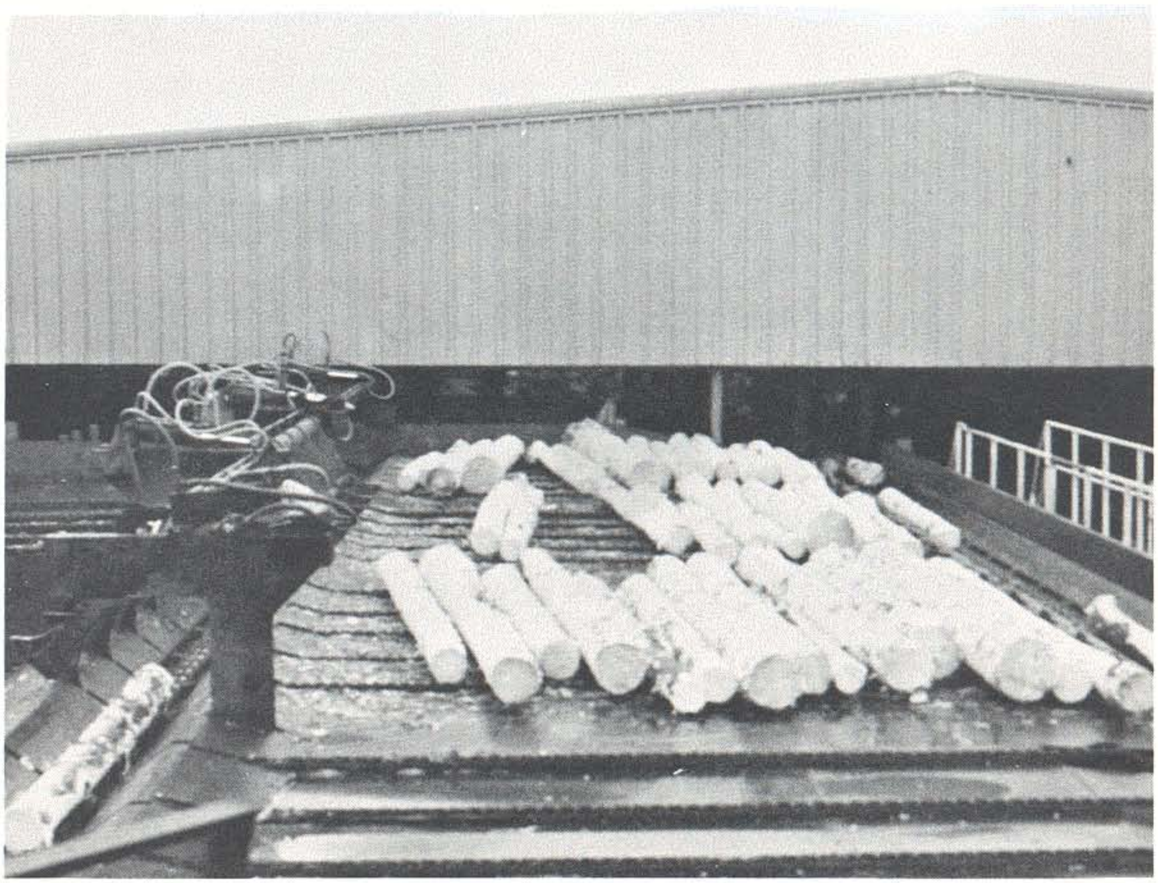
Breeding Good General Combiners

For several years we have made good progress in crossing the best good general combiners. A partial diallel breeding scheme has been used to maximize the number of new combinations among these most outstanding parents in our program. Trees are being crossed within breeding regions as well as among breeding regions. To date, approximately 800 crosses have been initiated. This effort is truly a cooperative working at its best, with the breeding work being shared equally among all members of the cooperative.

The purpose of the good general combiner breeding program is to develop a base for selection that is genetically better than any previously attained. Breeding the best with the best will accomplish this, since the best are determined from the performance of their progeny in extensive tests. This breeding program represents one way to capitalize on information and plant material already developed in the program.

Plantation Selection

The goal of selecting 100 new trees from plantations (wild stands if plantations are not available) continues to be a major activity of each Cooperative member. Grading of candidates has occupied a great deal of the Cooperative staff time. During one week in February we had five staff members scattered across the South, grading trees, each with a different cooperator. Good progress continues to be made on this project by most members (Table 13). We have one more year of work to complete this program on schedule. Real



The Cooperative continues to breed for stem straightness and small branches with good success. Quality traits take on increasing importance as the average sawlog diameter decreases. Breeding for value, not just volume, makes good economic sense.

urgency is necessary if trees are to be established in breeding clone banks and breeding completed for incorporation into the third-generation production program without loss of time or potential genetic gain.

Table 13. Progress in selecting superior trees from plantations derived from unimproved seed

Species and Source	Plantation Selections To April 1, 1977	Selections Added in the Last Year	Plantation Selections To April 1, 1978
Loblolly--			
Coastal	389	273	662
Piedmont and Mountain	325	49	374
Slash	96	3	99
Total	810	325	1135

We do not anticipate that plantation selection work will be discontinued when the planned four-year intensive program is completed July, 1979. However, the urgency for new selections will be less intense because of the long-range scheduling of subsequent breeding and selection work. Many young plantations will be just at the right age for selection in the early 1980's. To pass up the opportunity for locating superior phenotypes in these stands would be a great loss. Once these stands are cut and replaced with genetically improved regeneration stock, the opportunity to exploit this resource will be gone forever.

Breeding Clone Banks

Every selection obtained for advanced-generation breeding is being established in a breeding clone bank with at least six to eight grafts. This includes both plantation and second-generation selections. A good, up-to-date, conveniently located clone bank is where the orchard manager can best accomplish the control-pollinations for advanced-generation tests. The clone bank in its early years also serves as a convenient source of scion material which can be used for advanced-generation production orchard grafting activities.

Progress in establishing the clone banks was slow at first but nearly all cooperators will soon be right on schedule with this project. It is vitally important that there be no time delay in establishing selections in these breeding clone banks. All too frequently selections have been lost before they were preserved as a result of fire, tornados, overzealous loggers and other such ravages of nature.

SPECIAL PROJECTS

From initiation, the program has operated as a true cooperative, with all members expected to participate in certain primary functions such as selection, breeding and testing of select trees and the establishment of production seed orchards. Information and plant resources (genetically improved parent trees) developed through these efforts are freely shared by all members of the Cooperative. Progress achieved in this overall effort has been further enhanced by numerous special projects which have been an integral part of the program through the years. These special projects, started by Cooperative members, the Cooperative staff and graduate students, have increased our understanding of developing technology and the biological constraints on use of plant resources.

Examples of special projects are as follows: The wide planting of progeny from our best good general combiner parents over diverse sites and in different geographic areas. Virtually every cooperator has made one or more plantings of the good general combiner progeny lines resulting in their testing under very diverse conditions. In addition, nearly twenty plantings have been made overseas. Another study in which nine companies participated was the pulping of rust-infected trees to evaluate the influence of diseased trees on yields, paper properties and by-product production. This study has been completed and the results published. A third example of a special project has been the development of two-clone orchards. These orchards can capture the genetic improvement of an outstanding specific cross. Improvements could be as much as double those from a routine seed orchard.

As we move into advanced-generation breeding programs the need for a pollen bank at N. C. State becomes increasingly evident; we had numerous requests for better coordination and a central clearinghouse. Jerry Sprague established such a bank which is now fully operational. To complete this project it was necessary to learn much more about long-term pollen storage techniques than was previously known. Information of great value resulted as a spin-off from the pollen bank special project.

Since 1973 we have learned much about pollen extraction and have initiated several studies on pollen storage methods. One of the first investigations dealt with vacuum storage of pollen. It was felt this method would have merit for long-term storage (3 to 5 years) and would also afford extra protection during shipment of the pollen. The method has proven better than the conventional methods (no vacuum) but we are not certain if it is superior enough to justify the added expense of the method. Presently we are investigating some less expensive methods to see if they will produce the desired result.

Our pollen studies have indicated that moisture content is the most important factor in successful pollen storage. If pollen is good when stored

Rust! Rust! Rust! What a mess! On the positive side is the fact that rust-free trees selected from such heavily infected stands produce progeny with good rust resistance.

and if the moisture content is low (8 to 10%), then it will apparently store well regardless of the method used. Proper moisture content after extraction will depend a lot on the extraction process. The extractor at N. C. State was designed especially to minimize the time required to extract the pollen and dry it to the proper moisture content. This is accomplished by controlling the temperature and humidity and by drying the pollen with forced air. Recently a few of the industrial members have constructed similar pollen extractories at their seed orchard complexes.

Numerous special projects have resulted from graduate student research. For example, the relative performance of selfs versus outcrosses was started by Dr. Carlyle Franklin for his Ph. D. research in cooperation with one member of the Cooperative. It has been carried on by our Cooperative staff, students, and the Eastern Carolina Division of Champion International (formerly Hoerner-Waldorf). Results of the 10th-year measurements are reported in Table 14. The average depression from selfed crosses, 32% for height and 73% for volume growth, is a clear warning of the dangers of selfing that can result in a seed orchard if the proper designs are not carefully followed.

Table 14. Height and volume data from a 10-year comparison of self and outcross families*

	Height (feet)	Volume (cu.ft./tree)
Outcrosses--44 families	23.2	1.17
Selfed crosses--44 families	15.6	0.32
Difference (Outcross--self)	7.6	0.85
% Depression from Selfing	32%	73%

*Study initiated by Dr. Carlyle Franklin on lands of Champion International

A special project that has been widely reported over the years is the Loblolly Pine Heritability Study developed jointly by N. C. State and International Paper Company scientists with financial support from the National Science Foundation and the National Institute of Health. This study, the largest of its kind in the world, is located at International Paper's Southland Experiment Forest, Bainbridge, Georgia. Results obtained have contributed more to the inheritance of economically important traits in loblolly pine than any other single research project.

The magnitude of differences in wood qualities within loblolly pine related to geographic source is well documented and has been reported many times in our annual reports. The current usage of more topwood, thinnings, and younger trees has resulted in an increased interest in wood variation and its effect on yields and quality of the final product. At the request of Union Camp, we recently summarized the mature wood densities by county for all trees for which we have data in the Cooperative; an example is shown in Table 15.

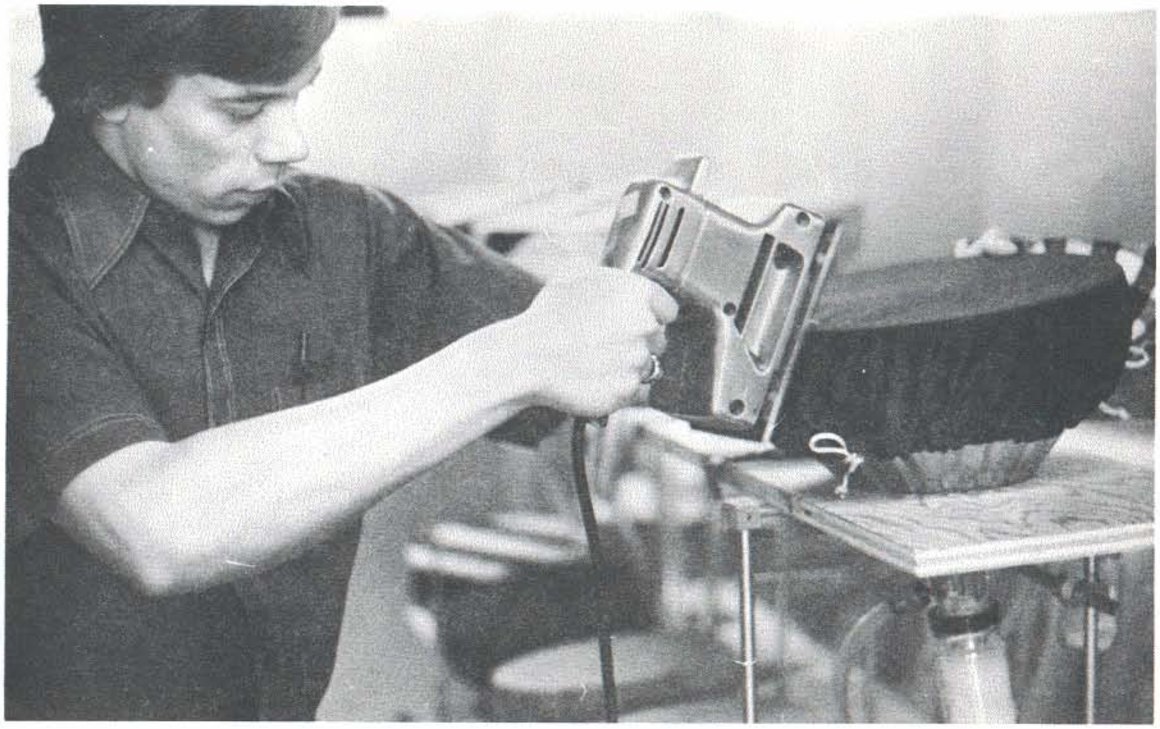
Table 15. Specific gravity data for a number of counties in two states to illustrate the type of data available*

North Carolina			Alabama		
County	# Trees	Avg. Sp. Gr.	County	# Trees	Avg. Sp. Gr.
Beaufort 1/	318	.56	Sumter	182	.53
Craven 1/	180	.55	Choctaw	116	.53
Onslow 1/	168	.55	Butler	126	.55
Halifax 2/	163	.53	Wilcox	138	.53
Franklin 2/	132	.54	Lamar	104	.53

1/ Coastal Plain

2/ Piedmont

* The complete summary is available to members of the Cooperative upon request.



The Cooperative Pollen Bank is fully operational. During extraction, pollen is shaken from the drying funnel into the collection jar by means of an electric sander (top). Sealed containers of extracted pollen are stored under refrigeration for future breeding work (bottom).

The vast majority of the special projects undertaken by Cooperative members have been initiated at their request. Most often these projects or studies are designed to answer questions pertaining to specific problems encountered by one or more Cooperative members. The Cooperative staff encourages these projects and offers assistance in work plan development, provides leadership and coordination of activities and analysis and interpretation of results. We thought it would be of interest to list by member organization some of the types of special studies that have been undertaken over the years. Such a list is presented in Table 16. It is not intended as a complete list; however, it does highlight many of the special efforts within the Cooperative. Without these investments in time and resources, our Cooperative effort would have been far less productive.

Table 16. Examples of Cooperative membership special research studies and projects

Member Organization	Special Projects and Studies
American Can Company	Shortleaf-x-loblolly hybrid tests for disease resistance
Brunswick Pulp Land Company	Economic evaluation of spacing and site preparation in slash pine Disease diallel plantings
Bowaters: Catawba Timber Company	Orchard irrigation and fertilization studies Two-clone orchard Disease diallel plantings
Hiwassee Land Company	Special wide-cross on the Cumberland Plateau Comandra rust tests with loblolly pine
Champion International: Carolina East	Pine arboretum containing over 70 species Special pine hybridization work Self-clone bank

Table 16 (continued)

Member Organization	Special Projects and Studies
Champion International: Carolina West	Disease diallel crossing for other Cooperative members Two-clone orchard
Alabama	Special Virginia pine progeny and provenance tests Seed orchard gains test
Chesapeake Corporation of Virginia	Insecticide applicator tests Operational evaluation of genetic gain
Container Corporation of America	Effect of fumes on seed orchard health Plantation wood study (in progress) Disease diallel plantings
Continental Forest Industries	Loblolly vs. slash comparison tests Plantation vs. natural wood study Geographic variation in slash and loblolly pine
Federal Paper Board	Wood quality tests Determine species most suitable for the Sandhills
Kimberly-Clark Corporation	Virginia pine diallel and seed-ling orchard Virginia vs. loblolly pine wood studies
MacMillan-Bloedel	Growing Livingston Parish loblolly pine for studies by Cooperative members Wide-cross plantings for rust resistance Plywood studies (planned) Insecticide applicator tests
Masonite Corporation	Good general combiner in Gulf Coast area Disease diallel plantings

Table 16 (continued)

Member Organization	Special Projects and Studies
North Carolina Forest Service	Longleaf orchard management studies Christmas tree studies White pine orchard management studies Pitch-x-loblolly hybrid tests
Rayonier Inc.	Test of Rust Center survivors Variation in slash pine wood by family and fertilizer study Marion County, Florida selections
Scott Paper Company	New member-special studies being planned
Georgia Kraft Company	Test of Rust Center survivors Rooting pine cuttings Wide crossing for dry sites and rust resistance Insect control studies with USFS and the Cooperative
Georgia-Pacific Corporation	Plywood yields from straight, small-limbed trees and average trees Special tests of Florida source loblolly Spruce pine improvement program Tests of South African families
Great Southern Paper Company	Disease diallel tests
Hammermill Paper Company	Pulping of 12-year-old plantation thinnings Selection of trees from high-rust plantations Site preparation studies
International Paper Company	Heritability study Juvenile wood and pulping studies Pulping straight and crooked trees Tests of South African families
South Carolina State Commission of Forestry	Early cone-ripening studies Orchard fertilization-irrigation study in slash pine
St. Regis Paper Company	Dry site studies of East Texas loblolly pine Competition study (planned) Sand pine improvement program

Table 16 (continued)

Member Organization	Special Projects and Studies
Tennessee River Pulp and Paper Company	Developing loblolly pine for cold and severe climates Clone-banking natural loblolly-x-shortleaf pine hybrids
Union Camp Corporation: Savannah, Ga.	Tests for resistance to pitch canker Vacuum seed harvester Sand pine improvement program Tests of Rust Center survivors
Franklin, Va.	Irrigation-fertilizer studies in orchard Thimet treatment of progeny tests Subsoiling studies in orchards Wet site progeny tests
Virginia Division of Forestry	Air-pollution tolerance studies Cone crop prediction studies Effect of seed size on progeny growth Orchard subsoiling studies
Westvaco Corporation: Southern Unit	Two-clone orchard Wet site orchard Hybrids of local and Texas loblolly for dry sites
Northern Unit	Pitch-x-loblolly hybrid program Loblolly provenance trials for cold climates
Weyerhaeuser Company: North Carolina	Pilot program for accelerated breeding Two-clone orchard Orchard dieback studies
Miss.-Ala.	Orchard fertilizer studies Maximum-care progeny tests

COOPERATIVE TRAINING PROGRAMS

If an applied forestry program is to proceed satisfactorily, supportive research is needed to keep the operational program productive and vigorous, and research findings must be understood and put to use by the operational forester. At the start of the Cooperative Programs the decision was made that the supportive studies (sometimes called basic or fundamental research) needed as a base for the applied program should be done by graduate and postdoctoral students and, in a few instances, by special students. The basis for that decision was that (1) students do the best and most reliable work for the funds and effort expended by the Cooperatives and (2) trained people are made available in the profession to further its work.

The training program is summarized below, current to January 1, 1978. Because the two programs (Hardwood Research and Tree Improvement) were administered as one for so long, it was not possible or practical to distinguish between them for purposes of this summary.

Graduate Students--Past

Working with graduate students has been a major activity of the faculty associated with the Cooperative. All students listed in Table 17 were guided by one or more of the Cooperative staff members, and all studies were of interest to the members of the Cooperative. The high quality and large numbers of students have made a major contribution to the Cooperative, and many key jobs are now held by former students (see last column in Table 17). At a recent international meeting in Australia, Bruce Zobel reported 23 former students were present, 17 of whom gave papers.

A breakdown of the degrees granted as of January 1, 1978 is of interest:

	Number	Percentage
Ph. D. degrees granted	57	55%
M. S. degrees granted	41	40%
M. F. degrees granted	5	5%
Total degrees granted	103	100%
Degrees awarded foreign students	30	29%
Students to whom both M. S. and Ph. D. were awarded	17	17%
Students from North Carolina granted degrees	10	10%

Table 17. Students who have completed degrees--from 1957 to January 1, 1978[1/]

	Student	Degree	Year	From*	Thesis Research	Present Location
1.	Tom Adams	M. S.	1970	California	Competition in loblolly pine	Prof., New Hampshire
2.	Jim Barker	Ph. D.	1972	Florida	Location effects on heritability estimates in loblolly pine	Research Geneticist, IP Company, Bainbridge, Ga.
3.	Walt Beineke	Ph. D.	1965	Indiana	Inheritance in survival following planting	Prof., Purdue Univ.
4.	Roger Blair	Ph. D.	1970	Illinois	Fusiform rust resistance, loblolly pine	Research Forester, Potlatch Corp., Idaho
5.	Miguel Caballero	M. S.	1966	Mexico	Variation in Mexican pines	Research Center, Mexico
6.	Jaime Castillo	M. S.	1964	Colombia	Genetics of coffee	Colombia (??)
7.	Wei-Min Chang	M. S.	1962	Taiwan	Effect of spacing on limbs and wood quality in Virginia pine	Forest Research, Taiwan
8.	Roger Chapman	Ph. D.	1977	Washington	Growth modeling, loblolly pine	Prof., Washington State Univ.
9.	Lert Chuntanaparb	Ph. D.	1973	Thailand	Inheritance in wood specific gravity of loblolly pine	Prof., Kasetsart Univ., Thailand
10.	Don Cole	Ph. D.	1973	Georgia	Difference between slash and loblolly pine	Research
11.	Tom Conkle	M. S.	1962	California	Plot size and shape	USFS, Research, Calif.
12.	Armand Corriveau	Ph. D.	1975	Canada	Genetic potential by clonal performance, Virginia and loblolly pine	Genetics Research, Quebec, Canada

(cont.) [1/] All but two students listed (Hilbourn and Drew) have had Bruce Zobel or Bob Kellison as chairman of committee member; these two are listed because we worked so closely with them.

* Not where born but where they came from to school--usually from another university or job.

	Student	Degree	Year	From	Thesis Research	Present Location
13.	James Deines	M. S.	1972	New York	Hardwood Nursery fertilization	Regeneration Forester, Federal Paper Board Co.
14.	Roberto Delmastro	M. S.	1975	Chile	Hybrids in southern pine	Prof., Univ. Austral, Valdivia, Chile
15.	Neville Denison	M. S.	1973	So. Africa	Variation in families of *Pinus patula*	Research, SAFFI, South Africa
16.	Hilton do Couto	Ph. D.	1977	Brazil	Dry weight yield tables of hardwoods	Prof., Univ. São Paulo, Brazil
17.	John Drew	Ph. D.	1973	Australia	Photorespiration and photosynthesis	Research, Weyerhaeuser Co.
18.	Carlyle Franklin	Ph. D.	1968	Virginia	Self-pollination in loblolly pine	USFS Research, South Carolina
19.	Carl Gallegos	Ph. D.	1977	Colorado	Seed orchard location	Research Forester, IP Co., Mobile, Alabama
20.	Bill Gladstone	Ph. D.	1968	New York	Pulping early and latewood in loblolly pine	Research Forester, Weyerhaeuser Company, Tacoma, Washington
21.	Floyd Goggans	Ph. D.	1962	Alabama	Inheritance of tracheid characteristics in loblolly pine	Prof., Auburn Univ.
22.	Jim Gregory	M. S.	1968	North Carolina	Fertilization and irrigation seed orchards	Prof., Virginia Polytechnic Institute
23.	Jim Gregory	Ph. D.	1975	North Carolina	Subsoiling seed orchards	" " "
24.	Earl Haught	M. S.	1961	Tennessee	Compression wood in loblolly pine	USFS, New Mexico
25.	Ted Hilbourn	M. S.	1965	California	Effects of disking on land productivity	Weyerhaeuser Company, Tacoma, Washington
26.	Serena Hunter	M. S.	1977	Tennessee	Isozyme analysis of loblolly pine	N. C. State Univ., Technician
27.	Sheikh Ibrahim	M. S.	1971	Malaysia	Variation in wood of *P. caribaea*	Research Inst., Malaysia

	Student	Degree	Year	From	Thesis Research	Present Location
28.	Jesus Jasso	M. F.	1965	Mexico	None	Forest Research, Mexico
29.	John W. Johnson	Ph. D.	1971	Georgia	Nutrient analysis of forest floor	Prof., N. C. State Univ.
30.	Ke Won Kang	Ph. D.	1966	Korea	Hybrids between pond and loblolly	Medical technician, Indiana
31	Hyun-Chung Kang	Ph. D.	1978	New York	Merits of different selection schemes	USFS, Rhinelander, Wis.
32.	Joseph Kasile	Ph. D.	1972	Iowa	Cluster sampling and computer simulation	Prof., Ohio State Univ.
33.	Robert Kellison	M. S.	1966	West Virginia	Geographic variation in yellow-poplar	Director, Hardwood Research Program, NCSU, Raleigh
34.	Robert Kellison	Ph. D.	1970	"	Phenotypic and genotypic variation in yellow-poplar	" " "
35.	Bohun B. Kinloch	M. S.	1964	N. Carolina	Evaluation of resistance to fusi-form rust in loblolly pine	USFS Research, Calif.
36.	Bohun B. Kinloch	Ph. D.	1968	"	Inheritance of resistance to fusi-form rust in loblolly pine	" " "
37.	Robert Kitchens	M. F.	1971	Georgia	None	USFS, Region 8, National Forests
38.	Jay Kitzmiller	Ph. D.	1972	West Virginia	Effects of fertilization on sycamore	USFS, Research, Calif.
39.	John Kundt	Ph. D.	1972	Virginia	Analysis of diallel in Virginia pine	Prof., Univ. of Maryland, Extension
40.	Yves Lamontagne	M. S.	1971	Quebec, Canada	Variation in bud and needle anatomy of white pine	Research, Quebec Forest Service
41.	Sam Land	M. S.	1967	Virginia	Intraspecific variation in sea-water tolerance of loblolly and slash pines	Prof., Miss. State Univ.
42.	Sam Land	Ph. D.	1973	"	Genetic control in tolerance of loblolly pine to sea water	" " " "
43.	Carl Lane	M. S.	1960	N. Carolina	Performance of seed sources of loblolly and shortleaf pine	Prof., Clemson Univ.
44.	Clark Lantz	Ph. D.	1970	Virginia	Graft incompatibility of loblolly	USFS, S&PF, Atlanta, Ga.

	Student	Degree	Year	From	Thesis Research	Present Location
45.	Charles Lee	Ph. D.	1972	West Virginia	Wood property variation in sycamore	Dept. Head, Univ. of Ark., Monticello, Ark.
46.	Tom Ledig	M. S.	1965	New Jersey	Root-shoot ratio and photosynthetic efficiency of loblolly pine	Prof., Yale Univ.
47.	Tom Ledig	Ph. D.	1967	" "	Photosynthesis and respiration in loblolly pine	" " "
48.	Ralph Lewis	Ph. D.	1973	West Virginia	Electrophoretic investigations of disease resistance in loblolly pine	USFS, Region 8, Tree Improvement
49.	Alan Long	Ph. D.	1973	California	Variation in response to mycorrhizae in loblolly pine	Research, Weyerhaeuser, Washington State
50.	Ed Mallonee	M. S.	1971	West Virginia	Effect of site preparation and fertilization in a pocosin	Research, Crown-Zellerbach, Washington State
51.	Ed Mallonee	Ph. D.	1974	"	Fertilizer effect on pine growth	" "
52.	Dimitrios Matziris	M. S.	1971	Greece	Inheritance of juvenile characteristics	Research Inst., Greece
53.	Dimitrios Matziris	Ph. D.	1974	"	Realized vs. predicted gain in loblolly pine	" " "
54.	Szafii Manan	M. S.	1972	Indonesia	Seed from loblolly orchards after fertilization	Indonesia
55.	Fred Matthews	M. S.	1960	Georgia	Pine cone rust in slash pine	USFS, Research, Athens, Georgia
56.	Robert McElwee	M. S.	1960	Louisiana	Factors affecting pine pollen flight	Prof., Virginia Polytechnic Inst.--Extension
57.	Robert McElwee	Ph. D.	1970	N. Carolina	Radioactive tracers and pollen flight in loblolly pine	Prof., VPI--Extension
58.	Gene Namkoong	Ph. D.	1963	New York	Introgression in loblolly and longleaf pine	USFS, Pioneer Project, NCSU
59.	Garth Nikles	Ph. D.	1966	Australia	Taxonomic relationship of Caribbean pines	Research, Queensland, Australia

	Student	Degree	Year	From	Thesis Research	Present Location
60.	Fred Owino	Ph. D.	1976	Kenya	Genotype-x-environment interaction in loblolly pine	Prof., Univ. of Nairobi, Kenya
61.	Richard Porterfield	M.S.	1970	Ohio	Financial maturity of southern hardwoods	Prof., Miss. State Univ.
62.	Richard Porterfield	Ph.D.	1973 (Yale)*	"	Gains from tree improvement	" " " "
63.	Clayton Posey	Ph. D.	1964	Oklahoma	Effects of fertilization on wood	Administration, JARI Company, Brazil
64.	Marcelino Quijada	M. S.	1967	Venezuela	Variation of wood of longleaf pine	Prof., Univ. of Merida, Venezuela
65.	Marcelino Quijada	Ph. D.	1970	"	Drought resistance in young pine	" " "
66.	James Roberds	M. S.	1965	Georgia	Patterns of variation in sweetgum	USFS, N. C. State Univ.
67.	Donald Rockwood	Ph. D.	1972	Illinois	Terpene analysis of loblolly pine	Prof., Univ. of Florida
68.	Mahmoud Salem	M. F.	1961	Egypt	Eccentricity in post oak	Egypt (?)
69.	Leroy Saylor	M. S.	1960	Iowa	Karyotypic analysis of Pinus	Prof. & Assoc. Dean, NCSU Forest Resources
70.	Leroy Saylor	Ph. D.	1962	"	Chromosome behavior in pine species and hybrids	" " " "
71	Dan Schmitt	Ph. D.	1963	Florida	Self-compatibility of sweetgum	USFS, Research, Admin.,NE
72.	Tony Shelbourne	Ph. D.	1966	Rhodesia	Heritability of stem form	For. Res. Inst. New Zealand
73.	Earl Sluder	M. S.	1960	N. Carolina	Racial variation in yellow-poplar	USFS, Research, Georgia
74.	Earl Sluder	Ph. D.	1970	" "	Variation in wood specific gravity of yellow-poplar	" " "
75.	Bob Smith	M. F.	1963	N. Carolina	Growth and development of rhododendron	USFS, Alaska National Forests
76.	Don Smith	M. S.	1962	Alabama	Specific gravity relationship between limb and bole of lob-lolly pine	Forester, Tennessee River Company

*Bruce Zobel served on his committee at Yale, using Cooperative data.

	Student	Degree	Year	From	Thesis Research	Present Location
77.	H. Don Smith	Ph. D.	1976	N. Carolina	Economic analysis of pine and hardwood plantations	Administrator, Potlatch Corp.
78.	Peter Smouse	Ph. D.	1970	California	Population studies in southern pine	Med. School, Univ. of Michigan
79.	Kowit Sombun	M. S.	1975	Thailand	Seed germination physiology from loblolly seed orchard	Ph. D. studies, NCSU
80.	David South	M. S.	1975	N. Carolina	Producing quality hardwood seedlings	Auburn Univ.--Research
81.	Per Ståhl	Ph. D.	1977	Sweden	Competition in loblolly pine	Swedish Forest Service
82.	Ray Steinhoff	M. S.	1961	Wisconsin	Variation in foliar nutrients in loblolly pine	USFS, Research--Northeast
83.	Roy Stonecypher	Ph. D.	1966	N. Carolina	Inheritance in loblolly pine	Weyerhaeuser, New Bern, N. C.--Research Center Leader
84.	Asham Sulaiman	M. S.	1964	Iraq	Dry weight, specific gravity, and cellulose of seedlings of 4-year Virginia pine	Minister of Agri., Iraq
85.	Vichien Sumantakul	M. S.	1973	Thailand	Genetic variation in sycamore	Kasetsart Univ., Thailand
86.	Kingsley Taft	M. S.	1962	Ohio	Increase seed viability of yellow-poplar	Administration, T. V. A.
87.	Kingsley Taft	Ph. D.	1965	"	Diallel analysis of yellow-poplar	" "
88.	Mike Taras	Ph. D.	1964	Wisconsin	Wood properties of slash pine	USFS, Wood Research
89.	Fred Taylor	Ph. D.	1965	Virginia	Wood variation in yellow-poplar	Wood Lab., Miss. State Univ.
90.	Eyvind Thor	Ph. D.	1961	Norway	Variation in loblolly pine	Prof., Univ. of Tenn.
91.	Martin Torrico	M. F.	1962	Spain	(None)	Res. Inst., Spain
92.	Ray Varnell	M. S.	1964	Oklahoma	Culture of female gametophyte of loblolly pine	USFS, Biol. Research
93.	Charles Webb	M. S.	1960	N. Carolina	Field grafting loblolly pine	International Paper Co., Maine--Research Mgr.

	Student	Degree	Year	From	Thesis Research	Present Location
94.	Charles Webb	Ph. D.	1964	N.Carolina	Variation in wood of sweetgum	International Paper Co., Maine--Mgr., Research
95.	Steve Webster	Ph. D.	1972	Oregon	Nutrition in seed orchards	Weyerhaeuser, Oregon
96.	Bob Weir	M. S.	1970	Maine	Sycamore on dry sites	Prof. & Head, Tree Improvement Cooperative, NCSU
97.	Bob Weir	Ph. D.	1976	"	Genetics of air-pollution on loblolly pine	" " "
98.	Kim von Weissenberg	Ph. D.	1971	Finland	Growth regulators in disease resistance of loblolly pine	For. Res. Inst., Finland
99.	Tim White	M. S.	1975	California	Conelet abortion in longleaf	Grad. Student, Oregon State Univ.
100.	Mike Wilcox	Ph. D.	1973	New Zealand	Inheritance of wood brightness of loblolly pine	Res. Inst., New Zealand
101.	Ron Woessner	M. S.	1965	West Virginia	Progeny evaluation of loblolly pine	JARI Company, Brazil--Research
102.	Ron Woessner	Ph. D.	1968	"	Intraspecific wide crosses in loblolly pine	" " "
103.	Gerrit van Wyk	Ph. D.	1975	So. Africa	Diallel analysis of Eucalyptus	Research Inst., S. Africa

Graduate Students--Present

We usually have between 15 and 30 graduate students working with various aspects of the two Cooperative Programs. There are always a couple who are working on their job so are no longer in residence at the university. The quality of students is increasing each year, allowing us to continually upgrade the program. Listed in Table 18 are students who are in pursuit of their degrees as of January 1, 1978. Note the dispersion of degrees and how similar they are to the degrees granted.

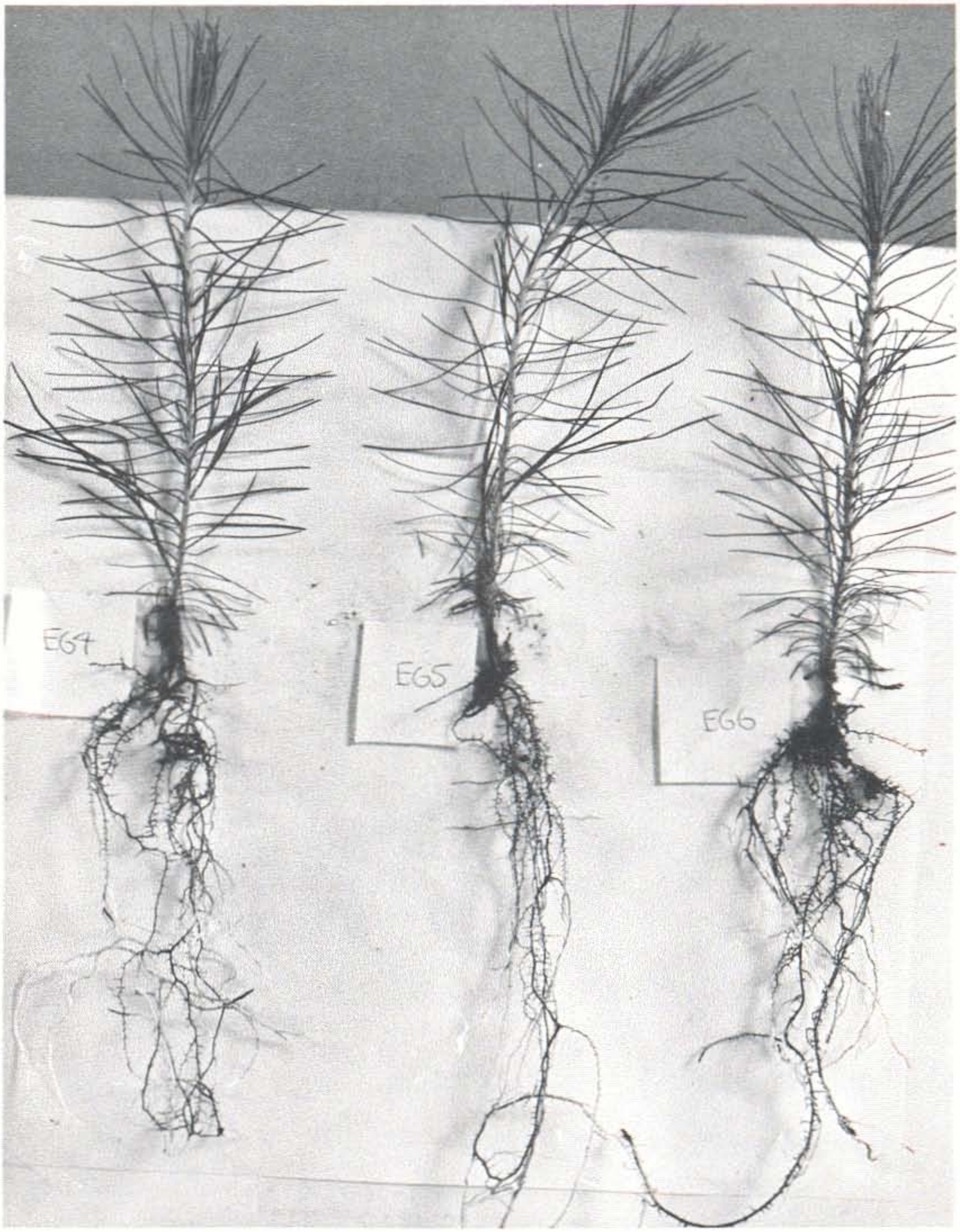
	Number	Percentage
Ph. D. Degrees	19	54%
M. S. "	15	43%
M. F. "	1	3%
Total Degrees	35	100%
Foreign Students	9	26%

Table 18. Students in residence or completing degrees as of January 1, 1978

	Student	Degree Sought	From	Research Interest
1.	Tim Adams	M. S.	N. Carolina	Fusiform rust testing
2.	Richard Braham	Ph. D.	Michigan	Sprout growth of hardwood stands
3.	Emily Butler Schultz	M. S.	Tennessee	Cold resistance in eucalypts
4.	Phil Cannon	Ph. D.	Nigeria (Ore.)	Dieback in *Terminalia ivorensis*
5.	Gary Cretcher	M. S.	Ohio	Geographic variation in willow oak
6.	Jose Gomide	Ph. D.	Brazil	New method of pulping eucalypts
7.	Paulo Gonçalves	M. F.	Brazil	Evaluating black alder in the Southeast
8.	David Harcharik	Ph. D.	Italy	(Undecided)
9.	Bill Jacobi	Ph. D.	W. Virginia	Toxic substance
10.	J. B. Jett	Ph. D.	Tennessee	Flowering in loblolly pine
11.	Charles Kelly	M. S.	New Jersey	Development of tissue culture plantlets
12.	Clem Lambeth	Ph. D.	Washington	Genotype-x-environmental interaction in Douglas fir
13.	Greg Leach	M. S.	New York	Development of tissue culture plantlets
14.	Cliff Lewis	M. S.	Virginia	Effect of disking on root development of hardwoods
15.	Leon Liegel	Ph. D.	Puerto Rico	Foliar analysis of tropical conifers
16.	George Lowerts	M. S.	New Jersey	Genetic variation in decay in hardwoods
17.	Kambiz Makoui	Ph. D.	Iraq	Relationship between paper and wood qualities in sweetgum

Table 18 (cont.)

	Student	Degree Sought	From	Research Interest
18.	Early McCall	M. S.	N.Carolina	Conelet Abortion in longleaf pine
19.	Lawrence Miller	M. S.	Maine	Genetics of Fraser fir
20.	Joao Moreschi	Ph. D.	Brazil	Relation between fiber quality and paper quality
21.	Chadegesin Otegbeye	M. S.	Nigeria	Inheritance of wood properties in eucalypts
22.	Jeff Paschke	M. S.	Indiana	What, when and how to measure progeny
23.	Jeff Paschke	Ph. D.	"	Mycorrhizae influence on growth of sweetgum
24.	Ron Overton	Ph. D.	California	Flowering and fruiting in sycamore
25.	Reungchai Pousujja	Ph. D.	Thailand	Vegetative propagation in loblolly pine
26.	Robert Rose	Ph. D.	Vermont	Mycorrhizae influence on growth of Eucalyptus
27.	Leo Schoenhofen	M. S.	California	Economics of total-tree harvest
28.	Richard Sniezko	M. S.	California	Studies of relatedness and selfing
29.	Dan Struve	M. S.		Rooting needle fascicles in white pine
30.	John Talbert	Ph. D.	N. Carolina	Genotype-x-environment interaction
31.	Mick Veal	Ph. D.	Australia	Effect of fusiform rust on wood quality
32.	Ken Wearstler	Ph. D.	Washington	Effects of competition and density on production
33.	Joe Weber	Ph. D.	Louisiana	Variation in Fraser fir
34.	Mary Lou Welby	M. S.	N. Carolina	Genetic relationships in water-willow oak
35.	Yahya Mouffaq	Ph. D.	Iraq	Isozyme studies in *P. strobus*



Cooperative graduate students Greg Leach and Chip Kelly have studied the behavior of tissue-cultured plantlets transferred from the "test tube" to soil. Note the unusual secondary needle formation near the base of the leftmost plantlet.

Graduate Students at Other Universities

Although uncommon, we are occasionally called upon to serve on committees of students outside the University or overseas. During the past, Bruce Zobel has served on three Ph. D. committees for Duke University, one for Yale, three in Australia, and one in New Zealand. Bill Johnson is currently serving as cochairman of a graduate committee for Syracuse University.

Special and Postdoctoral Students

Often it is not possible or desirable for a person who wants additional training or information in a subject to work toward an advanced degree. We have accommodated 11 such persons, all foreign, and have set up special training sessions from six months to a year, with one or two less than that. Such special training is a lot of work for members of the Cooperative but there are very positive benefits. The special students take on research projects and they always are helpful to other students.

The student having the greatest value to a research program is the postdoctoral. These people have a specialty, they know how to do research, they often help teach and they are always of great value to other students and faculty. We were fortunate to have six top-quality postdoctoral students supported by monies from the National Science Foundation and the National Institute of Health when those grants were active. The special and postdoctoral students are listed in Table 19.

Table 19. Students who have worked with the Cooperative as postdoctorals or special students. Stay in Raleigh was six months or more, and research done was on material within the Cooperatives.

	Name	Student Status	Area of Interest	Present Status
1.	Vasile Benea	Special	Plant breeding	Research Institute, Romania
2.	Axel Bergman	Special	Seed production in orchards	Forest Research in Sweden
3.	Mick Byrne	Postdoctoral	Isozyme analysis	National Univ., Canberra, Aust.
4.	Tom Conkle	Postdoctoral	Isozyme analysis	USFS--Research--California
5.	Jon Dietrichson	Special	Physiology of wood formation	Research Institute, Norway
6.	Jose Graçan	Special	Seed quality	Research Institute, Hungary
7.	Suekichi Hatakeyama	Postdoctoral	Competition	Research Institute, Japan
8.	Ivan Herpka	Special	Poplar breeding	Research Institute, Hungary
9.	Sacorn Jadjuabsein	Special	Plant breeding	Forest Service, Thailand
10.	Carlos Jaramillo	Special	Plant breeding	Forester, Cartón de Colombia
11.	Bill Libby	Postdoctoral	Quantitative inheritance	Prof., Univ. of Calif.
12.	Rex Mirams	Special	Tracheid length	New Zealand Forest Products, Inc.
13.	Leon Pederick	Postdoctoral	Inheritance of taper and bark	Research, Victoria Forest Service, Australia
14.	Lillian Rolfo	Special	Seed qualities	Research Inst., Uruguay
15.	Wally Smith	Special	Wood properties	Research, Queensland Forest Service
16.	Klaus Stern	Postdoctoral	Quantitative inheritance	Deceased
17.	Kay von Wedel	Special	Inheritance of knots	Forester, German Forest Service

Funding of Students

A portion of industrial contributions is used each year for graduate students. Although it varies by years, we usually have six students supported in the two cooperatives from industry funds (approximately $25,000/year).

The bulk of graduate student funding comes from grant monies. Funding agencies which have supported graduate students are listed below:

Union Camp Fellowship

Weyerhaeuser Fellowship

St. Regis Fellowship

Ford Foundation

Gunnar Nicholson Fellowship

A. I. D. monies

NASA

F. A. O.-United Nations

Kellogg Foundation

Rockefeller Foundation

National Science Foundation

National Institute of Health

N. C. Agri. Experiment Station

State funds, School of Forest Resources

Many home governmental funds for foreign students

MISCELLANEOUS

Supportive Research

An item of unfinished business left over from the 1976 Blue Ribbon Committee Report pertains to the Cooperative Tree Improvement Program's supportive research effort. Questions concerning how intense this effort should be and what priorities should be placed on different projects were left undetermined. To help expedite this matter, the Executive Committee of the Cooperative appointed a seven-member Supportive Research Task Force to further examine the matter. The task force is made up of the following individuals:

Sharon Miller	Chesapeake Corporation--Chairman
*Jim Renfro	Container Corporation
Barry Malac	Union Camp Corporation
Bob Howell	St. Regis Paper Company
*B. W. Gibbons	Tennessee River Pulp and Paper Company
Tom Dierauf	Virginia Division of Forestry
*Bob Tucker	Continental Forest Industries

Among the considerations of the task force was a determination of appropriate research priorities. From the numerous subject areas considered, the Task Force has recommended that seed orchard management research and research to maximize genetic gain receive highest priority.

* Member of Cooperative Executive Committee

A big boost has been received from the U. S. Forest Service in terms of our supportive research activities. After some considerable discussion with various administrative personnel in the Forest Service, a commitment has been made to place an experienced quantitative geneticist on the N. C. State campus for purposes of developing a coordinated research effort between the U. S. Forest Service and the Tree Improvement Cooperative. This will allow the Cooperative to undertake some much-needed work that could not otherwise be accomplished. Such a collaborative effort will be of great value for both the U. S. Forest Service and the Cooperative Program. It promises to be a most productive association.

Staffing

We have operated under our reorganized staffing arrangement for nearly 18 months and all seems to be functioning about as well as could be expected. One addition to our professional staff has been made. Effective January, 1978, John Talbert joined us as liaison geneticist. Bob Weir, as Director, has assumed the policy development and administrative responsibilities formerly held by Bruce Zobel. John Talbert, in turn, is picking up much of the quantitative genetics, experimental design, and analysis responsibilities formerly under Bob Weir. We also welcome some new people on board in the secretarial, laboratory and data processing sections. Our complete staffing is currently as follows:

Faculty Level Staff

Bob Weir	- Director
J. B. Jett	- Associate Director
Jerry Sprague	- Liaison Geneticist
John Talbert	- Liaison Geneticist
Bruce Zobel	- Professor, Forest Genetics (only part-time with Cooperative)

Support Staff

Laboratory and Field Technicians	Secretarial
*Vernon Johnson, Coordinator	*Martha Holland, Coordinator
*Martha Matthias	*Carolyn Cobb
*Addie Byrd	*Margaret Funderburg
*Ray Mann	
*Mike Williford (Part-time Student)	

Data Processing

Alice Hatcher, Coordinator

*Maude Hardee

*Individual's time and financial support shared by Tree Improvement and one or more other cooperative programs

PUBLICATIONS BY OR OF SPECIAL INTEREST TO MEMBERS OF THE COOPERATIVE

Blair, R., B. Zobel, R. G. Hitchings and J. B. Jett. 1976. Pulp yield and physical properties of young loblolly pine with high-density juvenile wood. Applied Polymer Symp. No. 28:435-444.

Bridgwater, F. E. 1977. Objectives of industrial tree improvement programs. Tappi 60(6):78-80.

Gibson, G. E. and E. C. Sossaman. 1976. Fifteen-year results on a sweetgum spacing study. Tree Planters Notes, USDA For. Ser. 28(1):18-20.

Goddard, R. E., B. J. Zobel and C. A. Hollis. 1975. Response of southern pines to varied nutrition. Physiological Genetics Conf., Edinburgh, Scotland. July. 13 pp. Tree Physiology and Yield Impr. pp. 449-462.

Gregory, J. D. and C. B. Davey. 1977. Subsoiling to stimulate flowering and cone production in a loblolly pine seed orchard. Southern Jour. of Applied Forestry 1(2):20-23.

Hunt, R. and B. Zobel. 1977. Developing frost-hardy Eucalyptus for the southeast coastal plain. South. Jour. App. For.

Hunter, C. 1978. An electrophoretic analysis of isoenzyme variation in a Piedmont loblolly pine seed orchard. M. S. Thesis, School of Forest Resources, N. C. State Univ. 47 pp.

Jett, Jr., J. B., R. J. Weir and J. A. Barker. 1977. The inheritance of cellulose in loblolly pine. TAPPI For. Biol. Comm. Meet., June 20-22, 1977, Madison, Wis. 4 pp.

Kang, Hyun-Chung. 1978. Limits of artificial selection under various mating systems. (Under the direction of Gene Namkoong and Bruce J. Zobel. Ph. D. Thesis, School of Forest Resources, N. C. State Univ. 140 pp.

Kellison, R. C. 1977. Changing philosophies of hardwood management. Paper prepared for second symposium on southeastern hardwoods. Dothan, Ala. Apr. 20-22, 1977. 7 pp.

Kellison, R. C. 1977. Promises and problems of the forest industry in Latin America. Speech given to Wood Pulp Section, Canadian Pulp and Paper Assoc. Meet., Feb. 2, 1977. 10 pp.

Kellison, R. C. 1977. Silvicultural impacts on production forestry in the South. Paper presented at 56th Ann. Meet., SAF, Appalachian Sec. Jan. 26-28, 1977. Richmond, Va. (in press) 10 pp.

Kellison, R. C. and J. B. Jett. 1977. Species-site relationships of pines and hardwoods in the Atlantic Coastal Plain. Paper presented to Soil Moisture-Site Index Symp., Myrtle Beach, S. C. Nov. 1-3. (In Proceedings)

Kellison, R. C. and B. Zobel. 1975. Genetics of Virginia pine. USDA For. Ser. Res. Paper WO-21. U. S. Govt. Printing Off., Washington, D. C. 10 pp.

Kellison, R. C. and J. B. Jett, Jr. 1977. Species selection for plantation establishment in the Atlantic Coastal Plain and Sandhills provinces. Paper presented at the Soil Moisture-Site Productivity Symp., Myrtle Beach, S. C. Nov. 1-3, 1977.

McCall, Early. 1978. Conelet abortion in longleaf pine. M. S. Thesis, School of Forest Resources, N. C. State Univ.

Matziris, D. I. and B. J. Zobel. 1976. Effects of fertilization on growth and quality characteristics of loblolly pine. Forest Ecology and Management 1(1):21-30.

Mott, R. L., R. H. Smeltzer, A. Mehra-Palta and B. J. Zobel. 1977. Production of forest trees by tissue culture. Tappi 60(6):62-64.

Owino, F. and B. Zobel. 1977. Genotype-x-environment interaction and genotypic stability in loblolly pine I. General introduction and description of the experiment. Sil. Gen. 26(1):18-21.

Owino, F. 1977. Genotype-x-environment interaction and genotypic stability in loblolly pine II. Genotypic stability comparisons. Sil. Gen. 26(1): 21-26.

Powers, Jr., H. R. and B. J. Zobel. 1977. Fusiform rust resistance of progeny from specific loblolly pine clones from different seed orchards. May. South. Jour. App. For. 1600-12.

Roberds, J. H., G. Namkoong and C. B. Davey. 1976. Family variation in growth response of loblolly pine to fertilizing with urea. Forest Sci. 22(3):291-299.

Smith, H. D. 1977. Economically optimum spacing and site preparation for slash pine plantations and comparison with hardwood plantations. Ph. D. Thesis, School of Forest Resources, N. C. State Univ. 181 pp.

Smith, H. D. and G. Anderson. 1977. Economically optimum spacing and site preparation for slash pine plantations. Tech. Rept. No. 59. 104 pp.

Sprague, J. R. and V. W. Johnson. 1977. Extraction and storage of loblolly pine (Pinus taeda) pollen. Proc., 14th South. For. Tree Impr. Conf. 8 pp.

Sprague, J., J. B. Jett and B. J. Zobel. 1978. The management of southern pine orchards to increase seed production. Symp., North American Forest Biol. Workshop, Gainesville, Fla. March.
Symp. on Forest Tree Seeds, IUFRO Workshop, Starkville, Miss. May.

Squillace, A. E., D. G. Nikles and L. C. Saylor. 1977. Monoterpene composition in cortical eleoresin of Pinus caribaea and relation to P. elliottii of Florida. Third World Consultation on Forest Tree Breeding, Canberra, Aust. Session 2: Advances in Species and Provenance Selection. 19 pp.

Ståhl, P. H. 1978. Interfamily competition in loblolly pine (Pinus taeda L.). Ph. D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 127 pp.

Weir, R. J. 1977. Genetic variation in loblolly pine (Pinus taeda L.) tolerance to ozone. Ph. D. Thesis, School of Forest Resources, N. C. State Univ., Raleigh. 88 pp.

White, T. L., H. G. Harris, Jr. and R. C. Kellison. 1977. Conelet abortion in longleaf pine. Repr. from Canadian Jour. of For. Res. 7(2):378-382.

Williford, M., R. A. Brown and B. J. Zobel. 1977. Wide crosses in the southern pines. South. For. Tree Impr. Meet., Florida. 12 pp.

Zobel, B. J. 1976. Will timber resources of the southern United States meet the demands? Paper given at Annual Meeting, TAPPI, February. Tappi 60(6):51-53.

Zobel, B. and M. Zoerb. 1976. Reducing fusiform rust in plantations through control of the seed source. Proc., Symp. on Management of Fusiform Rust in Southern Pines, Univ. of Fla. December. pp. 98-109.

Zobel, B. 1977. Increasing southern pine timber production through tree improvement. South. Jour. of Applied Forestry 1(1):3-10. February.

Zobel, B. J. 1977. Intensive forest management and the quality of the wood supply in the southern pine region. Southern Pulp and Paper Manufacture 40(5):24-28.

Zobel, B. 1977. Tissue culture as seen by a plant breeder. Panel discussion at the Forest Biol. Meet., Madison, Wis. June 22. Tappi 61(1): 13-15.

Zobel, B. and C. B. Davey. 1977. A conservation miracle. Alabama Forest Products 20(5):5-6.

Zobel, B. 1978. Progress in breeding forest trees--the problem of time. Breeders Roundtable, Kansas City, Mo. May.

Zobel, B. 1978. Gene conservation--as viewed by an applied forest tree breeder. (In press) Ecology and Forest Management. 10 pp.

Zobel, B. J. and R. C. Kellison. 1978. The importance of genotype-x-environment interaction in southern pine forestry. Paper to be given at 8th World For. Cong., Indonesia, October.

Zobel, B. J. and R. C. Kellison. 1978. The rate of growth syndrome. Silvae Genetica (In press)

Zobel, B., J. B. Jett and Roy Hutto. 1978. Improving wood density of short-rotation southern pine. Tappi 61(3):41-44.

Zobel, B. 1978. World timber supplies and effect on the southern pine region. Mimeo Rept. 25 pp.

Membership of Tree Improvement Cooperative

Organization	States Where Operating
American Can Company	Ala., Miss.
Brunswick Pulp Land Company	S. C., Ga., Tenn.
Bowaters	Catawba Timber Co.--S.C., N.C., Va., Ga. Hiwassee Land Co.--Tenn., Ga., Ala., Miss., N. C.
Champion International	Alabama Region--Ala., Tenn., Miss. East Carolina Region--N.C., Va. West Carolina Region--S.C., N.C., Ga.
Chesapeake Corporation of Virginia	Va., Md., Del., N.C.
Container Corporation of America	Ala.
Continental Forest Industries	Savannah Div.--S.C., Ga. Hopewell Div.--N.C., Va.
Federal Paper Board Co., Inc.	N.C., S.C.
Georgia Kraft Company	Ga., Ala.
Georgia-Pacific Corporation	Va., N.C., S.C., Ga., Fla.
Great Southern Paper Company	Ga., Ala., Fla.
Hammermill Paper Company	Ala.
International Paper Company	S.C., N.C., Ga.
Kimberly-Clark Corporation	Ala.
MacMillan-Bloedel Corporation	Ala., Miss.
Masonite Corporation	Miss.
North Carolina Forest Service	N.C.
Rayonier Inc.	Fla., Ga., S.C.
Scott Paper Company	Ala., W. Fla., Miss.
South Carolina State Commission of Forestry	S.C.
St. Regis Paper Company	Ala., Miss., W. Fla., Ga.
Tennessee River Pulp and Paper Co.	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--S.C. North--Va., W. Va., Ohio, Tenn., Ky., Miss.
Weyerhaeuser Company	N. C. Div.--N.C., Va. Miss.-Ala. Div.--Miss., Ala.

. . . after one year as Director of the Cooperative . . .