EIGHTEENTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

June, 1974

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Cooperative Hardwood Research Program

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FOREWORD

The past year was one of the best for the forest industry in the history of our program; prices were good, demand for forest products was high, and an air of optimism was generally evident, at least early in the year. The general attitude toward forest management was much different from the previous year, with an evident renewed interest in hardwoods and a rapid expansion of activities in pine tree improvement. However, even with excellent markets for paper and a good demand for solid wood products, there were concerns due to transportation difficulties, labor problems, shortage of raw materials, heavy expenditures for environmental controls, and price controls.

An especially important element affecting the availability and cost of timber was the "explosion" of chipping saw installations, plywood plants, and other solid wood-using plants. These are placing heavy pressure on local timber supplies, and the result has been very high bidding even for what in the past has been considered pulpwood timber. An equally important development has been the rather general acceptance of "total-tree" logging and utilization of the "dirty" product produced when bark, limbs and leaves are chipped together. The energy shortage has produced some unique developments and has brought into sharp focus the wastage of energy in the form of unused wood in a typical logging operation and the value of trees as a readily renewable resource.

When all is taken into account it was a good year for the Cooperative, with good support for studies needed but with greater emphasis on the necessity for increased timber production on each acre. Because of the high price of food products and competition for best quality forest lands, a greater effort is being placed on growing merchantable forest crops on land now economically marginal for production of forest products.

Rather than being relaxed, the attempt to speed up the use of genetically improved trees and to increase yields from forest lands has intensified. Several members of the Cooperative undertook extensive, and in some instances basic, studies which supplement the broader programs of the Cooperative. As a result, information will be available in the next few years that is very badly needed for an efficient intensification of efforts to increase yields and quality from the forest resource.

The policy of the Cooperatives has generally been to "hold the line" as far as new members are concerned. Since we are reaching the limit of manpower and facilities, only the most progressive and productive organizations have been considered for membership; during the past year we declined a number of requests but accepted two new members and one additional working unit of a current member. As of now the Cooperatives consist of the following members:

Pine		Hardwood	
Members	Second Working Units 1/	Members	Second Working Units 1/
26 forest industries	6 forest industries	16 forest industries	4 forest industries
3 state forest services		1 state forest service	
		1 research council	

1/ A second working unit is essentially another company, since geographic area and operating organizations are quite different. All members of the Hardwood Cooperative are also members of the Pine Cooperative except the Hardwood Research Council. In total, 26 different industries, 3 states, and 1 council are members of either or both cooperatives; the additional second working units mean that 32 separate operating industrial organizations are serviced by the Cooperative in 13 southeastern states.

Each year, we emphasize a different theme for the annual report. This year, because of a great deal of good information, emphasis in this Eighteenth Annual Report will deal with economic aspects of tree improvement and hardwood management.

THE COOPERATIVE TREE IMPROVEMENT PROGRAM--PINE

General

The most important activities in the pine program involve testing and development of improved pine seed for advanced-generation or specialty orchards. Establishment of such orchards is underway on a large scale; the Cooperative now has specialty orchards for growth rate, for wood, for problem environments, for pest resistance and other conditions for which normal trees are not suitable. Second-generation orchards are now being established on an operational scale by many members of the Cooperative.

The past year was a year of contrasts. We experienced good seed crops, superb growth on most progeny tests (some 4- and 5-year tests grew an average of over five feet in height during the year), and several important wood studies were completed; we also had the greatest damage ever from tornadoes, ice storms, fires, and cone and seed insects. In retrospect, we have been lucky that more catastrophes have not hit, considering that we have a total of 171 seed orchards scattered in the 13 southeastern states. Several times hurricanes have woven in and around the orchards, and tornadoes or ice storms have stopped just short of, or jumped over, an orchard, resulting in minimal damage where complete destruction could easily have occurred. In 1971 and 1972 the cone collection season was long and "relaxed" because of favorable weather, but in 1973 weather conditions caused fast maturity and early ripening of cones. The 1973-1974 winter was unusually warm so the generally very heavy crop of pine flowers developed too early, with some being destroyed by the cold weather which followed.

High stumpage prices, periodic low inventories at the mills, and a shrinking land base all combine to make intensive pine management seem more attractive. This has resulted in speeded-up planting programs with more intensive site preparation and the use of fertilizers, all of which make the need for genetically improved stock more urgent. Tree farming of pines is a fact, no longer an idealistic goal, and one that increasingly looks more profitable.

Seed Orchards

The major objective in the pine program is to produce maximum quantities of genetically improved seed as quickly as possible. First-generation orchards have developed well and rapidly; we obtained enough seed for nearly 150,000,000 trees in 1973 from the 2700 acres contained in the 171 seed orchards now established, even though over 30 percent of the orchards are still too young to produce commercial cone crops (See Table 15). We estimate that by 1978 or 1979, if all goes well, enough seed will be produced to supply all the needs for the 300,000,000 trees (400,000 acres) planted annually by members of the Cooperative.

The objective of a seed orchard is to produce cones and seed, as in this orchard of the North Carolina Forest Service. The Cooperative produced enough seed to grow 150,000,000 genetically improved seedlings in 1973. Problems such as insect damage and difficulty of cone collection are challenges, but overall difficulties are few.

Table 15. Acreages of the 171 seed orchards established by members of the N. C. State University Pine Cooperative as of January 1, 1974

	Orchard Acreage by Generation and Type					
Species and Source	First-Gen.	1.5-Gen.	Second-Gen.	Disease Resistance	Other Specialty	Total
Vegetative Orchards:						
Coastal Loblolly	1106.5	90	21	39.5	13.5	1270.5
Piedmont and Mountain Loblolly	808.2	75	7	30	5	925.2
Slash	490	50	-	5	-	545.0
Longleaf	75	-	-	-	-	75
Virginia	75	-	-	-	-	75
White Pine	62	-	-	-	-	62
Sand Pine	37	-	-	-	-	37
Pond Pine	32	-	-	-	-	32
Shortleaf Pine	23	-	-	-	-	23
Pitch Pine	4	-	-	-	-	4
Spruce Pine	3	-	-	-	-	3
Sycamore	8	-	-	-	-	8
Sweetgum	15	-	-	-	-	15
Yellow-Poplar	7	-	-	-	-	7
Seedling Orchards:						
Fraser Fir (4)	4	-	-	-	-	4
Virginia Pine (12)	12	-	-	-	-	12
Total	2761.7	215	28	74.5	18.5	3097.7

The largest single seed orchard complex has been established by the state of Virginia. They have the following:

Species and Source	Acreage	Number of Living Grafts
Loblolly Pine--Coastal Plain	179	16,650
Loblolly Pine--Piedmont	172	16,760
Virginia Pine	15	1,560
Shortleaf Pine	8	1,040
White Pine	38	4,060
Total	412	40,070

Soon all seed needs for the states of Virginia, South Carolina and North Carolina will be filled with genetically improved seed from seed orchards. Improved stock will then be generally available to small landowners as well as the large industrial concerns that are members of the Cooperative.

Of greatest interest is the expansion in advanced and specialty orchards. Already 215 acres of 1.5-generation orchards have been established and this figure will double within the next two years. Although only 28 acres of second-generation orchards are now in the ground, within several years there will be over 200 acres established; this activity will be on a definite up-swing as more selections are obtained from the progeny tests. The specialty orchards, of which we already have nearly 100 acres, such as disease resistance, wet site-tolerant, drought-tolerant, two-clone and others, are also rapidly expanding.

Cone and Seed Yields

Considerable concern has been expressed about a supposed drop in cone and seed production from seed orchards, usually accompanied by a drop in germination rate of the sound seeds that are obtained. At least for loblolly pine and the more northern slash pine orchards, this concern is not warranted. Yields are generally good although we expect cone crops to fluctuate from year to year due to numerous causes. Most common of these are freezes at time of pollination; we had severe losses from the 1971 freeze, and less severe losses from the 1972 freeze. Resulting cone crops vary as shown by the four-year data, made available to us by Westvaco Corporation, summarized in Table 16. Despite the rather severe freeze in 1973 it appears the 1974 cone crop will be better than the 1973 crop.

Table 16. Cone production for Westvaco Corporation Production Seed Orchard at Summerville, South Carolina

Year Grafted	Acreage	Bushels of Cones Collected 1970	1971[1/]	1972[1/]	1973[1/]
1963, 1964	10.4	203	524	60	184
1965, 1966	12.2	48	228	73	222
Total	22.6	251	752	133	406

[1/] Freezing weather caused loss of flowers.

Total production from seed orchards in the Cooperative is reported each year (Table 17). The yields per bushel for 1972 are compared with the 1973 crop. It appears now as if 1974 will be very good. As orchards mature and our knowledge about care of orchards increases, seed yields increase annually in spite of natural disasters.

Table 17. Cone and seed yields in 1973 from pine seed orchards of the Cooperative, compared to 1972 1/

	Bushels of Cones	Pounds of Seed	Pounds of Seed/ Bushel of Cones
Coastal Source Loblolly Pine	7812	8457	1.08
Piedmont and Mountain Source Loblolly Pine	4041	4331	1.07
Slash Pine	2779	1615	.58
Virginia Pine	214	72	.34
White Pine	66	11	.17
Longleaf Pine	4	3	.75
Shortleaf Pine	47	21	.45
Total	14,963	14,510	---

[1/] In 1972 we obtained 8,491 bushels of cones from loblolly and slash pines. These averaged 1.06 pounds/bushel for coastal loblolly, .84 pounds/bushel for Piedmont loblolly, and .60 pounds/bushel for slash pine.

We take extreme caution in a seed orchard to prevent self-pollination within the same clone. The reason is dramatically shown in this progeny test of Kimberly-Clark in which the selfed row (center) will soon be killed by suppression from the more vigorous crosses.

Looks like a disaster? Yes, but it's merely the roguing of a Continental Can Corporation seed orchard in Georgia. Based upon performance of their progeny, the best parents are left in the seed orchard and the poor ones are removed. Such roguing can improve the superiority of seed orchard seed over commercial stock by 5 to 8 percent or more.

Because of the high value of genetically improved seed, there is increasing attention to the yield and quality of seed from seed orchards. Some losses are caused by disease such as cone rust, but a great deal is from a combination of the numerous insects that attack flowers, cones and seeds. Much of the yield differences among clones are genetically caused by inherent differences in fruitfulness along with differences in clonal susceptibility to damage by pests.

Every member of the Cooperative shares in the concern to increase seed yields, and some have recorded detailed data by clone to use as a guide in seed orchard management. Such information is vital; for example, one company found that in 1971 half of their cone production came from one clone that yielded only 6 seeds per cone. Luckily this same clone yielded 27 sound seeds per cone in 1972, still low but encouraging relative to the average of approximately 50 sound seeds per cone generally obtained.

Many of the seed data are obtained through services of the S.O.S.[1/] and S.O.S.E.T.[2/] programs sponsored by the U. S. Forest Service Seed Laboratory at Macon, Georgia. Seed yield patterns vary, whether on poor or good years, especially in relation to damage by pests. This is illustrated by three years' data for loblolly pine from twenty members of the Cooperative (Table 18). It is evident that our rule-of-thumb of 30 seedlings per cone is too conservative.

[1/] Seed Orchard Survey

[2/] Seed Orchard Survey Establishment Tests

Table 18. Three-year loblolly pine cone and seed yields summarized for members of the Cooperative

	Year-Cone Crop	Cones/ Bushel		Total Seed/ Cone		Percent Full Seed		Percent Germ.[4/] Full Seed	
		Avg.	Range 3/	Avg.	Range 3/	Avg.	Range 3/	Avg.	Range 3/
S.O.S.[1/] Results:									
	1971--Good	254	141-407	75	48-94	76	50-87	94	86-99
	1972--Poor	241	108-393	68	20-106	66	37-85	86	63-97
	1973--Fair	262	176-356	84	60-119	70	46-86	95	82-89
S.O.S.E.T.[2/] Results:									
	1972--Poor	-	-	83	51-107	70	40-86	89	78-97
	1973--Fair	-	-	83	50-124	77	62-90	97	87-99

1/ Seed Orchard Survey

2/ Seed Orchard Survey Establishment Tests

3/ Data on ranges give an estimate of the huge clonal variability.

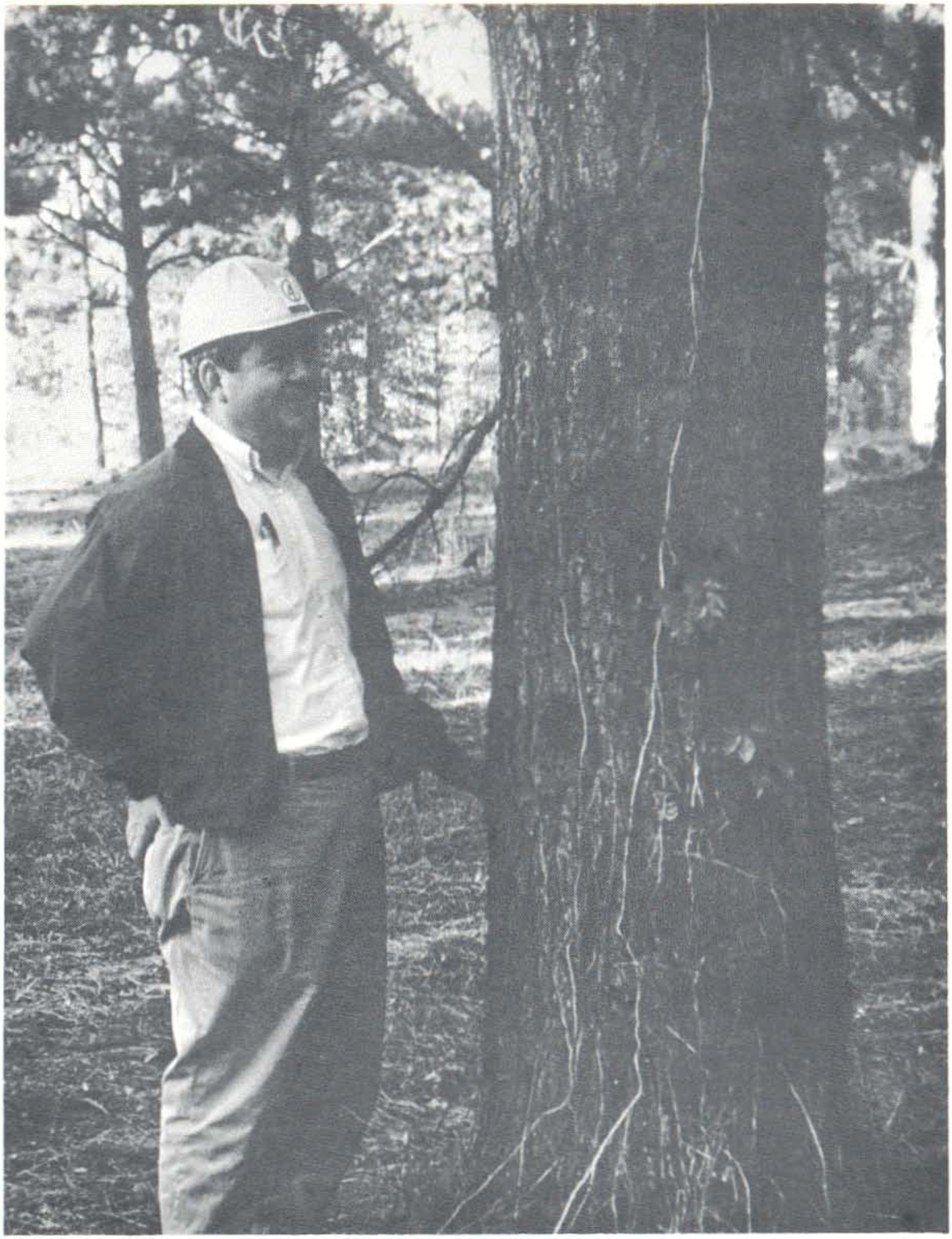
4/ Percent germination of sound seed

Some members of the Cooperative are obtaining seed data in addition to S.O.S. and S.O.S.E.T. for all clones in their seed orchards. For example, the North Carolina Forest Service obtained the data shown in Table 19 for their Piedmont seed orchard.

Table 19. Seed and cone characteristics for the N. C. Forest Service Piedmont seed orchard

	Number Seed/ Cone	Number Seed/ Pound
Mean	69	15,779[1/]
Range	8 - 123	11,077 - 23,092

1/ Values are somewhat higher than normal because several of the clones in the orchard are pond-loblolly hybrids which produce small seed.



Growth of loblolly pine grafts has been exceptionally rapid, as can be seen by this 16-year-old graft of International Paper Company in South Carolina. This orchard is supplying the planting needs for this division with genetically improved stock which grows about 15 percent faster than unimproved material.

Insect Losses

Perhaps of greatest concern to members of the Cooperative is the still very high cone mortality and seed damage from insects. This problem has not yet been solved. Its importance generally fluctuates with size of cone crop, but in some orchards losses approach 30 percent or more. According to Gary DeBarr (U. S. Forest Service), who has worked closely with the Seed Protection Committee of the Cooperative, the actual losses are much greater than realized because of undetected destruction of seed and unmeasured losses of flowers and yearlings. Even though only a fraction of the losses due to insects can be measured directly as insect-damaged cones and seeds, insect losses detected by S.O.S. and S.O.S.E.T. are of considerable interest (Table 20).

Table 20. Insect damage detectable by measurements from S.O.S. and S.O.S.E.T.

	S. O. S.				S. O. S. E. T.	
	Percent Insect-Damaged Cones		Percent Insect-Damaged Seed		Percent Insect-Damaged Seed	
Year	Avg.	Range	Avg.	Range	Avg.	Range
1971	6	0 - 27	8	2 - 18	--	--
1972	12	2 - 43	14	4 - 66	9	3 - 22
1973	11	1 - 24	12	3 - 27	5	1 - 8

Because of the seriousness of insect losses, a Seed Protection Committee was formed within the Cooperative. This group, chaired by Norm Johnson of Weyerhaeuser, has been very active. A unified study design was developed and tests were made by 15 members of the Cooperative; these consisted of Gardona, Thimet, and a check. Results are now available but are somewhat inconsistent. In general, results were:

1. Gardona appeared partially successful against Dioryctria (cone worm), especially in the more northern orchards.

2. Thimet produced spotty results, being good in some orchards but not in others. Thimet was generally the best against seed-bug damage, often reducing losses considerably, relative to the Gardona or check treatments.
3. It is obvious that better and more consistent chemicals are needed.

The Seed Protection Committee has outlined additional tests for 1974-75. A promising new systemic, Furadan, will be tried in several orchards along with Guthion, Gardona and Thimet. Close liaison is being maintained with other groups working on this problem, to achieve a regionwide, broadly based attack on seed and cone insects.

The Cooperative has been most fortunate in that Bob Weir has been placed on several committees dealing with use of chemicals in forestry, including chemicals to control seed and cone insects. He is able to keep members of the Cooperative fully up to date on legislation and new results, including chemicals such as 2-4-5-T. We have found that group action, in which the Cooperative speaks collectively for its members, is much more effective than when each organization tries to get action alone.

Seed Orchard Irrigation and Fertilization

Several members of the Cooperative have established irrigation systems in their seed orchards, based on results of several years' studies by Catawba Timber Company, Hoerner-Waldorf Corporation, and others. Generalizations about the effect of irrigation are as follows:

1. In dry years, irrigation can be most beneficial, sometimes increasing yields as much as fourfold. Since nearly three growing seasons are involved in the development of a seed crop, care is necessary in assessing the value of irrigation. This is illustrated by results from Catawba

Timber Company's study in very wet 1973 which showed considerable cone production improvements over the checks (Table 21). The most important time to irrigate seems to be when flower buds are being initiated, which occurred in summer 1971 for the 1973 crop.

2. Irrigation without fertilization is generally not very beneficial. Fertilization alone results in greater seed yields than does irrigation alone, but the combination is always the best, especially in dry years.
3. Seed yield per cone and seed quality are only slightly affected by fertilization and irrigation.

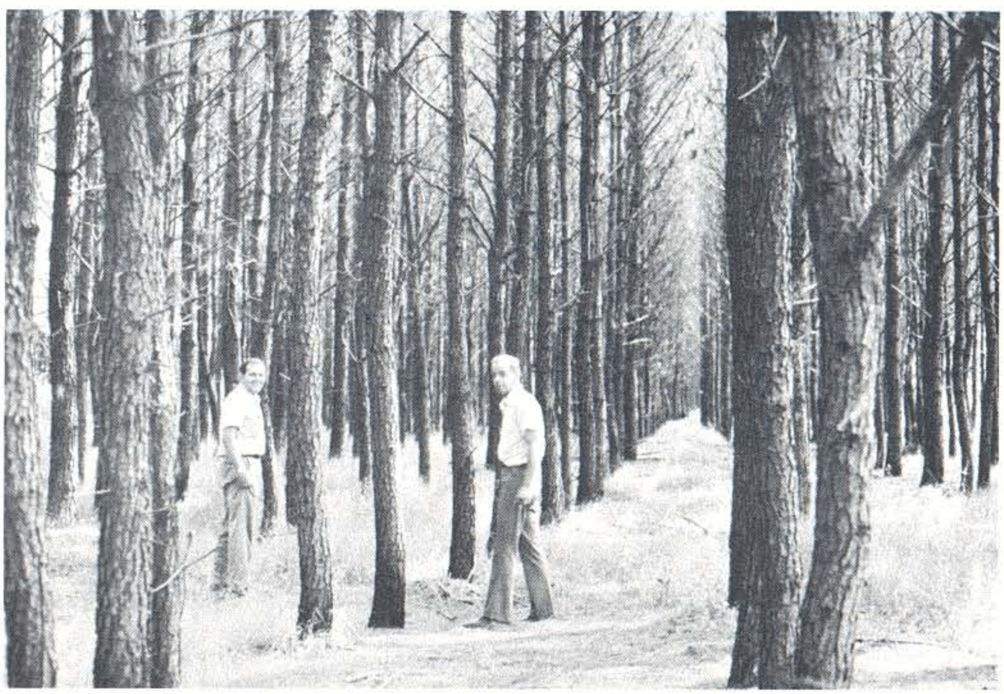
Table 21. Cone yields in 1973, by treatment, for loblolly pine in the orchard of Catawba Timber Company

Treatment	Cones per Tree	Percent Improvement Over Check
Check	44	--
Fertilizer alone	55	26
Irrigation alone	55	26
Fertilization and Irrigation	63	43

The Virginia Division of Forestry has carried on studies of the effects of different kinds of fertilization in their seed orchards for a number of years. The results obtained in 1973 can be summarized as follows:

1. Fertilization generally increased seed production; the highest NP levels resulted in greatest seed yields (47% above the checks), while the low fertilizer levels were not much better than the checks.
2. The N-only and P-only treatments gave the same results as the unfertilized check.
3. There are much larger differences among clones than among fertilizer treatments. For example (across all clones), cones per tree varied with treatment from 25.2 to 97.3. Differences among clones (over all treatments) varied from 30.4 to 179.1 cones per tree.

Insect damage to cone crops is a serious problem and considerable research has been done to determine how to control it. The Seed Protection Committee sponsored tests in 15 seed orchards. Shown is a test tree in the South Carolina Forest Service seed orchard. Progress is being made.



Conversion of marginal sites to productive forests is one major objective of the Cooperative. This vigorous loblolly stand in the Green Swamp on Federal Paper Board Company's lands in North Carolina has achieved this without benefit of genetically improved stock. However, many sites are so marginal that such conversion would not be possible without specially bred stock.

It is clear that if maximum cone production is to be obtained, fertilization is a necessity. In a study by graduate student Saja Manan, it was found that seed orchard fertilization had little effect on percent germination, germination value, or percent filled seed; however, differences in these values were very distinct from clone to clone.

The Value of Seed

Cooperative members have had several ideal years for cone collection, but the fall of 1973 was adverse, with the cones ripening and opening rapidly. A number of members of the Cooperative were caught by the fast development and a few organizations lost over 200 bushels of cones because they did not gear up soon enough to collect the cones before they opened.

The loss of seed precipitated several members of the Cooperative to inquire as to the value of seed from seed orchards. Don Smith prepared Table 22 to illustrate the value of one pound of genetically improved seed based upon the worth of the extra wood produced at the end of the rotation, discounted to present value. He prepared two case studies having two growth rates for a 25-year rotation, one for conditions of good seed-to-plant ratio at relatively wide plantation spacing, the other for a poor seed-to-plant ratio using higher-density plantation conditions. The two examples fairly well bracket the extremes of conditions found within the Cooperative.

We are obtaining improvements in yield of 10 to 20 percent or more. Stumpage prices are very high in some parts of the South. To illustrate the value of seed with a 20 percent improvement and stumpage value of $40, Don found that the present value of a pound of seed is worth $1,051, using an 8 percent rate of interest. No matter what assumptions are made, seed orchard seed is very valuable and considerable effort is justified to assure maximum production and a reduction in loss to pests or adverse climatic conditions.

Table 22. Present value of additional wood obtained from one pound of seed orchard seed for several stumpage values, two growth rates, and two combinations of nursery production, genetic gain, and plantation stocking

Case 1

1. One pound of seed produces 9,000 plantable seedlings.
2. 500 seedlings are planted per acre (1 lb. of seed plants 18 acres).
3. Rotation age = 25 years
4. Genetic gain = 15%.
5. Interest rate = 8%.

Stumpage Value $/cord at time of harvest	Base Growth (cords/acre/year)	
	1.5	2.0
6	$89	$118
10	148	197
12	177	236
15	221	296
18	266	355
24	354	473
30	443	591
40	591	788

Case 2

1. One pound of seed produces 7,000 plantable seedlings.
2. 800 seedlings are planted per acre (1 lb. of seed plants 8.8 acres).
3. Rotation age = 25 years.
4. Genetic gain = 10%.
5. Interest rate = 8%.

Stumpage Value $/cord at time of harvest	Base Growth (cords/acre/year)	
	1.5	2.0
6	$29	$38
10	48	64
12	57	77
15	72	96
18	86	115
24	115	153
30	144	192
40	192	255

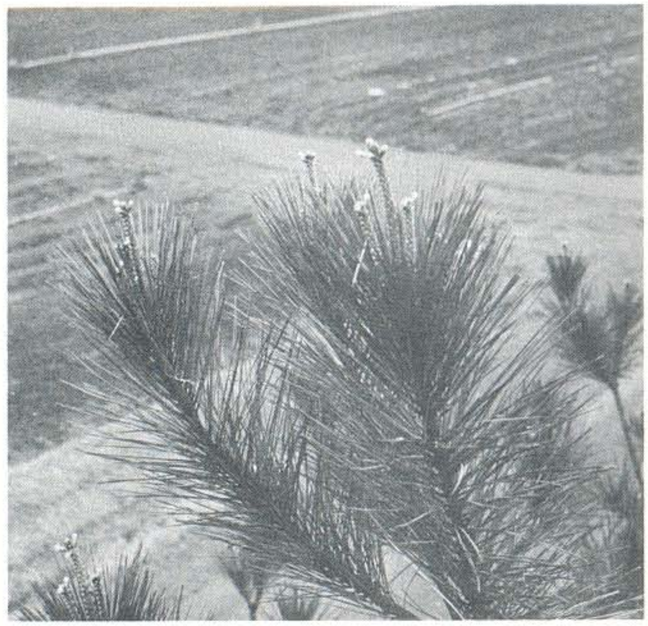
Progeny Tests

Methods and analyses of progeny tests continue to require much of our time and effort. The buildup of work from 1,670 acres of tests consisting of 15,100 lots by 1973 is so rapid it's startling (see Table 23). Economic studies have shown the necessity of progeny testing if desirable gains are to be achieved, and the magnitude of our efforts in this direction is rapidly expanding. Accurate analyses and quick turnaround are key to progress of our program. Our current data entry program has become outmoded and no longer will be available to us after next year. The most promising alternative for maintaining accuracy and quick turnaround is a portable data entry terminal that has been developed to record progeny information in the field directly on a tape cassette. The measurements will be forwarded to a receiver in Raleigh, where they are put on computer tape for immediate analysis. By eliminating the need to transfer handwritten data to typed input, turnaround time can be decreased by several months and greater accuracy achieved by eliminating errors which always occur when data are transferred. The new system will remove the need for several typists and typewriters necessary to process the more than 250,000 measurements we now assess; this will increase to 500,000 or more within the next year or two.

Table 23. Acreage planted and number of lots of control-pollinated progeny tests in the N. C. State Cooperative

Species and Geographic Location	Acreage Planted Through 1973	Acreage Planted in 1974	Total Acreage Planted
Loblolly--Coastal	701.5	96.8	798.3
Loblolly--Piedmont	481.9	92.3	574.2
Virginia Pine	47.1	18.4	65.5
Slash Pine	110.7	46.2	156.9
Pond Pine	39.3	6.7	46.0
Shortleaf Pine	12.7	4.2	16.9
Hybrid Pines	11.4	3.2	14.6
Total	1404.6	267.8	1672.4
Kind of Test			
Main	860.9	153.2	1014.1
Supplemental	516.7	111.3	628.0
Special	27.0	3.3	30.3
Total	1404.6	267.8	1672.4

A total of 15,140 seed lots and their checks have been planted.



The objective of all the work done in a seed orchard is to produce seed. Shown on a Kimberly-Clark tree is the kind of flower crop we all hope for. In spring 1974 we had the best flower crop ever in nearly all of the 177 seed orchards in the Cooperative. In a few orchards, however, flowers were injured by late spring freezes. Extent of the damage is not yet known.

Fusiform rust is a major forestry problem for Cooperative members and it drastically reduces yields. On the right is a row of trees from a disease-resistant cross; and on the left is a susceptible cross in a progeny test of Union Camp Corporation in Georgia. Over 200 acres of disease resistance seed orchard have been established.

Growth Performance

Crosses with a good (7-56) and poor (7-51) parent showed a difference of 5 feet in height, 1.1 inch in diameter, somewhat better crown form, much better straightness, much higher volume production (1.2 cords/acre/year), and higher dry weight yields of 1.1 tons dry wood/acre/year; this certainly emphasizes the value of having a good general combiner parent such as 7-56 (Table 24). It is of special interest that the cross 7-56 x 7-51 is intermediate in most characteristics. The commercial check grew faster than the 7-51 crosses, indicating how essential it is to remove poor parents such as 7-51 from production seed orchards. Another striking result was the poor growth of the Piedmont source relative to coastal sources when grown in the Coastal Plain. Although the average specific gravities did not differ, the moisture contents were higher and tracheid lengths were shorter when 7-56 was one of the parents involved in a cross.

Pulping of several trees from selected crosses has shown considerable family differences in yield and quality not directly related to specific gravity. Although only one family was tested, the fertilized trees produced lower pulp yields, despite the fact that specific gravity was the same for both fertilized and unfertilized replications. The possible effect of fertilizers on pulping qualities must be checked further.

Table 24. Growth and wood qualities of a very fast-growing, 7-year-old loblolly pine progeny test of International Paper Company in coastal South Carolina. Shown are crosses with the best and the poorest parents.

Seed Source	Height	Diameter	Crown[1/]	Straightness 1/	Cords/ Acre/ Year	Tons/ Acre/ Year	Wood Specific Gravity	Percent[2/] Moisture Content	Tracheid Length (mm)
(Poor parent 7-51)									
7-51 x 7-51	26	4.5	3.9	4.0	1.4	1.3	.38	157	3.12
7-29 x 7-51	27	5.4	4.1	3.7	1.5	1.5	.39	162	3.18
7-51 x 7-22	28	5.5	4.1	4.0	1.5	1.4	.38	173	3.16
7-51 top cross	28	5.4	3.7	3.8	1.1	1.1	.39	157	3.27
7-51 x 7-33	29	5.0	3.8	4.2	1.4	1.3	.37	179	3.13
7-51 x 7-2	30	6.1	3.5	3.8	1.5	1.4	.38	169	3.25
7-34 x 7-51	30	6.4	3.9	3.7	2.3	2.3	.40	154	3.29
Average, Parent 7-51	28	5.5	3.9	4.0	1.5	1.5	.38	164	3.20
(Good parent 7-56)									
7-56 x 7-29	32	6.4	3.9	3.2	2.5	2.4	.38	168	3.16
7-56 top cross	33	6.5	3.8	3.2	2.4	2.3	.38	172	3.00
7-56 x 7-33	33	6.8	3.4	2.9	2.8	2.6	.37	180	3.07
7-56 x 7-2	34	6.8	4.3	3.7	3.0	2.9	.39	166	3.04
Average, Parent 7-56	33	6.6	3.8	3.2	2.7	2.6	.38	172	3.07
(Good x poor Parent, 7-56 x 7-51)	32	5.9	3.5	3.5	1.7	1.6	.38	160	3.05
Seed Prod. Area Piedmont	25	4.8	3.8	3.7	1.4	1.4	.38	163	3.15
Commercial Check	30	6.2	4.5	4.3	2.0	1.9	.38	165	3.06

[1/] The higher values show heavier limbs and more crooked boles; the roughest trees by far were those in the commercial check.

[2/] Based on dry weight

Some of the progeny tests are old enough to have been thinned for the second time. One test, by International Paper Company, was thinned at 7.5 years of age and again at 11 years of age. Changes with age are very interesting, as shown in Table 25.

Table 25. Growth of 7.5- and 11-year-old open-pollinated progeny tests--International Paper Company, Georgetown, S. C.

	Specific Gravity		Growth-- Cords/Acre/Year		Growth-- Tons/Acre/Year[1/]	
Clone	7.5-Yr.	11-Yr.	7.5-Yr.	11-Yr.	7.5-Yr.	11-Yr.
7-2	.38	.42	2.3	2.7	2.1	2.8
7-18	.38	.41	2.7	3.1	2.6	3.1
7-22	.38	.41	2.1	2.7	2.0	2.7
7-29	.39	.41	2.3	2.6	2.3	2.6
7-33	.38	.41	2.5	2.8	2.4	2.9
7-34	.40	.44	2.5	3.0	2.5	3.2
7-43	.36	.41	2.3	2.8	2.1	2.8
7-52	.39	.43	2.3	3.0	2.2	3.2
7-56	.39	.43	2.6	3.2	2.5	3.4
7-58	.38	.42	2.4	2.6	2.2	2.6
7-59	.39	.44	2.1	2.9	2.1	3.1
7-62	.38	.44	1.9	2.2	1.8	2.4
7-67	.38	.41	2.3	2.8	2.2	2.8
7-70	.38	.41	2.2	2.6	2.1	2.6
7-71	.40	.43	2.4	3.3	2.4	3.5
7-72	.40	.43	2.0	2.4	2.0	2.6
Average	.39	.42	2.3	2.8	2.2	2.9

[1/] Dry wood

Clone 7-71 was the most outstanding in growth and wood density and had the heaviest dry wood tonnage yields, although 7-56 was nearly as good. Clone 7-62 is a real "loser" in this group, even though it grew over two cords/acre/year. It is of interest to note during the 3.5-year period between thinnings that, despite removal of half the stems, the plantation grew at the rate of 2.8 cords/acre/year. In another thinned, open-pollinated progeny test on a poor, eroded Piedmont soil, Champion International obtained the following (Table 26):

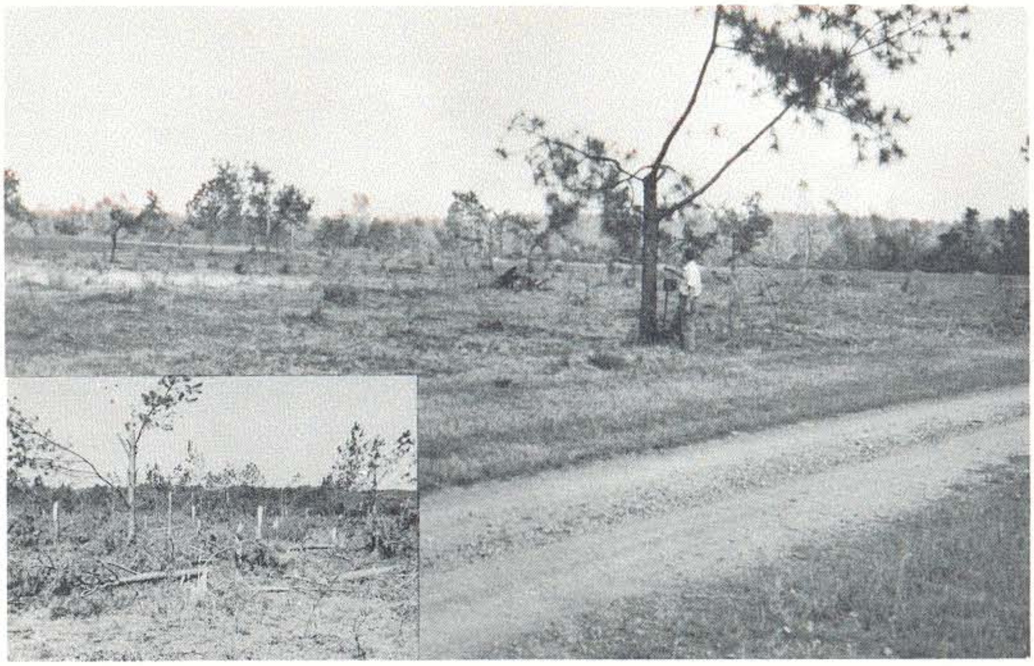
Table 26. Growth of a 9.5-year-old open-pollinated progeny test of Champion International on an eroded Piedmont soil in South Carolina

Clone	Specific Gravity	Cords/Acre/ Year	Tons/Acre/ Year (Dry Fiber)
3-25	.36	1.8	1.6
3-29	.38	1.5	1.5
3-30	.37	1.7	1.6
3-32	.36	1.7	1.5
3-34	.38	1.6	1.5
3-36	.37	2.1	1.9
3-40	.39	1.7	1.7
3-43	.36	1.3	1.2
5-8	.37	2.1	1.9
5-18	.38	1.8	1.7
7-45	.37	1.5	1.3
7-46	.38	2.0	1.9
Average	.37	1.73	1.60

An average growth rate of 1.73 cords/acre/year at 9.5 years of age on eroded Piedmont soil is very good. Note the lower gravity of the Piedmont trees relative to those from the Coastal Plain (Table 26, approximately 2 lbs./cu.ft. less); this is reflected in the cord-to-ton ratio, which is usually near 1 for trees about 10 years old.

We again received growth rate measurements for a number of clones from members of the Cooperative established in tests in Rhodesia. Results were similar to those found for the third-year measurements:

1. The more southern sources considerably outgrew the northern sources; for example, the best clone from a South Carolina coastal source was 27.4 feet tall, 4.6" in diameter; the poorest grower from the northern Piedmont was only 13.7' tall and 2.6" diameter. The general observation that geographic differences become greater under ideal growth as an exotic is again confirmed.



Disaster! The worst accident yet in the Cooperative occurred when Kimberly-Clark's seed orchard was hit dead center by a tornado. Shown (above) is a general view of the destroyed orchard after cleanup, and (inset) what it looked like just after the tornado.

Below is a photo of the destruction of progeny tests in an area adjacent to the orchard. Many years' work was destroyed in just a few moments.

2. Outstanding clones tend to maintain their superiority. For example, clone 7-56 grew fastest in both of the Rhodesian plantations and has been the best for us in the southern United States; in contrast, 7-58 was relatively poor in both exotic plantings. For bole and limb form, clone 8-27 was best in both locations, while 7-59 was one of the poorest. Many of the faster growing southern sources had the poorer tree form.

Thinning

The policy regarding thinning progeny tests is to evaluate each one separately and thin when there is need. One of the fastest growing tests, a supplemental test of International Paper Company in South Carolina, was thinned after seven years' growth, using a combined silvicultural and spacing method that removed half the trees. In addition to regular measurements for all trees, wood properties were determined on the cut trees and selected families were pulped. Depending on survival and disease incidence, 9 to 15 trees per family were removed and analyzed for wood qualities, with 15 of the 30 planted per family being left. There have been questions as to a bias that might be caused by such a thinning; the concern is that the variable and poor families would be considerably upgraded by removal of the poorest trees compared to removal of the poorest trees from the best, most uniform families. A test was made to see whether a strong bias was introduced, and, in fact, it appeared to be small--see the rankings in Table 27 for the better and poorer growth families in the study.

Table 27. Ranking of crosses before and after thinning, illustrating the small changes that took place

Family	Volume: Rank Before Thinning	Volume: Rank of Trees Left After Thinning	Crown Form: Rank Before Thinning	Crown Form: Rank of Trees Left After Thinning
Best Crosses:				
7-56 x 7-2	1	1	8	8
7-56 x 7-33	2	3	1	1
7-56 x TC 1/	3	2	4	3
7-56 x 7-29	4	5	5	4
Poorest Crosses:				
7-51 x TC 1/	16	17	3	5
7-29 x 7-51	17	19	6	6
7-51 x 7-33	18	18	4	4
7-51 x 7-51	19	16	5	7

1/ Top cross (pollen mix)

Wood Properties

Interest in wood quality is constantly increasing, especially since recent economic studies have shown that specific gravity is a key characteristic if major gains in cellulose yields are to be achieved through breeding. For those organizations interested in wood qualities, the first progeny thinning gives an ideal chance to determine wood properties and to obtain yields in tons of dry fiber as well as in volume growth.

The first thinning of Cooperative control-pollinated progeny tests was done at the Eight Oaks supplemental plantation of International Paper Company at Georgetown, South Carolina. This supplemental test had grown very rapidly and was thinned after seven years' growth (Table 24). Wood qualities were determined from each of five trees (sometimes as few as three trees) thinned from each of three replications, for a total of 15 trees sampled. One "replication" was an unfertilized check, one was heavily fertilized, and one received light (optimal) fertilization. Wood was analyzed for all families for which sufficient trees were available. Specific gravity and moisture content were determined by sampling so that weighted tree values could be determined. Tracheid length was measured only for the top of the first five-foot bolt.

Among the 20 families analyzed, specific gravities ranged from .367 to .397, moisture content from 154 to 182 percent, and tracheid length from 2.91 to 3.29 over all three replications. In this study, the effect of fertilization on wood properties could be determined; average results are shown in Table 28.

Table 28. Wood properties for the thinned, 7-year-old control-pollinated loblolly pine progeny test of International Paper Company at Georgetown, South Carolina, as affected by fertilization

	No Fertilization (Check)	Moderate (Optimal) Fertilization	Heavy Fertilization	Average of all Treatments
Specific Gravity	.390	.372	.384	.381
Moisture Content (%)	161	172	164	167
Tracheid Length	3.10	3.10	3.08	3.10
Height (Ft.)	29.4	30.8	30.5	30.2
Diameter (In.)	5.9	6.1	6.1	6.1
Dry fiber/tree (Lbs.)	64.8	69.2	70.7	68.2

It is obvious that on this excellent site, fertilization has had only a small effect on wood properties, with the fertilized trees having somewhat lower specific gravity than the checks. Clearly, cellulose production changes are almost directly related to growth effects of the fertilizer, and the slight fall in specific gravity is more than offset by increased volume. Tracheid lengths on the 7-year-old trees were not affected by fertilizers.

Seed orchards produce well-formed trees with good growth. This eleven-year-old loblolly pine plantation of Westvaco Corporation in South Carolina has been thinned twice; it is now growing at more than three cords/acre/year.

Although individual cross differences in specific gravity varied widely from .361 to .406, the three parental clones with enough crosses to make a meaningful assessment of wood values had nearly identical specific gravities but, as expected, were higher than the commercial checks.

	Progeny Specific Gravity
Open-pollinated seed orchard	.392
7-51	.384
7-2	.382
7-56	.380
Commercial checks	.373

A recent analysis of specific gravity from a loblolly pine progeny test of Union Camp Corporation in Virginia showed some interesting trends (Table 29).

Table 29. Specific gravities by clone, based upon a 6-year-old control-pollinated progeny test of Union Camp Corporation in Virginia

Clone	Number Crosses Tested	Specific Gravity	Lbs. Dry Wood/ Cu.Ft.
2-20	7	.395	24.7
2-40	12	.391	24.4
2-22	10	.391	24.4
2-21	2	.388	24.2
2-28	2	.386	24.1
2-8	5	.385	24.0
14-11	4	.378	23.6
2-39	2	.376	23.5
Commercial Check		.380	23.7
Seed Production Area		.379	23.7
Average		.386	24.1

Even at this young age the three best parents produced trees with approximately 95 pounds more dry weight per 100 cubic feet of wood than did the commercial check. Translated on an acre basis for 25-year rotations, this would amount to 4500 pounds additional dry wood per acre from the better genetic stock. However, this value is very conservative because the genetic differences in specific gravity will increase as the trees become older.

In a similar assessment of 8-year-old progeny in the North Coastal Plain source of North Carolina, Weyerhaeuser found that the selection of high-gravity parents has shown up positively in their progeny. Only three crosses had a specific gravity as low as the commercial check, and the average specific gravity of families from the orchard = .425, while the gravity of the commercial checks averaged .410.

Container Corporation (Brewton, Alabama) has recently completed a study of dry wood weight and moisture content for plantations in their area. Results are shown (Table 30) for weighted, whole-tree values.

Table 30. Wood weight and moisture content of slash and loblolly pines from plantations of different ages (Container Corporation, Brewton, Alabama)

	Specific Gravity		Wood Density (Lbs./Cu.Ft.)		Moisture Content (%)	
Age Class	Slash	Loblolly	Slash	Loblolly	Slash	Loblolly
10 - 15	.431	.395	26.9	24.7	143	146
16 - 20	.469	.402	29.3	25.1	113	157
21 - 25	.491	.412	30.7	25.7	109	145
26 - 30	.507	---	31.7	---	95	---
31 - 35	.515	---	32.2	---	92	---

Trends with age were as expected, the slash pine being almost "classical." Differences between loblolly and slash pine in this area are considerable, a result opposite to that found farther north, where the two species have similar specific gravities.

We participated in the wood aspects of an extensive study of pitch pine with Dr. Tom Ledig of Yale. Specific gravity of this species followed the general trend for the southern pines in having high gravities in the South, low in the North, longer fibers in the South, shorter in the North. The ranges in specific gravity by stand location were remarkably large, being from .55 to .42; tracheid length ranged from 3.7 mm to 2.6 mm. Generally speaking, the wood of pitch pine appears to be quite suitable for the manufacture of some papers.

Resin Content of Wood

There has been an increasing interest in the resin content of wood[1/] of loblolly pine and we have been questioned about whether we are breeding for this characteristic. Some years ago we made a study on young loblolly pine to determine inheritance of resin content of wood. The moderate to high heritabilities found, similar to those later reported by other organizations, indicated that an increase in resin content of the wood could be obtained if intensive breeding were undertaken. However, we found the tree-to-tree variation to be small, enabling an expected gain from intensive selection of only about one percent in extractable resin for young loblolly pine. Therefore, we have not included wood resin content as a major factor in choice of parents for seed orchards.

Interest in resin production is now at an all-time high because of the pressures brought on by lack of fossil fuels. The U. S. Forest Service has reported a method of increasing resin by treatment of the tree with Paraquat prior to harvest. A number of companies are testing this method; at least one is testing it by clone to see if some genotypes of loblolly pine will be more responsive than others. Results are not yet obtainable but it is probable that there will be a difference of considerable magnitude among clones.

[1/] This refers only to resin content of the wood per se, not to resin obtained through naval stores methods.

We are now getting results from the more western and northern companies. Shown above is one of Tennessee River's best three-year-old crosses in Tennessee. Below are the three-year-old progeny of 17-16, one of the best trees in American Can Company's seed orchard.

Economics of Tree Improvement

Programs have matured so that the costs and returns from tree improvement can be analyzed with some confidence. Several studies were previously reported, but during the last year some excellent results on the economics of tree improvement have been obtained. Bruce Zobel has been asked to summarize what is known about the economics of tree improvement in southern pines for the S. J. Hall Lectures in Forest Economics at the University of California in Berkeley. The paper[1/] will be published by the University of California; certain sections are abstracted in the next several pages of the annual report. The economic emphasis has been much enhanced through the contributions of Don Smith, Liaison Economist for the Cooperative.

The recent summary of the long-term, detailed Heritability Study[2/] gives a good but conservative indication of the magnitude of improvement that can be obtained through use of genetics on southern pine. Even though the reported heritabilities obtained from natural, unselected stands are lower than many published papers indicate, gains were still relatively large (Table 31).

[1/] Zobel, B. J. 1974. Increasing productivity of forest lands--better trees. S. J. Hall Lecture, Univ. of Calif., Berkeley. 27 pp.

[2/] Stonecypher, R. W., Zobel, B. J. and Blair, R. L. 1973. Inheritance patterns of loblolly pine from a nonselected natural population. Tech. Bull. 220, N. C. Agri. Expt. Sta., N. C. State Univ., Raleigh. 60 pp.

Table 31. Gains from mass selection from wild stands in percent of the mean for six traits based on 280 families in the open-pollinated study--loblolly pine 1/

Trait	Gains, as Percent of Mean	Heritability
Height	14	0.26
Basal Area	18	0.13
Straightness	7	0.14
Crown	4	0.08
Cronartium Score	18 2/ (42) 3/	0.22
Volume	25	0.15
Specific Gravity	10	0.52
Dry Weight	26	0.19

1/ From Stonecypher, Zobel and Blair (1973)

2/ When a selection of 1 in 2 was made

3/ When a selection of 1 in 10 was made

Improvements of volume (25%) or dry weight (25%) are considerably more than any of us had hoped, especially when based upon the very low heritabilities obtained from the unselected stands used in the Heritability Study. In an operation such as our Cooperative, for example, in which 400,000 acres are planted each year, the value of a 25 percent improvement in volume is worth many, many millions of dollars.

The gains shown in Table 31 can be achieved when breeding for individual traits. Gains possible from multiple-trait breeding through use of selection indices give a more accurate measure of the total improvement possible. When such calculations are made for the combined values of individual traits, height and wood specific gravity were found to contribute the bulk of the improvement when the five criteria of height, dbh, volume, specific gravity, and dry weight were assessed together.

In order to quantify potential gains, Porterfield (1973) made an intensive study of the economics of tree improvement. His studies included one industrial organization, one state forest service, and a generalized program based upon the 19 industries contributing to an extensive TAPPI study. The heritabilities which Porterfield used to determine gain were conservative, being based upon parent-progeny relationships obtained in the Heritability Study which have been distorted by heavy fusiform rust and tip moth attacks. His findings were based on a model of a tree improvement program that could be varied at will. The results were:

1. Total volume gains from seed orchard seed over unimproved plantations varied from 12 to 14 percent for unrogued seed orchards in the tree improvement programs assessed. Additionally, there was a gain of 5 percent for specific gravity while bole straightness and crown improvement were in excess of 5 percent. Volume gains of more than 20 percent are quite possible by increasing roguing intensity and intensifying wild stand selection intensities.
2. Progeny testing is essential if an organization is to meet its goals for improvement in volume and disease resistance. Minimum rates of return can be earned without progeny testing, but in every case profitability is considerably increased by progeny testing and subsequent roguing of the seed orchard. Volume improvement can be up to five times greater with progeny testing.

These findings indicate that, while good gains are obtained from wild tree selection, considerable additional gains will result from progeny testing. Without progeny testing for fusiform rust, it would be necessary to greatly increase the selection intensity for wild trees if only minimum improvement goals are to be achieved. Two short-term methods could be used:

(a) Select trees only from stands heavily infected with fusiform rust, with up to 90 percent infected stems.

(b) Screen potential parents by artificial inoculation.

3. An increased expenditure on wild stand selection results in higher genetic gains and greater economic returns; current selection intensity could be more than tripled and still be economically justified, as shown in Table 32. It shows marginal revenues and costs when selection expenditures are multiplied two to five times.

Table 32. Effect of increasing the cost of selection for each parent tree, above the current $312[1/]

Multiple of Current per-clone Expenditure	Total Cost/ Clone ($)	Marginal Revenue ($)	Marginal Cost ($)
2	624	2891	312
3	936	1795	312
4	1248	266	312
5	1560		

[1/] Adapted from Porterfield, R. L. 1973. Predicted and potential gains from tree improvement programs--a goal programming analysis of program efficiency. Ph. D. Dissertation, Yale University. 240 pp.

4. The profitability of a tree improvement program is closely related to seed yields from the orchard. The best genetic stock is of no value until sufficient seeds are collected and planted; and the more seeds, the more acres that can be planted with superior seedlings. Porterfield's study illustrates the extreme importance of maximizing seed yields from orchards by use of the best clones, fertilization, irrigation and pest control. Only 8 pounds of seed/acre/year in the seed orchard (after age 10) are necessary to break even for seed which produce

The so-called minor species in the South have a place in forestry operations. Shown is the one-year-old sprout growth of a pond pine killed by fire (center of photo) on lands of Hoerner-Waldorf Corporation. A nearby loblolly pine plantation was completely destroyed and had to be replanted.

Species suitable for deep sands are difficult to find. Sand pine has done very well under some circumstances; but in other plantings, such as the one by St. Regis Corporation (above), root rot has caused heavy mortality. The living trees are slash pine, the row of dead trees is sand pine.

seedlings 10 percent genetically superior in volume, at an 8 percent rate of return; however, each pound of this kind of seed has a present value of $116, and every effort should be made to obtain maximum seed yields.

5. On the average, a seed orchard costs between $4,500 and $6,500/acre to establish and test the genetic worth of the parents.
6. At 1971 prices ($7 to $8/cord), the rates of return (R.O.R.) for the tree improvement programs ranged from 10 to 14 percent. When modestly increased future stumpage prices were assumed, the R.O.R. ranged from 12 to 16 percent. The internal rate of return would be 16 percent if stumpage prices increased at an annual rate of 3.2 percent. Even though economic returns were calculated on volume alone, considerable value will accrue from improvement in quality traits, so the quoted R.O.R. values are conservative for several reasons.
7. The profitability of seed orchards in the Coastal Plain or Piedmont are about the same. Volume gains and stumpage prices are higher in the Coastal Plain but seed yields are lower; Piedmont orchards are able to match the Coastal Plain profitability with higher seed yields.
8. Volume improvement can vary from 9 to 20 percent under normal circumstances, depending on the additional goals that must be satisfied. If a volume gain is 12 percent when all other goals are satisfied, either heavy orchard roguing or higher heritability estimates will increase potential volume gains to highs of 23 to 25 percent (Table 33).

Table 33. Volume gains resulting from varying factors from the current tree improvement programs 1/

Change in Program	Total Volume Gain (Percent)
None	12.0
Selection intensity doubled	17.0
High roguing intensity used	25.1
Select rust-free trees from heavily infected stands	20.2
Heritabilities are closer to published values rather than the very low values used	19.5

1/ From Porterfield, R. L. 1973

Porterfield concludes that the management of the tree improvement programs he studied is consistent with the goals of the organizations. His recommendations for bettering current programs are on degree of emphasis rather than on major changes. Porterfield ends his study with the following: "There is little doubt about the economic justification of tree improvement work with loblolly pine. Even when using very conservative genetic gain estimates and seed yields 25 percent less than normal, the internal rate of return was 12 percent for the 'representative' program. Progeny testing and subsequent roguing of the seed orchard increases profitability." A new study now in progress by Matziris backs Porterfield's findings, with an indication that usually about half the clones should be rogued from the first-generation orchards.

A recent, very large study sponsored by TAPPI has been completed on the relative value of changing wood through silvicultural manipulation, genetic manipulation, or changing wood through mill processes. The first part of the study dealt with linerboard from southern pines; it included data from approximately 20 pulp and paper industries. Results, obtained from a complex linear programming approach, were generally determined on a discounted cash flow after tax basis, with the value of the objective function being the total profits from processing and selling linerboard plus the profit from growing wood.

Specific findings from this study cannot be released until the results are published by TAPPI in late 1974 but we can note some general points:

1. All economic analyses to date of pine genetics programs have shown tree improvement to be an extremely good investment. The evidence indicates that rates of return from 17 to 21 percent are feasible, and this agrees well with the study by Porterfield when similar stumpage prices are considered.
2. The optimum rotation length will be relatively short for the production of many fiber products.
3. There is some trade-off between higher specific gravity and mill processing costs, and the most profitable strategy depends greatly on the interest rate selected.
4. An important point to consider when evaluating a tree improvement program is that an increase in wood production per acre reduces the acres necessary to support a mill.
5. To date, two important studies have shown that volume and wood specific gravity are the most important traits to manipulate in a genetics program. A major consideration is that once a genetic change has been made it is permanent, whereas costs of altering silvicultural and mill processes must be repeated each generation. The TAPPI study has strongly bolstered the tree improvement approach and has shown a high rate of return from genetic improvement.[1/]

[1/] A summary of the TAPPI studies will be presented at the Forest Biology Committee Meeting in Seattle in September 1974 and will be published in Tappi.

Miscellaneous

Genotype-x-Fertilizer Interaction

There is considerable interest in the reaction of different clones to fertilization, and results have been summarized for several field studies in past annual reports. Additionally, Westvaco Corporation is making a series of fertilizer response tests in the greenhouse and all clones in their operational seed orchards will ultimately be tested. The 1972 tests included six clones, all of which gave a moderate response to phosphorus and a sizeable response to a complete fertilizer. Especially for the complete fertilizers, differential responses were found with clones 7-56, 11-26, and 11-41 having the best response, while 11-99, 11-88, and 11-10 did not respond as well. However, after three years of greenhouse testing, no outstandingly responsive clones have yet been found.

Early reports, particularly for slash pine planted in Florida, have indicated that some families are very responsive, others only slightly responsive, while occasional families even have their growth retarded when fertilizers are used. To ascertain definitely what this relationship might be in loblolly pine, most of the progeny tests in the Cooperative are grown under both normal and fertilized conditions. Although the majority of the tests are not over five years of age, the general picture in loblolly pine is that the fastest growing clones maintain that position whether or not they are fertilized. This is good news! However, there are enough exceptions to keep us alert to fertilizer response differential. Most of the exceptions to date are for specific crosses and generally all crosses with a given clone do not respond in the same manner.

To illustrate what sometimes happens with specific crosses, we chose an eight-year-old South Coastal loblolly test of Weyerhaeuser. This planting was on a wet site grown with minimal care and minimal site preparation. Half the test was fertilized with P and K but no nitrogen was added. Competition normally found on wet sites, such as red maple, was fierce and the trees are only now beginning to "capture" the site. Most crosses maintained their relative ranking but a few did not, as illustrated in Table 34. Note the nearly 50 percent improvement in height growth resulting from the fertilization and the relatively poor growth of the commercial check.

Table 34. Crosses that have interacted in height growth with fertilization compared to those that did not. Eight-year-old loblolly pine on the Coastal Plain of North Carolina, at Weyerhaeuser Company.

Cross	Unfertilized Average Height (Feet)	Unfertilized Rank	Fertilized Average Height (Feet)	Fertilized Rank
No interaction:				
8-33 x 8-103	10.96	8	15.48	8
8-65 x 8-33	10.11	17	14.64	18
8-31 x 8-64	9.88	20	14.48	21
8-46 x 8-141	9.60	23	14.29	23
Interaction:				
8-76 x 8-31	11.68	4	14.27	24
8-64 x 8-76	10.07	19	15.93	4
8-33 x 8-21	9.43	25	16.00	3
8-33 x 8-73	9.17	30	15.46	9
Commercial Check	9.23	27	13.83	27
Plantation Average	10.19		14.90	

No clonal patterns can be determined from this study of six replications of 10-tree rows with 30 crosses; in general, clonal response patterns to fertilization in loblolly pine have not been evident.

International cooperation is helpful and essential. Shown are three-year-old loblolly pine on lands of Georgia-Pacific Corporation in Georgia. Seed were sent by Neville Denison from some of the best families growing in South Africa--growth rate has been excellent. Second-generation selections from trees such as these will be made to increase gains and help keep a broad genetic base.

Another way to keep a broad base is to make crosses among trees from widely different geographic areas. Ten plantations of wide crosses have been planted; shown are two good four-year-old families in Continental Can Company's wide-cross plantation in Georgia. Many good second-generation selections have been made from the wide-cross plantations.

Disease Resistance

One of the major activities within the Cooperative is to locate and use pines resistant to fusiform rust and other diseases, and we have had good, almost dramatic, results. Through efforts of the Cooperative, many clones have been located that produce resistant progeny. These clones have been used to establish a number of disease resistance seed orchards.

Basic studies on fusiform rust by governmental organizations, universities, and industry have resulted in a large fund of information about both the host and pathogen. As a result of these studies, such activities as the U. S. Forest Service Disease Testing Center at Asheville, North Carolina have been possible and should result in a rapid buildup of useful breeding material. Although emphasis within the Cooperative has usually been toward applied results, considerable basic information has been amassed, largely through studies conducted by graduate students. Normally, results are concisely reported but a summary of one of the latest studies for a Ph. D. by Ralph Lewis is given below for those interested in the type of basic studies that have been underway within the Cooperative.

A study on biochemical indicators of fusiform rust resistance in loblolly pine was made by Dr. Ralph Lewis, now in Kentucky. He made quantitative and qualitative analyses of selected systems in loblolly pine seedlings in an attempt to find consistent biochemical parameters that could serve to differentiate between fusiform rust resistant and susceptible trees. On the basis of previous biochemical studies of disease resistance in plants, three classes of enzymes (peroxidases, polyphenol oxidases, and esterases) were used. A total of 525 plants from 11 open-pollinated and 22 control-pollinated families were utilized. Electrophoretic techniques were employed.

Spectrophotometric assays were made for peroxidase activity, polyphenol oxidase activity, and total extractable protein in the crude extract. Although a significant amount of this variation was associated with family differences, considerable variation within families was also found. Within-tree variability appeared to be primarily associated with the age and the stage of tissue development.

Rank correlations between enzyme assays of noninoculated shoots from twelve families and the relative rust resistance of the same families in field tests were statistically significant for polyphenol oxidase ($r_s = 0.696$). A combined ranking for perioxidase and polyphenol oxidase activity was also highly correlated ($r_s = 0.713$) with field resistance. However, comparisons of individual trees that were classified as resistant or susceptible by the results of artificial inoculation did not indicate a strong cause-and-effect relationship between enzyme levels and resistance.

In a series of special tests made for us by Dr. Harry Powers, U. S. Forest Service, to rank field and greenhouse tests, some surprising results were found. For the eastern seed sources, there was an excellent correlation between greenhouse and field resistance. But for the western sources (Alabama and Mississippi) the correspondence was very poor; the only plausible explanation is that the fusiform spore source from central Georgia did not react like those from Alabama. Other tests by the U. S. Forest Service also suggest the importance of disease spore source as well as seed source of the pine for effective resistance evaluation.

Selfing in Pines

As we make routine crosses for progeny tests, selfs are usually made on the trees being crossed, especially on the testers. The successful selfs have been outplanted as part of the regular progeny tests, and for the past several years they have also been planted for research purposes on Hoerner-Waldorf's area at Tillery, North Carolina. As of January, 1973, seventy-three selfed families have been established and are growing well. There are several reasons for making the selfs:

1. Obtain information on self-compatibility necessary to make decisions as to spacing in 1.5-generation orchards and for use of outstanding clones in two-clone seed orchards.
2. Relate the selfing performance to outcrossing performance. There is some indication that good selfers are also good general combiners. This idea must be tested.
3. Make basic studies of the inheritance patterns in pines, to help determine proper crossing designs for future breeding strategies.

Most selfed trees produce few or no viable seed and, if seed are obtained, germinate so poorly that sufficient trees are not available for testing. A considerable number of trees that do produce viable seed following selfing yield small, weak (often chlorotic) seedlings that will not grow normally to a reproductive age. Some selfs appear to be nearly normal and we occasionally find a selfed tree that produces outstanding progeny. (A detailed study on selfing was completed in 1968 within the Cooperative by Dr. Carlyle Franklin, now with the U. S. Forest Service.)

Dr. Mike Wilcox, who has now returned to New Zealand, summarized the current results on the selfs growing at the Hoerner-Waldorf research center at Tillery, North Carolina:

1. In 1971, the three-year-old self planting averaged 6.9 feet in height, the tallest family of selfs being 7.2 feet, the shortest 4.7 feet.
2. There is considerable correlation between the performance of outcrosses and the selfs; the good general combiners in the field tests have selfs that average 6.5 feet in height while the average trees produced selfs 5.7 feet tall. No parents that produced progeny with poor growth yielded any selfs.

There was only limited evidence of inbreeding effects such as needle abnormalities. A statistical analysis showed a large within-plot component, indicating considerable within-family variance for the selfs. After flowering has started, considerable basic research will be possible with this large reserve of selfed families. Because of their young age (four years) the self plantings on Hoerner-Waldorf's test area are not yet flowering. In the older progeny tests (up to ten years of age) the selfs are usually suppressed so do not flower. It will therefore be a few years before breeding work can be done with this material.

Developing Trees for Problem Sites

As some of the better lands are taken out of timber production it has become necessary to develop and test trees better adapted to marginal sites than those currently in use. This activity is urgent and one in which the genetic contribution can be great.

The deep sands have long been a problem. Slash pine was commonly used on these sites in the past but if the sand is very deep the slash plantations often failed to attain merchantability. Numerous studies have been made by members of the Cooperative to find species suitable for the deep sands. In the South sand pine looks very good although root rot is causing much damage. Farther north in the Carolinas, sand pine probably won't grow well but it is being tried, along with longleaf, slash, drought-resistant loblolly, and other species in two very good studies by Federal Paper Board and Catawba Timber companies.

Adaptability of the Best-Performing Clones

We have now isolated a group of over sixty clones that have performed exceptionally well when planted in a number of tests; such clones are classified as good general combiners. The best of these are currently being placed in special tests by members of the Cooperative, to determine their suitability outside their original natural range. Sufficient seed was supplied to us by members of the Cooperative to establish thirty plantations of these good combiners throughout the Southeast. As a result of these tests, additional clones will become available to broaden the genetic base of individual seed orchards and we will also obtain definitive information as to genotype-x-environment interaction in loblolly pine.

Such tests have been underway for several years by a couple of members of the Cooperative. For example, in West Tennessee and Kentucky, after two years in the field, Westvaco Corporation found the two best clones were from Champion International's lands in South Carolina. The next best was a clone from Tennessee River, an expected result; however, the next several best parent trees were all from the Piedmont of South and North Carolina. If these results are confirmed, the value of the wide testing will be very great.

Approximately ten years ago a series of wide crosses between individuals from widely different geographic areas was made by Ron Woessner. Pollen from ten areas ranging from Texas through the Cumberland Plateau of Tennessee

With the great increase in sawtimber and plywood production in the South, there is greater need for large, well-formed pine. Shown is a beautiful stand of loblolly pine on lands of Georgia-Pacific Corporation in South Carolina. Such natural stands are rapidly being depleted, but, in the future, plantations of genetically improved stock will provide high-quality material for solid wood products.

future generation breeding. Growth has been good and we have obtained a large number of very valuable second-generation selections from the wide crosses.

These data indicate the general superiority of the Texas drought-resistant x North Carolina Coastal cross (E), in both growth rate and disease resistance; a Piedmont N. C. x Texas drought-resistant cross (A) is less outstanding. In general, a specific cross may be superior in one location but not in others, an indication of relatively strong genotype-x-environment interactions. Most obvious, the performance of the cross was less dependent on its geographic location than the general combining ability of its parents.

Pollen Bank

As part of the long-range developmental plans, the Cooperative started a pollen bank at N. C. State University where pollen would be stored for future breeding needs. During the spring of 1973 the Cooperatives staff conducted experimentation on extraction and storage procedures for pollen. A pollen extractor was constructed which consists of twenty-four 12-inch gasoline funnels constructed so that air is blown into the funnels to aid drying of the catkins. The extractor is operated in a temperature-humidity control chamber, set at 80°F. and 40% relative humidity. Equilibrium moisture content for pollen under these conditions is 8 to 10 percent, which is suitable for long-term storage. Last spring, over 150 lots of catkins from 11 different organizations were processed. Results were very good, with the pollen drying to the desired moisture level and the germination rate generally very acceptable. Time required for pollen extraction varied from 30 hours to one week, depending on the maturity of the catkins when picked.

The literature indicates that vacuum storage is a promising method for long-term storage of pollen. Therefore, the Cooperative has constructed the future generation breeding. Growth has been good and we have obtained a large number of very valuable second-generation selections from the wide crosses.

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The literature indicates that vacuum storage is a promising method for long-term storage of pollen. Therefore, the Cooperative has constructed the necessary apparatus to seal pollen under vacuum in glass vials for shipping and storage. The method works very well for the transmittal of pollen to its place of use, but evaluation of long-time storage has not yet been made. Short-term results have been very good.

Effect of Tip Moth Control on Growth

There has been controversy about the effect of tip moth and whether control results in better height growth. Union Camp Corporation established a small test in 1970 in Virginia to determine the effect of thimet on tip moth control and fertilizers on height growth. At the end of the first year it appeared that thimet provided a definite increase in height; after the fourth year it is evident that all treatments were better than the control. This very heavily tip moth-damaged planting did not show an effect of tip moth control on height growth after four years in the field (Table 36).

Table 36. Growth and tip moth infection following treatment with fertilizer and thimet in a 4-year-old test of loblolly pine by Union Camp Corporation in Virginia

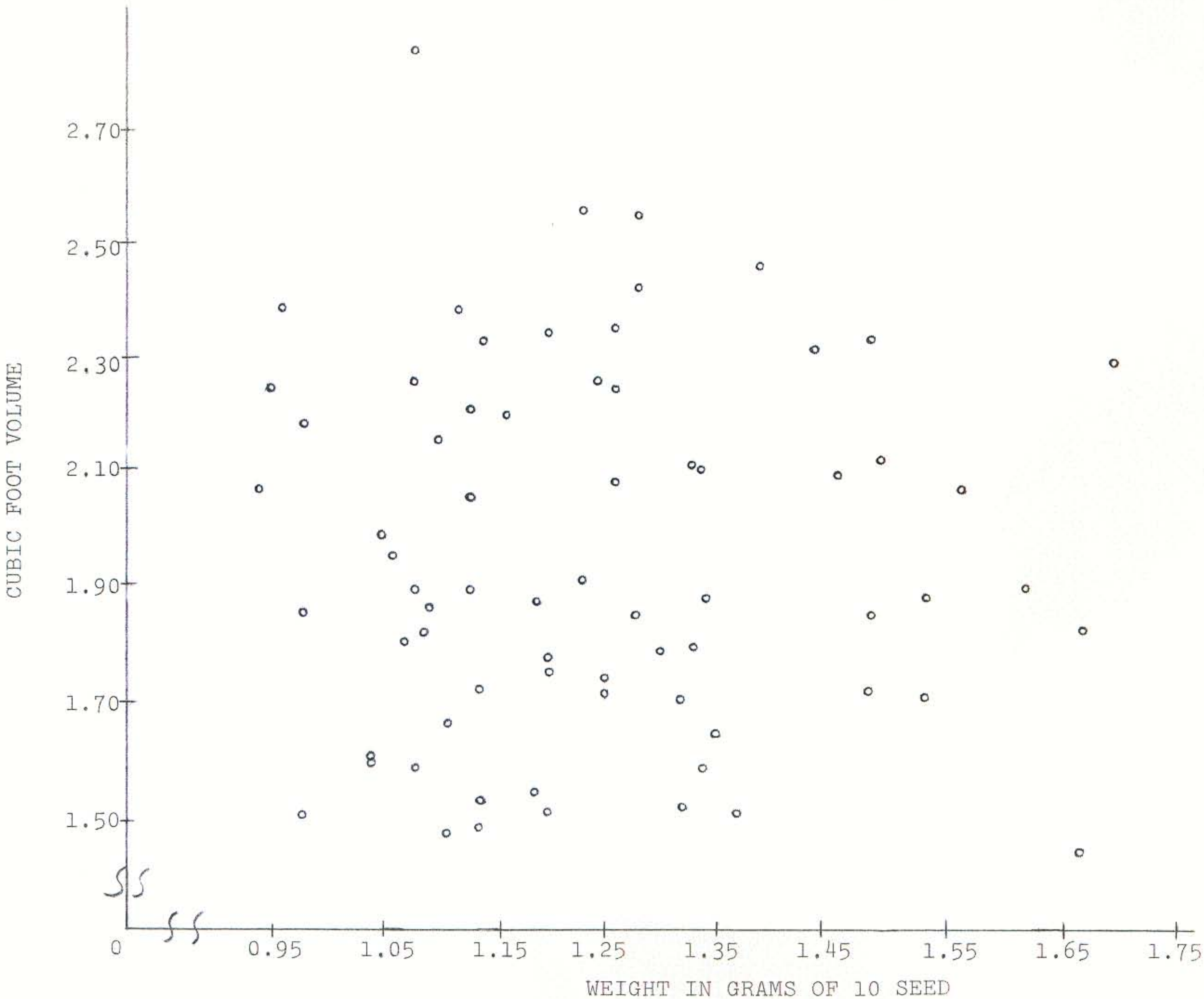
Treatment	1-Year Height (Feet)	4-Year Height (Feet)	Percent Tip Moth Attack Year 1	Survival Year 4 (Percent)
Control	0.8	5.2	100	92
Thimet Only	1.3	7.8	2	97
Fertilizer Only	1.3	8.5	96	95
Fertilizer and Thimet	1.7	7.7	0	89

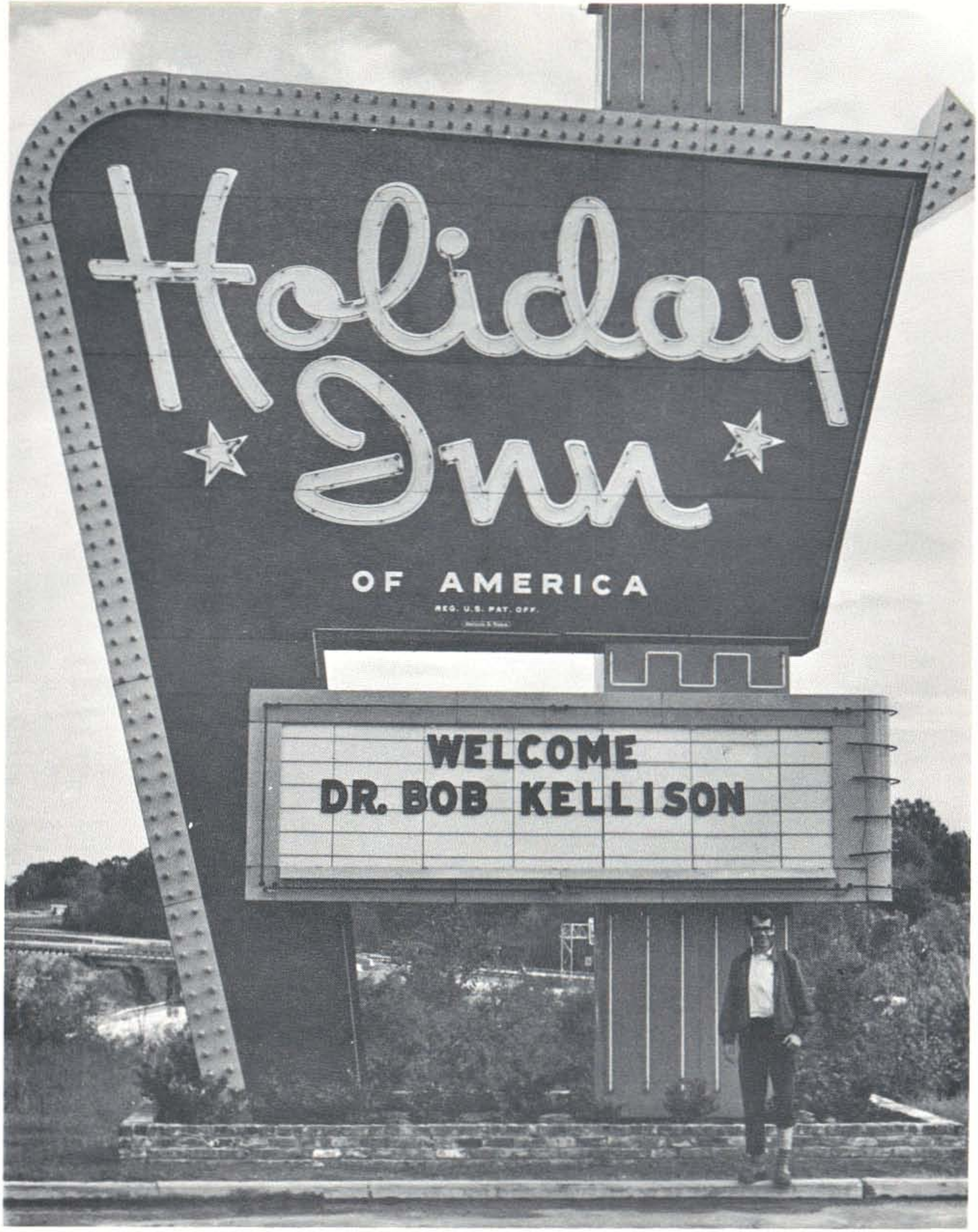
Seed Size Effects

There is a great difference in size of seed from clone to clone. We know that, in general, larger seed produce larger seedlings. The question immediately arises as to whether some of the fastest-growing progeny are merely big-seeded progeny.

Dr. T. O. Perry at N. C. State, Tom Dierauf of the Virginia Division of Forestry, and Homer Gresham of St. Regis are making studies of this, especially to determine how long initial height growth superiority will be retained in the progeny after field planting. Our own studies have indicated that the effect of seed size on growth rapidly becomes less with age and disappears by year 8. We found, for example, in the Heritability Study, where exact data on seed size were available for a large number of families, that no relationship existed between seed size and volume of tree after ten years of age (see graph on following page).

TEN YEAR VOLUME AS RELATED TO SEED WEIGHT





Some people asked why Bob Kellison wanted to go to New Zealand. It appears from this photo that his popularity was about to get to him.

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.
MacMillan-Bloedel Corporation	Ala., Miss.
North Carolina Forest Service	N. C.
Rayonier, Inc.	Fla., Ga., S. 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--S. C. North--Va., West Va., Ohio, Tenn., Ky., Miss.
Weyerhaeuser Company	N. C. Div.--N. C., Va. Miss.-Ala. Div.--Miss., Ala.

Membership

On January 1, 1974, Rayonier, Inc. became a member of the Pine Cooperative. Activities will be primarily directed toward loblolly pine in their Georgia and South Carolina lands. Seed orchards are already under establishment and activities with this new member started immediately "full steam ahead."

MacMillan-Bloedel Corporation, whose landholdings are interlaced with several other companies in the Cooperative, became a member of the Pine Cooperative on April 1, 1974. A seed orchard site has been prepared, trees have been graded, and tests of good general combiners are already established. Primary emphasis will be on loblolly pine in Alabama.

Because of extensive acquisition of lands and intensification of hardwood activities, Westvaco Corporation established a second working unit in hardwoods for their Central Woodlands in Tennessee, Kentucky, Missouri, and Mississippi. Plantation establishment is underway and seed orchards for sweetgum, sycamore and willow oak are being established.

A hearty "Welcome Aboard!" from other members of the Cooperative to the new, progressive, and active organizations!

Personnel

The past year found Bob Kellison far from the Cooperative scene. Bob wanted experience in another part of the world, so, since July 1, 1973, he has been with the New Zealand Forest Research Institute in Rotorua, New Zealand, where he has been advising on seed orchard management. He will return to Raleigh in July this year. In Bob's absence, Don Smith has filled in, and current plans are for him to continue working with the Cooperative until the end of December, 1974.

Due to a greatly increased computer work load, Miss Becky Wagner was hired this year as a typist to prepare field data for optical line scanning. Except for these changes, our staff remains the same:

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

Except for Bob Kellison and Don Smith, the faculty members associated with the Cooperatives remained the same for the past year. Bruce Zobel, Bob Weir, J. B. Jett, and Jerry Sprague continue with their usual team efforts in a wide range of duties.

A valuable member of our laboratory staff this year has been Mike Williford, who has worked part-time in addition to attending high school. He has done a fine job, and we are pleased to learn that he now plans to study forestry at N. C. State.

Graduate Students

One of the major activities of the Cooperative relates to training graduate students, with emphasis on those studying for the Ph. D. Degree. The 15 to 20 students associated with the program remain the same as in previous years. We had a record number of inquiries this year, enabling a choice of those best qualified. Graduate students still undertake the bulk of basic research essential for an efficient applied program.

The balance between U. S. and foreign students remains good. With the shortage of funds, it appeared for a while that the foreign student ratio might exceed the 30 to 40 percent we considered desirable, but the desired ratio has been maintained. During the past year we have had foreign students from Greece, Chile, South Africa, Canada, Thailand, Kenya and Australia.

One of the most pleasant happenings during the past year was the announcement of support of a student from Sweden by means of the Gunnar Nicholson Fellowship, administered through the American-Scandinavian Foundation. We look forward to working with the Swedish students; past experience has shown them to be well-trained scientists. We wish to express appreciation to Mr. Nicholson for initiation of this fellowship in forest genetics.

Publications by, or of Special Interest to, Members of the Cooperative

1. Adams, T., Roberds, J. and Zobel, B. 1973. Intergenotypic interactions among seedling families of loblolly pine (*Pinus taeda* L.). Theoretical and Applied Genetics 43:319-322.

2. Cole, D. E. 1973. Comparisons within and between populations of planted slash and loblolly pine: A seed source study. Proc., Twelfth South. For. Tree Impr. Conf., Baton Rouge, La. July. pp. 277-292.

3. Debarr, G. L., Merkel, E. P., O'Gwynn, C., Zoerb, M. H., Jr. 1972. Differences in insect infestation in slash pine seed orchards due to phorate treatment and clonal variation. For. Sci. 18(1):56-64.

4. Deines, J. 1973. The effects of fertilization on the growth and development of 1-0 sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.) and green ash (*Fraxinus pennsylvanica* Marsh.) seedlings. M. S. Thesis, School of Forest Resources, N. C. State Univ. 80 pp.

5. Denison, N. P. 1973. Variation in families of patula pine (*Pinus patula* Schlecht and Cham) grown at two locations in the Republic of South Africa. M. S. Thesis, School of Forest Resources, N. C. State Univ. 133 pp.

6. Dorman, K. W. and Zobel, B. J. 1973. Genetics of loblolly pine. U. S. For. Ser. Res. Paper WO-19. 21 pp.

7. Jett, J. B. and Finger, G. 1973. Stimulation of flowering in sweetgum. Proc., Twelfth South. For. Tree Impr. Conf., Baton Rouge, La. July. pp. 111-117.

8. 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.

9. Land, S. B. 1974. Variation and inheritance in tolerance of loblolly, slash, and pond pine seedlings to sea-water floods. Sil. Gen. (In press)

10. Ledig, F. T., Zobel, B. J. and Matthias, M. F. 1974. Geoclimatic patterns of specific gravity, tracheid length, and percent extractives in wood of pitch pine. Can. Jour. For. Res. (In press)

11. Long, A. J. 1973. Genotype and ectomycorrhizal fungi as factors in feeder root development and patterns of growth in four and one-half-month-old loblolly pine (Pinus taeda L.) seedlings. Ph. D. Thesis, School of Forest Resources, N. C. State Univ. 127 pp.

12. Manan, S. 1972. Germination test of loblolly pine (Pinus taeda L.) seed produced from seed orchard after fertilization treatments. M. S. Thesis, School of Forest Resources, N. C. State Univ. 66 pp.

13. Matziris, D. I. and Zobel, B. J. 1973. Inheritance and correlations of juvenile characteristics in loblolly pine (Pinus taeda L.). Sil. Gen. 22(1-2):38-44.

14. Porterfield, R. L. 1972. Financial returns from managing southern hardwood stands for pulpwood. Jour. of For. Oct. pp. 624-627.

15. Porterfield, R. L. 1973. Predicted and potential gains from tree improvement programs--a goal programming analysis of program efficiency. Ph. D. Diss., Yale Univ., New Haven, Conn. 240 pp.
Also Tech. Rept., School of Forest Resources, N. C. State Univ. (In press)

16. Rockwood, D. L. 1973. Variation in the monoterpene composition of two oleoresin systems of loblolly pine. For. Sci. 19(2):147-153.

17. Rockwood, D. L. 1973. Monoterpene-fusiform rust relationships in loblolly pine. Phytopathology 63(5):551-553.

18. Saylor, L. C. and Kang, K. W. 1973. A study of sympatric populations of Pinus taeda L. and Pinus serotina Michx. in North Carolina. Jour. of Elisha Mitchell Scient. Soc. 89(1 & 2):101-110.

19. Smith, H. D. 1973. Economics of hardwood plantations. Proc., Twelfth South. For. Tree Impr. Conf., Baton Rouge, La. July. pp. 158-168.

20. Smith, H. D. 1973. Decision-making under uncertainty: Should hardwood plantations be established? Tech. Rept. No. 49, School of Forest Resources, N. C. State Univ. 62 pp.

21. Sprague, J. and Weir, R. J. 1973. Geographic variation of sweetgum. Proc., Twelfth South. For. Tree Improve. Conf., Baton Rouge, La. July. pp. 169-180.

22. Stonecypher, R. W., Zobel, B. J. and Blair, R. L. 1973. Inheritance patterns of loblolly pine from a nonselected natural population. Tech. Bull. No. 220, Agri. Expt. Sta., N. C. State Univ. 60 pp.

23. von Weissenberg, K. 1973. Indirect selection for resistance to fusiform rust in loblolly pine (Epäsuora valinta Cronartium fusiforme-kestävyyden lisäämiseksi Loblolly-männyllä (Pinus taeda L.). Acta Forestalia Fennica Vol. 134. 46 pp.

24. 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.

25. Weir, R. J. 1973. Realizing genetic gains through second-generation seed orchards. Proc., Twelfth South. For. Tree Impr. Conf., Baton Rouge, La. July. pp. 14-23.

26. Wilcox, M. D. and Smith, H. D. 1973. Selection indices for wood quality in loblolly pine. Proc., Twelfth South. For. Tree Impr. Conf., Baton Rouge, La. July. pp. 322-340.

27. Zobel, B. J. and Dorman, K. W. 1973. Loblolly pine as an exotic. Forest Genetics Resources Information No. 2. FAO. pp. 3-15.

28. Zobel, B. 1973. Conifers in the northern Andean region. Paper given to the Instituto Interamericano de Ciencias Agricolas de la OEA. Oct. 22-26. Quito, Ecuador. 13 pp.

29. Zobel, B. 1973. What trees to plant, where to plant them, and why. South. For. Conf., "Plantations, People and Profits." May 9-11. Biloxi, Miss. 7 pp.

30. Zobel, B. 1973. Improvement of trees through genetics and the resultant physical and chemical properties of fibers. TAPPI-API Meet., Mobile, Ala. Nov. 16 pp.

31. Zobel, B. 1974. Progress in hardwood forest management. Talk given at Hardwood Symp., Cashiers, N. C. May. 14 pp.

32. Zobel, B. 1974. Improving yields from forest land. Pulp and Paper Seminar. Chicago. May 31. 16 pp.

33. Zobel, B. 1974. Increasing productivity of forest lands through better trees. S. J. Hall Lectureship, Univ. of Calif. (In press)