TWENTY-SEVENTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
Raleigh

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EXECUTIVE SUMMARY

1. The selection, breeding and testing program of the Cooperative is in a transition between generations.
   a. Workloads have increased during the transition period.
   b. There is some evidence that flower stimulation treatments will work outside a breeding greenhouse.
   c. To date 123 second generation diallel breeding groups have been formed. Breeding is complete for 10% of these groups.
   d. Breeding progress has been made on 72 of the 500 plantation selection diallels to be formed.
2. The 1982 cone and seed crop was the second largest in the history of the Cooperative.
   a. Members of the Cooperative harvested 30.5 tons of genetically improved loblolly pine seed in 1982. This is enough seed to regenerate 813,000 acres of forest land.
   b. The Cooperative averaged 1.36 pounds of seed per bushel of loblolly cones. Six member orchards reported yields in excess of 1.69 pounds of seed per bushel.
   c. Use of ground cover net and top pruning have been examined as ways to harvest seed from tall orchard trees at a reasonable cost.

3. Cooperative program research initiatives are providing important supportive information.

   a. Tree improvement rate of return estimates are 17 to 19 percent after taxes.

   b. Full season irrigation of young seed orchard trees can add two additional potential flower sites per branch.

   c. The occurrence of annosus root rot in a Cooperative orchard has led to certain revisions of management regimes on high hazard sites.

   d. East Texas source loblolly pine grows well and has virtually no fusiform rust when planted on Sandhills and/or high rust hazard sites.

   e. Pulping rust infected wood may lower pulp yields slightly and will greatly increase extractive recovery.

   f. Loblolly pine tissue culture plantlets grow thicker, less fibrous root systems with fewer lateral roots.

   g. Twelve year-old loblolly pine produced from wide geographic crosses (North Carolina x Texas) grew faster and had less rust than their parents when grown in northeastern North Carolina.

4. A total of 13 graduate students are working directly with the Cooperative on M.S. and Ph.D. programs.

5. A total of 28 members operate 37 working units in the program.

INTRODUCTION

The North Carolina State University-Industry Cooperative Tree Improvement Program has completed its 27^{th} year of operation. It has been a difficult year in which the practice of "survival economics" has become commonplace. Most tree improvement operations and research programs have been forced to reduce expenditures through what some believe has been the forest industry's worst business cycle since the 1930's depression. Despite these pressures, core support for the Cooperative tree improvement effort has been sustained.

It is now generally accepted that genetic improvement is contributing to increased forest land productivity. Tree improvement can help ensure the continued supply of raw materials at a reasonable cost. Such investments can provide opportunities for the expansion of manufacturing capacity, and increase the profitability of owning and managing timberland. It is also well understood that tree improvement is a long term investment that once begun must be continuously supported if the full potential is to be realized. It is this recognition that provided the justification for continued support of the core program through these most difficult months.

We have enjoyed substantial success to date, with return on investment estimates in the 17% to 19% range and enough improved seed produced to regenerate more than 4 million acres of land. We are now challenged to exploit the potential for future improvement in a timely fashion. It is a potential estimated to be substantially larger than the benefit realized to date.

Even with intense pressure to restrain spending, many members have made substantial progress in the advanced generation breeding and testing work during the past year. Increased efficiency over the first generation has been evident; progress is being made sooner with a minimal increase in costs. A solid base for future generations of improvement is being formed. No longer is it just a plan; it is now an action program with measurable progress. As the economic climate improves, we anticipate the pace of progress will accelerate.

SELECTION, BREEDING AND TESTING

Program in Transition

The Cooperative Loblolly Pine Tree Improvement Program has been active for 27 years. The program is now in a transition phase between the completion of the first generation and beginning the second and future generations of improvement. While excellent progress has been made. There is great potential for additional genetic gains in the future.

Cooperative members have completed the breeding of first generation seed orchard parents with the last field tests planted in the spring of 1983. Only a few special projects, such as the loblolly-shortleaf hybrid tests of American Can, remain to be completed. The Cooperative has now focused attention on breeding and testing programs designed to capture additional improvement in future generations. The program has adopted an aggressive yet realistic schedule of activities to accomplish this work. "Accelerated breeding" technologies are being employed to shorten the generation interval. A particular challenge for all is the task of aggressively pursuing the breeding and testing programs on which future gains will depend, continuing work associated with the first generation testing program.

The importance of accelerated breeding stems from increased economic returns on tree improvement investments when generations are rapidly turned over. The plan adopted for the Cooperative calls for completing breeding and test establishment for the next phase of genetic testing within 12 years following grafting of a new selection. It is an aggressive plan in that it calls for completion of the work eight years sooner than the "average" Cooperator's experience in the first generation. It is thought to be realistic in that it is only two years faster than experienced by the fastest Cooperator in the first generation. To meet this goal, it will require a concerted effort, and the use of some or all of the relatively new technology developed for early flower stimulation. In January, 1983, the Program staff conducted an accelerated breeding shortcourse. It was structured to achieve one major objective--provide "how to" information about accelerated breeding. Key features of loblolly pine flower initiation and development were discussed. While much is known about flower stimulation methods, the new technology must and will be refined before the "best" approach is certain. In the meantime, the need to recognize and pay attention to details that can improve efficiency in the breeding, testing and selection phases of the program is critical. Increased efficiency will save time and improve profitability.

Breeding and Testing Overview

A summary of the first-generation breeding effort and the system to be employed for the next generation is discussed below. A very generalized flow chart for the cooperative loblolly pine breeding program is shown in Figure 1. As can be seen from the figure, the breeding program is divided into a "first-second generation selection" phase and "plantation selection" phase with a merger of the two lines planned for the third-generation.

Each member of the Cooperative was originally responsible for the selection of approximately 30 superior phenotypes from natural stands[1/].

1/ Organizations who joined the Cooperative very recently did not make selections in natural stands. Their initial orchard establishment efforts were with fully progeny tested clones from other Cooperators (1.5 generation orchards) or with second-generation selections.

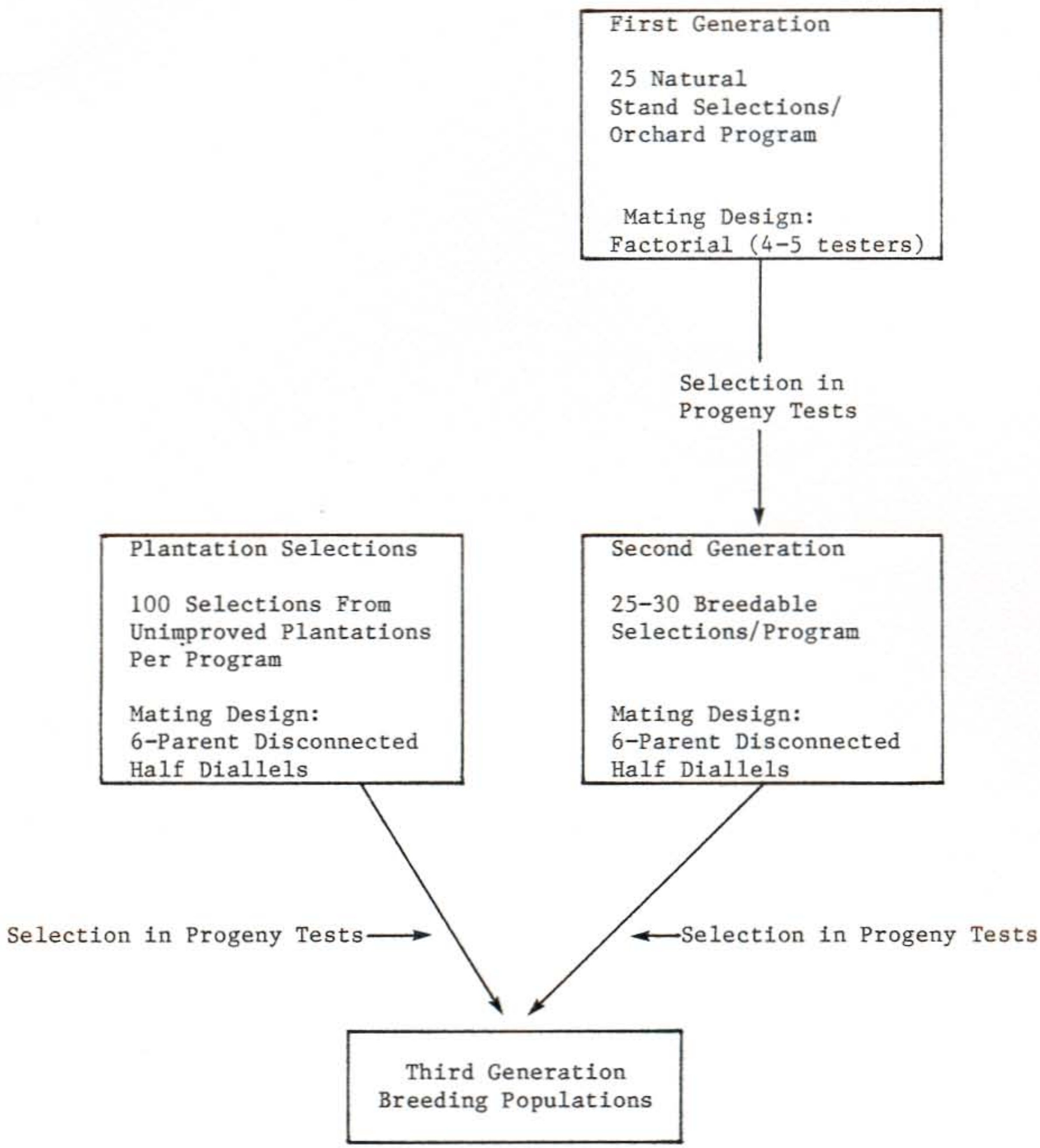


Figure 1. Cooperative Loblolly Pine Breeding Plan.

These are known as "first-generation" selections. The selections were established in first-generation production seed orchards. A tester mating scheme was used to progeny test the selections and to create a base population for advanced-generation selection. Most organizations employed four or five tester clones which were mated to all other selections in the orchard. Each Cooperator is expected to make about 100 "second-generation" selections from each orchard program of which approximately 30 will ultimately be bred. This process of selection has begun, and for some Cooperators is nearly complete.

First-generation breeding was conducted largely by individual organizations. In future generations, breeding and testing will be done on a regional basis, with all Cooperators in a region pooling resources to maximize gain and maintain a broad genetic base. Breeding regions were established on the basis of physiographic and environmental factors and are such that each region will have five to ten Cooperators contributing to breeding efforts.

When second-generation selections are completed, there will be up to 1,000 select individuals per breeding region. In actuality, the diversity of the population is much less than it may seem because of the co-ancestry among many of the selections. The number of unrelated selections that an individual Cooperator can contribute is limited by the number of testers used in first generation breeding. Most breeding regions will be able to move 25 to 50 unrelated families through to the second generation. In many instances, half-siblings and sometimes full-siblings will be used in the second generation phase of the program, although they will not be mated together.

Each Cooperator recently located up to 100 new selections from unimproved plantations. These selections compose the "plantation selection" breeding line. These select individuals from plantations have been established in breeding orchards and are to be tested concurrently with the second-generation selections. Selections from the genetic test populations of the plantation material will be available for incorporation into third-generation production and breeding programs. The plantation-derived selections will have undergone one less generation of selection at the time of merger. However, it is thought that the more uniform environmental conditions encountered in plantations should lead to a higher initial rate of genetic gain than that achieved with first-generation selections, and the two populations should be of comparable quality when they are merged. Estimates of anticipated genetic gains show this to be the case. The plantation selection program has resulted in from 300 to 700 new unrelated selections per breeding region, significantly broadening the genetic base of the Cooperative breeding population.

Mating Second Generation Selections

Second generation selections are being mated in six-parent disconnected half-diallels. Each diallel has 15 crosses to be tested. Crossing requirements for each diallel will normally be shared by several Cooperators in a breeding region. This will necessitate the use of a centralized pollen bank which is located at N. C. State University. The number of diallels created from second generation selections will depend upon the number of available selections for a given region, but breeding loads for each Cooperator will generally be the equivalent of 4 or 5 diallels, or 60 to 75 crosses.

The Cooperative's "crack" grading crew with an excellent second generation selection belonging to Hiwassee Land Company

To obtain maximum information from diallel mating schemes, all crosses called for in a diallel must be completed and planted in the same test. Failure to successfully complete specified crosses results in a loss of information, with the loss becoming more serious as the number of missing crosses increases. Many of the causes for crossing failure are beyond human control. For example, despite their advanced age, certain first-generation clones have flowered so sporadically as to make testing them virtually impossible. Additionally, clones which flower regularly and heavily are occasionally found to be incompatible when crossed to certain other individuals.

When second generation breeding began, it was believed that the problem of missing crosses could be alleviated by not placing selections into diallels until they had shown an ability to produce flowers. In this way, diallels could be completed and ready for field testing in a timely manner. This system was successful as evidenced by the fact that crossing called for in 16 diallels formed by this method are being made very efficiently. However, as time elapsed, it became apparent that some revision was needed in the system of diallel information for the following two reasons:

1. Usually the first selections to flower were the earliest selections made in the second-generation program, often before good information was available on family performance. Selections made later are often of better quality, and it was feared that these selections would be "missed" in the breeding program because breeding commitments were being fulfilled with the earliest selection.

2. With the major push now in progress to apply accelerated breeding techniques, Cooperators needed to know soon after grafting which of their selections would be bred and should be subjected to intensive treatments to promote flowering.

Some sort of "a priori" diallel formation was needed which would indicate to Cooperators which of their clones would be bred while at the same time would allow timely completion of the necessary crosses. As a result, Cooperative staff members developed the following system of diallel formation:

1. All second-generation selections in the Cooperative were screened based upon their most recent evaluation (grade sheet) to determine if they were of breedable quality.
2. Breedable selections in each breeding region were placed into 8 tree groups with all members of a group being unrelated to each other. While not every selection was placed into a group, efforts were made to insure that at least one selection was used from every good family. More than one selection was used from the best families. As much as possible, selections were grouped according to the number of years since selection with comparable aged selections grouped together. However, care was taken not to compromise the genetic quality of any group.
3. The first six selections to flower in each group will be bred using the disconnected half-diallel design. The other two selections in each group will either be discarded or placed into new diallels at a later time.

Using the above system, an additional 107 diallel groups were formed this year from the pool of breedable second generation selections. Approximately 40 selections were used per orchard program for those organizations where second-generation selection efforts are essentially complete. For other Cooperators where selection activity is still on-going, fewer selections were used but more groups will be formed as new selections are made. If 75% of the selections put into groups are bred (six out of eight), then approximately 30 selections will be bred per orchard program. This is equivalent to five diallels. With the selections grouped in the manner described above, the genetic resource available to the Cooperative for second-generation breeding will be fully utilized, and crosses should be made in an efficient manner.

Two to three Cooperators will be designated as "primary breeders" for each clone included in the eight tree groups. Cooperators were chosen as primary breeders if the clone bears their ascension number, or if the clone was established in an early block of their second-generation production seed orchard. In the spring of 1983, Cooperators were asked to check the clones for which they are primary breeders to determine if pollen and/or female strobili were present. If pollen catkins were present, they were collected and either the catkins or extracted pollen sent to Raleigh for storage. Based on information provided by Cooperators, the Cooperative staff will decide upon the six trees in each group which will actually be bred.

As previously mentioned, all crosses called for in a given diallel will be field planted together in genetic tests. The Cooperative staff

The spring of 1983 turned to winter with snow accumulation on flowers during pollen release -- Aggravating!

will be responsible for the assignment of a diallel to a genetic test series and will designate which Cooperators will plant the test. The maximum number of crosses which can be used in any single genetic test depends upon environmental variation and experimental design, but experience gained in first generation testing has shown that 30-50 crosses constitute a very efficient test size. Each six-parent half-diallel will result in 15 crosses to be tested. Therefore, genetic tests of second-generation selections will consist of crosses resulting from two or three diallels.

Mating Plantation Selections

The Cooperative accumulated over 3100 new selections from plantations betweem 1975 and 1981. This represents a vital part of our future resource base, and all 3100 trees will be bred using the same 6-parent disconnected half diallel design described previously.

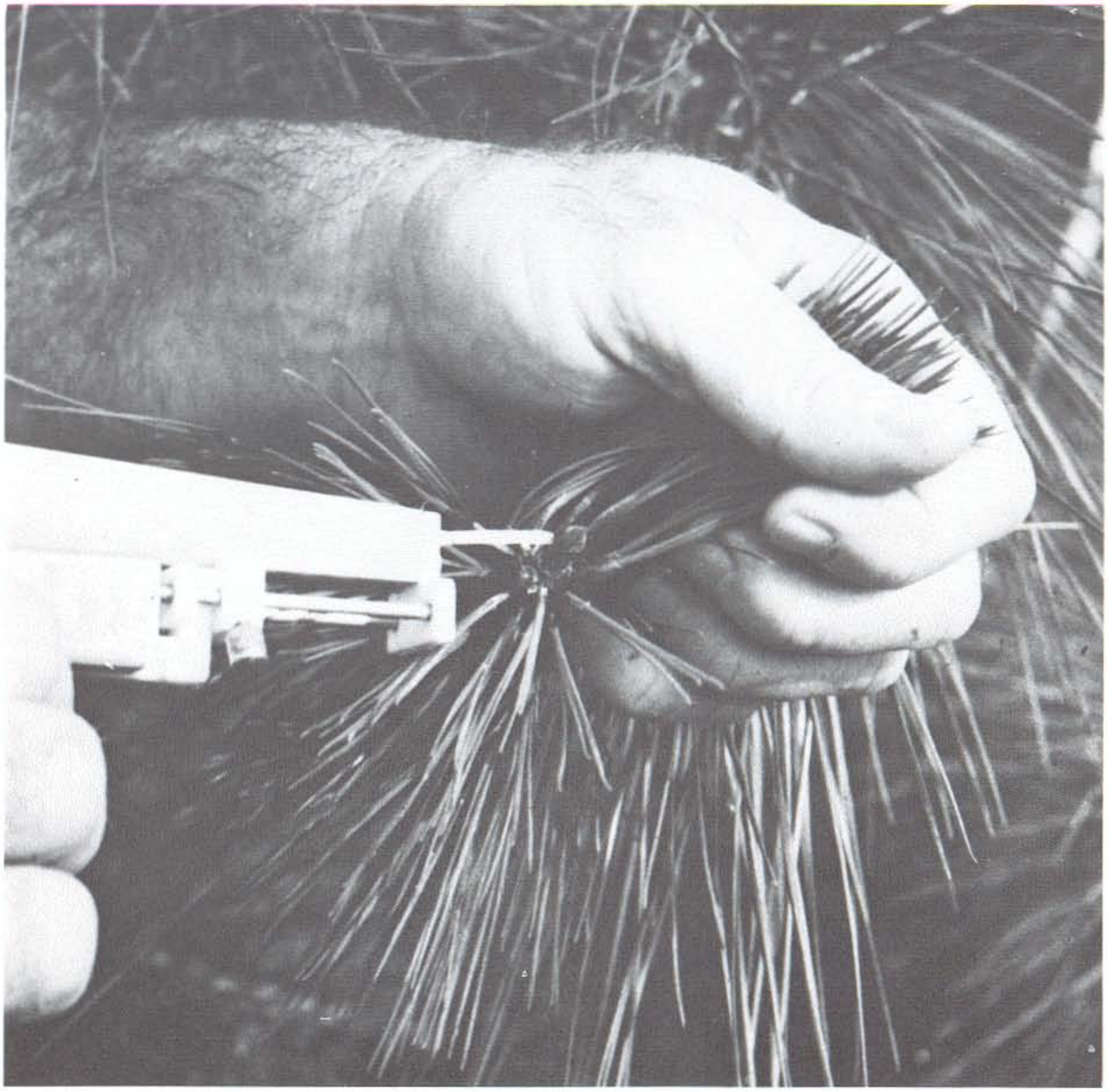
In an idealized situation, a Cooperative member will have 100 plantation selections to breed in addition to the 30 or so second generation selections. Since some of the second generation selections identified for breeding are related, the effective contribution to the future resource base from second generation selections is greatly reduced. Consequently, the plantation selections represent 85+% of the Coopeative's future genetic base. These trees are important to the program's future and work on their breeding and testing is receiving a very high priority.

The formation of 6-parent half diallels for the plantation selections is rather straightforward. For each member organization, the first six trees that flower will comprise their first diallel, the next six to produce flowers form the second diallel, etc.. As before, reciprocal crosses are allowed, in fact encouraged, if their use can speed up the work or increase the chances of making all crosses within a given diallel. In the case of plantation selections, pollen, collection, extraction and storage, will be done by the Cooperators. Pollen shipment is not needed since for any particular cross, the organization responsible has both the male and female trees. The Cooperative will, of course, provide back up support from the N.C.S.U. pollen bank when needed, and will do pollen viability tests when requested.

The field testing workload will be equalized to the extent possible within a breeding region. Some organizations with few trees to breed (usually those joining the program last) will be asked to take on a larger share of the field testing. The redistribution of seedlots for testing will be done within the limits of adequate testing on representative sites. Since the number of tests and the number of trees per test are reduced in this generation as compared to requirements in the first generation, the workload for breeding and testing the plantation and second generation selections is approximately equal to the work done in the first generation.

Advanced Generation Breeding Progress

Recently, excellent progress has been made in developing accelerated breeding techniques which promote flowers on very young grafts of selected trees. Weyerhaeuser personnel have led the way in devising cultural practices that stimulate pollen and female flower production on such grafts. Practices such as culturing grafts in large pots in a greenhouse environment, applying water stress and gibberelin treatments have been most successful. The Weyerhaeuser breeding greenhouses located in Hot Springs, Arkansas have produced over 5000 flowers in each of the last two



Stimulating female flower production with $GA_{4/7}$ treatments applied through a micro-pipette.

years on grafts that were grown for only three to four years. The greenhouse methods of flower stimulation work very well. Weyerhaeuser planted the first second generation genetic tests in the spring of 1982 and followed up with additional tests in the spring of 1983.

While the greenhouse system of flower stimulation is effective and has a proven track record, other approaches are being tried. Two organizations experienced good results with water stress and applications of gibberelin to grafts grown outside in pots. In one instance, approximately 2000 flowers were produced on about 100 potted grafts. This allowed over 450 pollination bags to be installed for breeding work this spring. Results on outdoor potted breeding orchards look very promising although flower stimulation in several successive years has yet to be demonstrated.

In another experiment gibberelin ($GA_{4/7}$) applied to four and five year-old loblolly grafts in Federal's second generation breeding orchard successfully stimulated female flowers (Table 1). In this experiment both 2% solutions of $GA_{4/7}$ produced positive results. The Pro-Gibb® treatment is a commercially available solution of 0.8% $GA_{4/7}$ used to promote male flowers on cucumbers. The Pro-Gibb® did not work as well on pines as the recommended 2% solution. Application of $GA_{4/7}$ every four weeks was compared in this study to treatment once every two weeks. The two week application (standard) produced 73% more flowers. Although the reported results of $GA_{4/7}$ treatment in a field breeding orchard appear promising, they should be judged with caution. Results are for one year only, and it may be that $GA_{4/7}$ treatments in field orchards will be less successful in less favorable years.

Table 1. Effects of several $GA_{4/7}$ formulations on production of female flowers in Federal's second generation loblolly orchard.

Treatment	Total Flowers[1/]
Untreated Control	26
Technical Powder - 2% Solution ethanol base	71a
Experimental Mixture - 2% Solution (ABG-3035)[2/]	87a
Pro-Gibb® - 0.8% Solution	41

[1/] A total of 80 branches were treated with each treatment.
[2/] Provided by Abbott Laboratories.
a - Values significantly different from the control (p = .05)

Steady progress is being made in learning how to stimulate flowering on young loblolly grafts in a variety of environments ranging from the greenhouse to the field. All seem to be providing some degree of success. As a result of these and similar efforts, the Cooperative members have made substantial progress in advanced generation breeding. A quick survey of the membership indicates that some crossing has been started on 29 of the 123 second generation diallel groups designated to date. Crossing on 12 of the second generation diallels (10%) is complete. Breeding has begun on 72 of the 500 plantation selection diallels to be formed. This represents meaningful progress on 15% of the plantation selection breeding workload. With such enthusiasm, commitment and measurable progress evident, the Cooperative is well on the way to meeting the breeding and testing schedules that are so important to maximizing the profitability of tree improvement investments.

Dramatic growth responses from intensive culture in the first few years are possible. The Cooperative is studying such cultural options as a possible way to get useful progeny data earlier.

SEED ORCHARD PRODUCTION

Cone and Seed Yields

The 1982 cone and seed crop was the second largest in the history of the Cooperative. This was to some extent a surprise. According to all early reports, the 1982 crop was considerably reduced from 1981. This was in fact true; the most recent harvest produced approximately 40% fewer cones and seeds than in 1981. However, the 1981 harvest was clearly a record setting production level. A comparison of cone and seed production for all conifers and loblolly pine in the Cooperative's five best years is shown in Table 2. The 1982 crop produced 30.5 tons of genetically improved loblolly pine seed. Assuming 8000 plantable seedlings per pound of seed and 600 trees planted per acre, the 1982 harvest of orchard loblolly pine seed was sufficient to produce 488 million improved seedlings and to regenerate 813,000 acres of forest land. The loblolly seed produced in the Cooperative's best five years (Table 2) was sufficient when combined to grow 2.5 billion improved seedlings and to regenerate over 4.2 million acres of land. Seed production levels have grown to a point where regeneration with genetically improved seedlings is standard practice by most Cooperative members.

Seed orchards of conifer species other than loblolly contributed an additional 8000 bushels of cones and 3.8 tons of seed to the 1982 harvest. Slash pine contributed nearly 7000 bushels of the additional cones harvested. Important quantities of seed were also harvested from orchards of Fraser fir, longleaf and Virginia pine (Table 3). Seed from these species will be used for regenerating special sites or for specialty

Table 2. A comparison of total cone and seed yields for all conifers and loblolly pine in the Cooperative's five best production years.

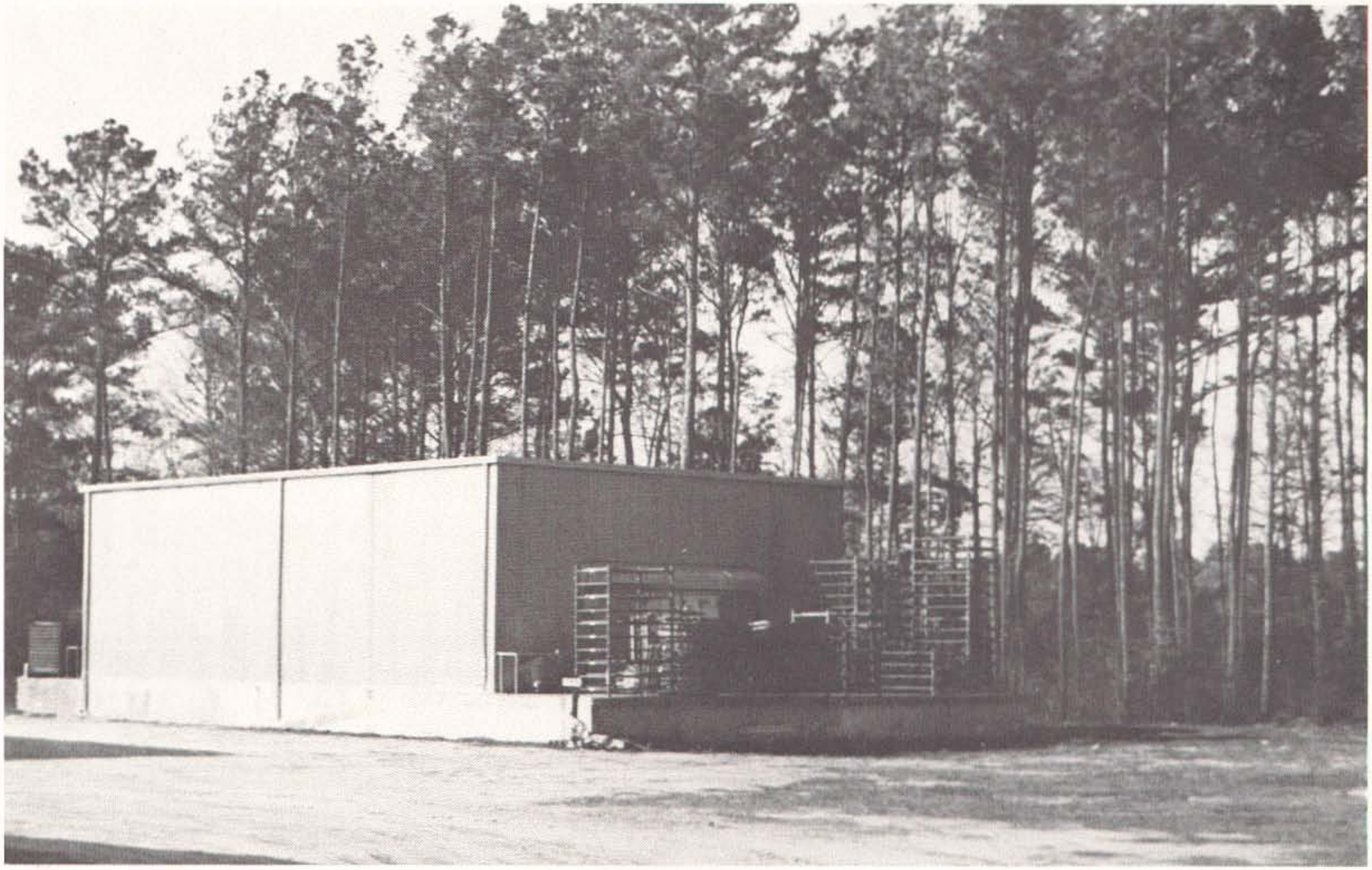
	All Conifers		Loblolly Pine	
Harvest Year	Bushels of Cones	Tons of Seed	Bushels of Cones	Tons of Seed
1977	46,041	32.8	32,152	24.8
1978	46,258	25.6	37,977	23.5
1979	49,415	31.6	38,693	27.7
1981	71,964	54.5	64,145	50.5
1982	52,827	34.3	44,761	30.5
Total	266,505	178.8	217,728	157.0

products such as Christmas trees. Genetically improved slash pine seed continues to be plentiful, in fact, a considerable surplus has been produced. In contrast, demand for longleaf pine seed and improved Fraser fir seed exceeds current production capacity; consequently, orchard expansion efforts are underway for these two species.

The cone production and seed yield statistics shown in Table 3 contrast the 1981 and 1982 information by species. These are the best two years the Cooperative has ever experienced. Yet, 1981 was substantially better than the 1982 production; this is especially true for loblolly, longleaf, white pine, Virginia pine and Fraser fir. Although good orchard management practices tend to smooth out the production curves, year to year variation in production must be taken into account when planning seed orchard acreage and seed inventory levels.

Table 3. Comparison of cone and seed yields for 1981 and 1982.

	Bushels of Cones		Pounds of Seeds		Pounds of Seed/ Bushel of Cones	
	1981	1982	1981	1982	1981	1982
Loblolly Pine Coastal Source	43819	29410	66579	39763	1.52	1.35
Loblolly Pine Piedmont & Mountain Source	20326	15351	34454	21292	1.70	1.38
Slash Pine	4880	6955	4701	6405	0.96	0.92
Longleaf Pine	1457	742	2039	730	1.40	0.98
White Pine	658	0	298	0	0.45	0
Virginia Pine	591	223	480	211	0.81	0.95
Fraser Fir	148	54	336	166	2.27	3.07
Pond Pine	46	32	14	48	0.30	1.50
Shortleaf Pine	39	22	35	18	0.90	0.82
Sand Pine	--	38	--	10	--	0.26
Total	71964	52827	108936	68643		



Storing surplus improved seed for the "lean" years is a must. Shown is Westvaco's seed and seedling cooler facility in South Carolina.

For years orchard managers have observed that there is a strong relationship between the size of the cone crop produced and the pounds of seed per bushel of cones. This trend is certainly evident for loblolly pine over the last 14 years (Table 4). For the Cooperative as a whole, the loblolly pine cone production in bushels is correlated with pounds of seed per bushel with r = .75. This is a surprisingly strong correlation considering the wide variation in orchard age, site quality, insect damage, etc., that exists over the entire range of the Cooperative.

A bright spot in this year's cone harvest is the improved production of second generation seed orchards. The crop in 1981 was too small to warrant separate accounting. However, in 1982, managers reported the collection of 692 bushels of cones which produced 763 lbs. of seed (1.10 lbs./bu.). The yield per bushel reflects the relatively young age of

Table 4. Cone and seed yields of the loblolly and slash orchards in the Cooperative for the last fourteen years.

	Loblolly Pine		Slash Pine	
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	6478	1.14	3795	0.80
1972	6807	0.98	1684	0.60
1973	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
1978	37977	1.24	4789	0.54
1979	38693	1.43	7460	0.62
1980	15296	1.04	4418	1.06
1981	64145	1.58	4880	0.96
1982	44761	1.36	6955	0.92

second generation seed orchards. This level of production is considerably ahead of the 1st generation experience. Orchards are certainly better managed now than they were 15 years ago. It is anticipated that these young higher value second generation orchards will come into production sooner and heavier than their 1st generation counterparts.

Production Leaders

Among the statistics gathered for the 1982 cone and seed crop was one new record for individual orchard yield. Once again it was the Champion International Corp. coastal orchard near Tillery, N. C. that showed the way with an all time high yield of 2.30 pounds of seed per bushel of cones. This is the second consecutive year that this orchard, under the management expertise of Ray Brown, has set a new record for seed yield per bushel. Last year, the yields were 2.25 lbs. of seed per bushel of cones. Just a few years ago, yields this high were thought to be impossible.

Pounds of seed per bushel of cones is an important indicator of seed orchard efficiency, which is a comparison of the actual yield per cone to the potential. In each of the last two years, the seed orchard efficiency in Champion's North Carolina coastal orchard was estimated to be in excess of 90%. This is indeed an outstanding record and can only result from excellance in orchard management, especially insect control, cone harvesting, and seed extraction. The six orchards that led the Cooperative in seed per bushel yields are listed in Table 5. All of these orchards experienced an outstanding year, and the management staff of each are congratulated for their demonstrated excellance.

Table 5. The best seed yields in the Cooperative for 1982, measured in pounds of seed per bushel of loblolly cones harvested.

Organization	Source	Bushels	Pounds of Seed	Pounds Per Bushel
Champion, N. C.	Coastal	405	930	2.30
N. C. Forest Service	Piedmont	455	862	1.89
Federal Paper	Wetlands	487	897	1.84
Westvaco	Coastal	420	774	1.84
Catawba Timber	Piedmont	896	1538	1.72
Chesapeake	Coastal	772	1308	1.69

Increased cost efficiency and greater returns on tree improvement investments are a direct consequence of high seed production per acre of orchard. The production leaders in the Cooperative for the 1982 loblolly harvest, measured by pounds of seed per orchard acre, are listed in Table 6. International Paper Company is to be congratulated for harvesting the most seed per acre for 1982 from their Piedmont orchard near Georgetown, South Carolina. This orchard is managed expertly by Roy Hutto. Three of the six orchards listed in Table 6 as production leaders are owned and managed by International Paper Company. Older orchards generally have the capacity to produce more seed per acre, yet good management and proper orchard siting are important components of per acre seed production success. Champion International's orchard near Newberry, South Carolina

Table 6. The seed production leaders of the Cooperative, measured by pounds of loblolly seed per acre of orchard.

Organization	Location	Source	Orchard Age	Pounds of Seed Per Acre
International paper	Georgetown, S. C.	Piedmont	16	169.3
Champion Int.	Newberry S. C.	Piedmont	24	139.9
International Paper	Georgetown, S. C.	Coastal	19	119.1
Union Camp	Varnville, S. C.	Coastal	22	105.0
Federal Paper	Lumberton, N. C.	Piedmont	20	98.8
International Paper	Natchez, Miss.	Coastal	19	89.1

ranked number two in per acre production this year; however, most noteworthy is the fact that 1982 makes seven out of the last eight years that this orchard has produced more than 100 lbs of seed per acre.

Finally, we congratulate Federal Paper Board for combined excellance in both categories. Federal's wetlands orchard was among the leaders for seed yields per bushel, and their Piedmont orchard ranked with the leaders in pounds of loblolly seed produced per acre of orchard.

Harvesting From Tall Trees

Several loblolly pine seed orchards in the Cooperative have grown very tall. In some orchards trees are over 75 feet tall, and the cost and difficulty of cone harvesting with lift equipment is substantial. These huge trees are not only tall but have very broad crowns. In order to pick all the cones, one must acquire a lift with a reach that exceeds the tree

A lucky escape - damage from a tornado at MacMillan Bloedel's seed orchard was light. Shown is the worst area.

height by as much as 10 feet. There is only a limited number of lift vehicles available for lease in this size category, and they are very large, heavy duty machines that are exceedingly expensive to rent. Furthermore, equipment of this size is rather cumbersome to operate and generally has lower production rates per day of operation. Faced with higher equipment costs and lower production levels per day, orchard managers have begun to evaluate alternative harvesting methods for these very tall trees.

The Virginia Division of Forestry used and evaluated a net system for harvesting loblolly pine seed in the fall of 1981. They were generally pleased with the results of this alternative, which has been used for many years by the Georgia Forestry Commission. The system involves spreading wide (16.5') strips of woven mesh netting on the orchard floor. The strips are overlapped and stapled together at the edges to form a complete ground cover in the orchard. The cones are allowed to open on the tree and, during a dry, sunny period, the seed are shaken from the cone by means of a tree shaker adapted from pecan orchards. The seed, along with large volumes of needles cast from the orchard trees, are gathered from the net. Once the seed are collected, the net is rolled up and stored until needed the following year. The system seems to hold considerable promise, although there are associated concerns.

In the fall of 1981, the Virginia Division of Forestry spread net in a 22 acre section of their New Kent Seed Orchard located in southeastern Virginia. Recent price information indicates that the netting represents a capital investment of from \$1000 to \$1200 per acre. Although expensive, the net is expected to last from 10 to 15 years which means the cost per year of use may be as low as $70 per acre. Virginia's experience indicates that care must be taken to purchase netting with a small enough mesh size so that seed cannot pass through the net and be left on the ground. Since seed size changes considerably throughout the loblolly range, the required mesh size may also. Using the net system, the Virginia Division of Forestry personnel harvested 509 pounds of loblolly seed from 22 acres with the following man hour requirements for the job:

Spreading the Net	-	252 man hours
Gathering the Seed	-	653 man hours
Rolling and Storing the Net	-	443 man hours
Total	-	1348 man hours

The 1981 seed crop in the New Kent Orchard was small with only 23 pounds of seed collected per acre of net or orchard. With this sparse and rather scattered crop, the net system rquired 2.66 man hours per pound of seed harvested. It seems probable that the net system could handle significantly larger seed crops with very small increases in man hour requirements.

Virginia Division of Forestry personnel estimated that 80% or 509 out of a potential 629 pounds of seed were successfully collected. This was despite the fact that the period following cone ripening was unusually wet and damp, and the cones did not completely open for shaking until well into the winter. The seed was actually gathered from the net in February and early March by which time it was apparent that a lot of seed had been lost to predators, birds and rodents. Seed that stays on the net that long will no doubt be partially or completely stratified. While it can be redried for storage, it is not known whether long term viability may be influenced. An additional concern with the net system is the possible damage to seeds that have fallen on the net and been driven on by equipment used during the tree shaking and seed gathering activities. It is not possible to harvest by clone or by genetic quality group using a net system. Despite these concerns, the net ground cover system does seem to offer a harvest option worth considering for orchards that have grown out of reach.

Top pruning tall trees as a means to harvest cones that have grown above the reach of available lifts is being used by at least one Cooperative member with some success. This is not the old idea of topping the tree repeatedly to "hold back" height growth. That method does not work for loblolly pine. The trees continue vigorous height growth; cone production is reduced and, as a result, the considerable expense for the annual "hair cut" is born for nothing. In contrast, the system currently being used calls for the treetop to be cut off during cone harvest about once every three to five years. It is topped when enough cones are located beyond the reach of the lift equipment to make the effort of topping worthwhile. The top is dropped to the ground and the cones removed. Obviously, some cones are lost in years the tree is not topped, and some immature conelets and flower buds are destroyed in the year the top is removed. It is a trade off that recovers a portion of the production at a rather low cost.

Insect Control

Large strides toward improved management of seed orchard insects continue to be made, however, much remains to be learned and accomplished. A second year of monitoring insect populations in Cooperative orchards was completed using species specific pheromone baits in sticky traps. This should allow a refinement of the initial orchard hazard ratings begun last fall and may suggest how variable certain insect populations are from year to year. Several orchard managers were surprised by significant damage to their cones by Dioryctria merkelii during late June of 1982, yet none of these moths had been trapped in 1982. Evidently, adult moths of D. merkelii were active during cone harvest the year before. They bred, laid eggs in the fall which in turn hatched and grew into destructive larvae early in the next growing season. This means that trap catches of adult moths in the fall of one year may dictate the need for an insecticide application the next year. Live and learn!

Several new or revised insecticide registrations are available for orchard managers in 1983. ICI Americas Inc. has obtained a supplemental label for Ambush® that allows its use in seed orchards for coneworms and seedbugs. Shell Chemical Company has modified the label for Pydrin® to increase the pounds of active ingredient per acre per year from 2.4 to 6.3 when used in seed orchards. Pydrin® also has a supplemental label for Nantucket pine tipmoth control in young seed orhcards. FMC Corporation will no longer manufacture Furadan® 10G. They are now making a 15G (15% granular) formulation which has been registered for seed orchard use. Additionally, Furadan® 15G has a 24C (local use) label for tipmoth control in Florida, Mississippi, North Carolina, South Carolina, Tennessee, Georgia, and Virginia. Similar local use labels have been applied for in Alabama.

During the 1982 "insect season," many orchards were aerially sprayed with Pydrin® for the first time. It was often used preferentially over

Guthion® because of some additional safety benefits. However, in several instances, orchard managers observed a significant build up of scale insects on trees treated with Pydrin®. Scale insects are more or less ubiquitous but concern arose when unprecedented population increases occurred. Some information suggests that large populations of scale insects may adversely impact flower and conelet production or survival. As this report is written, it is still unclear what may be causing this phenomena; it could be the choice of chemical (Pydrin® vs. Guthion®), or the method of application (aerial vs. ground sprayer). Are the natural predators of the scale insects being eliminated? Is cone production being reduced by scale insect outbreaks? Work is currently underway to answer these important questions. This work is being conducted jointly with U. S. Forest Service scientists, the Cooperative staff, and member organizations. This has been a mutually rewarding association in the past and will no doubt make important progress on insect problems in the future. One fact is now certain--if we fail to control insects in seed orchards, they will destroy more seed than we will harvest, and the economic returns on tree improvement investments will be substantially reduced.

Following ice damage in the winter of 1981-82, several orchards experienced an outbreak of pitch canker (Fusarium sp.). These trees are expected to recover.

RESEARCH RESULTS AND ASSOCIATED ACTIVITIES

Economics of Tree Improvement

There have been numerous economic analyses of tree improvement programs. Results have shown that in general the most profitable programs involve species that have high product values, are widely planted, can be grown on relatively short rotations, are genetically variable in important economic characteristics, have the potential to produce large quantities of seed in a reasonable period of time, and which can be easily control-pollinated for progeny testing purposes. Over 90% of the Tree Improvement work by N. C. State Cooperative members is directed toward loblolly pine which as a species meets all the criteria important for profitable tree improvement investments.

Most economic assessments of tree improvement have been based upon genetic gain information obtained from young progeny tests and from relatively young seed orchards. The N. C. State Cooperative now has many progeny tests at least 12 years old, and considerable information is available as to trends in performance of improved and unimproved stock through about half-rotation age. Additionally, costs associated with seed orchard programs have risen as orchards have matured and management intensity has increased. Recent work to evaluate the gains being realized in the Cooperative's first generation loblolly pine tree improvement program show that despite increases in the cost of producing improved seed, tree improvement remains an extremely attractive forestry investment.

Percentage gain estimates for height appear to be remaining constant at 3-4% through 12 years of age. Individual orchards differ widely in their performance, but combined gain figures are all significantly greater than 0

($p < .01$) and are not significantly different from each other. With intensive orchard roguing (removing poor parents) based on progeny test information, estimated percentage gains in height growth increase to approximately 7% in the average orchard. A growth and yield model was used to project from these height data the volume and stand value increases expected for an unthinned plantation on site index 60 (base age 25) land at a rotation age of 25 years. Cubic foot volume increases are approximately 7% and 12%, respectively, for unrogued and rogued seed orchards.

Projected improvements in stand value may be as high as 32% under similar conditions, depending on whether planting stock is derived from unrogued or rogued seed orchards (Table 7). The large increment of gain in value results from the harvest of larger, more valuable trees in stands where improved stock was used. The increases in stand values shown in Table 7 are probably conservative. Growth rate was the only trait considered, and improvements in quality characteristics have been ignored. Test data shows that genetic improvements in quality have been large, especially in stem straightness. The improvements in quality undoubtedly have an impact, especially in stands harvested at young ages where quality characteristics play a large role in determining whether a log is of pulpwood quality or whether it could be used for highly valued solid wood products.

Although gains from tree improvement are proving to be greater than anticipated at the outset of the program, they have not been obtained without costs. Investments in loblolly pine tree improvement have risen almost annually as first-generation programs have matured. Inflation has been one cause of increased expenditures, but a major factor has been

Table 7. Improvements in value in unthinned plantations at stand age 25 utilizing unrogued and rogued seed orchard seed on site index $60_{(25)}$ land.

Type Stock	Value (Dollars/acre)	% Gain
Unimproved	1887	--
Unrogued	2223	18%
Rogued	2489	32%

Assumptions:

Value of trees < 9 in. dbh = $12/cord
Value of trees 9-12 in. dbh = $40/cord
Value of trees 12+ in. dbh = $60/cord

increased management intensity of seed orchards and progeny tests as the value of tree improvement in forestry operations became widely recognized. For example, application of insecticides in seed orchards for protection of seed crops was a rarity until about 1970. As the economic impact of losses to cone and seed insects became widely recognized, insecticide applications became a standard operating procedure in essentially all orchards. Many organizations in the Cooperative are now applying insecticides aerially several times each year. Similar situations could be cited for seed orchard practices such as fertilization, irrigation, and subsoiling. Estimates of increased investment costs on a per acre basis for loblolly pine plantations using improved seed are given in Table 8. The calculations assume a seed orchard size of 60 acres and a 6% real discount rate. All figures are after-tax. The extra $5 to $8 cost of utilizing improved seedlings is highly dependent on seed yields, with the largest costs associated with poor seed crops. Surprisingly, costs seem to remain essentially constant or even increase slightly after yields surpass 50 lbs. of seed per acre. This reflects the increased variable cost associated with harvesting very large amounts of cones in a short period of time. Large cone crops necessitate expenditures such as renting of extra lift equipment, overtime wages to hourly workers, and extraction of very large quantities of seed. Harvesting costs in general have a major impact on the cost of seed and anything that can be done to decrease costs will significantly lower production costs for improved seed. Fortunately, harvesting costs are something that can be manipulated and reduced by innovative management. Seed orchard yields in excess of 100 lbs. of seed per acre are a recent phenomenon in the Cooperative. As very large cone crops become commonplace, managers are expected to devise harvesting systems which will lower costs.

With genetic gain and cost figures in hand (Tables 7 and 8), it becomes possible to calculate the return on investment for the tree

Table 8. Increased investment cost per acre for loblolly pine plantations using improved seed.[1/]

		Orchard Seed Yield Per Acre (lbs.)						
Spacing (ft.)	Trees/Acre	10	30	50	75	95	120	135
6x8	907	$20.58	8.64	6.86	6.38	6.90	6.82	7.33
8x8	681	15.46	6.48	5.15	4.79	5.18	5.12	5.51
10x10	436	9.89	4.15	3.29	3.07	3.32	3.28	3.53

[1/]Assumes 8,000 plantable seedlings per lb. of seed.

Table 9.--Rate of return on the tree improvement investment for the average rogued seed orchard under several seed orchard yield experiences.[1/]

Seed Yield Lbs/Acre	Net Investment Cost/Lb. of Seed	Net Investment Cost Per Acre 8' x 8' Spacing	Real, After-Tax Rate of Return
10	$181.53	$15.45	14.26%
20	99.51	8.47	17.05
30	76.20	6.98	18.31
40	63.91	5.44	19.14
50	60.52	5.15	19.40
75	56.30	4.79	19.75
95	60.88	5.18	19.37
120	60.14	5.12	19.43
135	64.69	5.51	19.08
150	69.54	5.92	18.74

[1/]Assumes 8,000 plantable seedlings per lb. of seed.

improvement dollar. After tax rates of return for several seed orchard yield situations are shown in Table 9. As would be expected, the highest rates of return are associated with good seed orchard production, with rates of return of 18% or more for production levels above 30 lbs. of seed per acre. Even at production levels as low as 10 lbs. of seed per acre, tree improvement appears to be a very attractive investment, despite the high cost of producing a pound of seed. Higher rates of return for high yielding orchards presents an excellent case for establishing seed orchards in productive environments, and for using management practices which will maximize seed yields. Cost of land used for seed orchards, even for good agricultural land, has almost no impact on the rate of return from tree improvement. Any acre reforested with unimproved planting stock represents a lost investment opportunity.

A plantation of genetically improved trees on land prepared with herbicides. Genetics must be coupled with overall sound management practices if the full potential is to be realized.

Irrigation and Fertilization in Young Orchards

A rule of thumb for loblolly pine is that 8-12 years usually elapse before orchards reach meaningful production levels. This delay has a negative influence on the profitability of tree improvement. Judicious choice of seed orchard sites and expenditures in orchard management practices which will enhance vigorous tree growth and promote early flowering will almost certainly be good investments. It is now recognized that in the first four to six years following orchard establishment, the management objective is rapid tree growth and crown expansion. With this in mind, recent research by Dr. J. B. Jett in conjunction with Weyerhaeuser examined the impact of full season irrigation and supplemental ammonium nitrate applied monthly from June through September.

Results from the study, installed in a very young orchard near Lyons, Georgia, indicate that irrigation significantly increased total height, stem diameter, crown diameter, crown volume, and limb diameter. Most importantly, the number of apical meristems, which indicate the number of potential flower sites, were increased on average by two per branch. Generally, ammonium nitrate applied monthly without irrigation inhibited tree growth and crown development. It is hypothesized that this inhibition may have resulted from high moisture stress on this rather well drained site. The study was conducted over two years that were exceptionally dry. Additional results from this work will be reported in future years when it is better understood how these treatments ultimately impact cone and seed production.

Seed Orchard Root Rot

During the past year, we experienced for the first time a rather significant outbreak of annosus root rot, (Heterobasidion annosum formerly Fomes annosus), in a production seed orchard, managed by the South Carolina Commission of Forestry. Approximately 5% of the trees in the orchard show some decline or thin foliage that is a strong indication of root rot problems. The actual fungus was identified in the roots of less than 2% of trees. Conks or fruiting structures of the annosus root rot were found on several dead or dying trees.

A detailed survey of the problem including excavation of some root systems indicated that the disease first developed in the root systems of stumps left after an orchard roguing operation. Apparently, the cut surface of the stump, which was treated with borax, was not the initial point of entry for the disease. Instead, it seems that the fungus gained entry into roots near the surface that were cut or injured by a subsoiler or Power-Till Seeder® used to apply Furadan®. The injured roots of the stump had no natural defense mechanism, and the annosus root rot spread easily. Roots of healthy nearby trees that contacted the infected stump roots subsequently became diseased.

As a result of this root rot outbreak, modified management practices on high hazard seed orchard sites have been developed. A high hazard site is one with 70% sand in the top 12 inches of soil. It is only on such seed orchard sites that the following is of major concern.

1. Do not use the Power-Till Seeder® to apply insecticides. Instead, control insects with ground or aerially applied sprays.

2. In all orchards, it is desirable to minimize soil compaction. It is especially important to reduce orchard traffic and reduce the need for subsoiling in sandy sites that have high annosus root rot risk. This can be helped by using herbicides to control grass and weeds in the orchard rows which elminate the need for cross mowing, which in turn reduces the traffic, soil compaction, and the need for subsoiling.
3. Cut orchard trees for roguing or thinning only in the heat of summer. If possible, remove the stumps. If stumps cannot be removed, then grind them down 10 inches below the ground surface and treat with the competing fungus Phlebia (Peniophora) gigantea. Finally, cover the treated stump with soil.
4. Avoid subsoiling in the orchard in the period from one year prior to roguing and up to two years following a roguing operation.
5. If infected trees are discovered, remove all conks (fruiting structures), stop summer amonium nitrate applications and, instead, treat weakened trees with phosphorous, either diamonium phosphate or triple super phosphate to enhance root system vigor.

It is hoped that no additional root rot problems are encountered in Cooperative members' orchards. However, if we should be so unfortunate, we are in a much better position to manage the outbreak as a result of the information gathered from the South Carolina Commission's seed orchard. Following the favorable 1982 growing season and treatment with DAP, the declining trees have apparently recovered very well. The color and foliage vigor has apparently returned to near normal.

East Texas Loblolly

Cooperators with special dry site management problems or high hazard rust areas continue to be concerned with which loblolly source can be used to greatest advantage. Recent reports from research by two Cooperators indicate the value of using loblolly from East Texas in such problem areas.

Catawba Timber Company reported nine year growth and rust data from a trial planted in the sandhills of South Carolina. The study included several sources of loblolly, Choctawhatchee sand pine, slash pine, Virginia and longleaf pine. While no source or species grew well on this very dry, infertile site, the loblolly pine from East Texas outperformed all others by a wide margin (Table 10). It was the tallest after nine years, had much more volume, essentially no rust infection, and high survival.

Table 10. Nine year results of Catawba Timber Company's species/source trial on a deep sand - high rust hazard site near Patrick, South Carolina.

Species/Source	DBH Inches	Height Feet	Survival Percent	Stem Rust Percent	Volume/Acre Cubic Feet
Loblolly Pine/Texas	4.3	21.7	96	1	554
Sand Pine/Choctawhatchee	3.8	19.5	82	-	355
Loblolly/Seed Orchard	3.5	17.6	86	38	296
Slash Pine	3.3	18.9	76	17	243
Loblolly Pine/Local	3.2	16.2	89	33	238
Virginia Pine/Local	2.6	13.0	99	-	148
Virginia Pine/Maryland	2.4	12.9	97	-	137
Longleaf Pine	2.3	12.6	17	-	22

Although clearly inferior to the East Texas loblolly, it was a surprise to see that sand pine survived and grew reasonably well several hundred miles north of its native range in northwest Florida. For years these Sandhill sites were regenerated with slash pine, which as can be seen from these data was clearly a poor choice. As is too often the case, longleaf pine had terrible planting survival; in addition, the surviving trees have grown very poorly.

Two plantings in which several unimproved sources of loblolly pine were compared have been summarized by Early McCall, research forester for Rayonier Corporation. The results are given in Table 11 for height and rust infection after four years in the field. Again, East Texas loblolly was clearly superior in tolerance to fusiform rust while always among the leaders for height growth.

Table 11. Four year results of Rayonier's unimproved loblolly source trial planted on a North Florida coastal plain site and a Georgia piedmont site.

Loblolly Source	Georgia Piedmont Planting Height-ft.	Georgia Piedmont Planting Rust-%	North Florida Coastal Planting Height-ft.	North Florida Coastal Planting Rust-%
East Texas	9.8	5	12.5	3
Livingston Parish, La.	9.8	15	11.3	16
Marion Co., Florida	9.8	40	13.2	15
North Florida-Coastal	9.0	50	13.8	38
Georgia-Piedmont	9.5	18	10.5	20
Georgia-Upper Coastal	9.0	30	11.4	20

Several Cooperators with the combination problem of dry sites and high rust hazard have recently established small specialty orchards of selected east Texas loblolly pine. We are indebted to Bill Lowe, Director, and members of the Western Gulf Tree Improvement Cooperative for their generosity and willingness to work with our members on this special problem.

Pulping Rust Infected Wood

Dr. Michael Veal recently completed his Ph.D. thesis which examined the impact of fusiform rust galls on the pulping qualities of young (10 year old) loblolly pine. Information from this study is of value to the mill manager and may be useful to procurement foresters as well. It helps the geneticist more fully appreciate the true impact of fusiform rust on forest productivity and, as a result, allows a more appropriate weighting of this economically important characteristic in tree selection. Excerpts from Dr. Veal's thesis abstract are included below:

> Composite mixes of 20% rust affected -80% non-affected and 30% rust affected -70% non-affected stemwood were pulped. Although no pulp yield loss could be detected, these mixtures required 2-4% more alkali for comparable delignification; pulp had significantly lower burst strength (5%) but yields of extractives were 20-30% higher than non-affected stemwood. Failure to detect a pulp yield loss was due to limits of precision of the experimental techniques.
>
> Measurement of all 721 trees in two replications of the heritability study at Bainbridge, Ga. at 10 years of age showed 30% of the trees had stem infections and 7% of the total dry weight of stemwood was affected by rust. Wood from this stand was estimated to use 10% more alkali in pulping, yield 1% less pulp of 3% lower burst strength, 25% more crude tall oil, 40% more crude sulfate turpentine, and 1% more oven dry wood per unit green weight than that from a completely rust-free stand. These properties tend to compensate each other making wood from a young stand with this amount of infection of similar economic value to non-affected wood for production of linerboard grade pulps.

Premature harvesting of infected plantations to minimize wood losses through rust-associated mortality produces large quantities of juvenile wood that has a negative impact in addition to the effects of diseased wood, on kraft pulping.

Diseased wood can probably be used for unbleached kraft pulp, in bleached kraft pulp with some care, but not in sulfite or mechanical pulps without extreme precautions.

Tissue Culture Research

The research done in the Special Project on Tissue Culture is ultimately expected to pay very high dividends to tree improvement efforts with loblolly pine. While not having day to day responsibilities in the conduct of the tissue culture work, the Tree Improvement Cooperative staff maintains a close association with the research through Steve McKeand's efforts as the Tree Improvement Specialist with tissue culture.

A great deal of progress has been made in the tissue culture program during the past year. Research in the laboratory by Drs. Henry Amerson and Ralph Mott in the Botany Department continues to move ahead. Methods to improve the rooting of tissue culture plantlets have been developed in Dr. Amerson's lab and is of major importance to future work with plantlets. Mass propagation of mature trees using callus cultures continues to be the primary goal of the project. Understanding the concepts of why and how buds form and develop has been very difficult. Dr. Mott has progressed well with the research and new systems to produce cultures look promising.

The greenhouse and field research phase of the project has been concerned with the growth and development of the plantlets once transferred to soil. Most of the recent effort has been to understand the development of the plantlet root systems. Plantlets tend to have thick unbranched roots (Figure 2) which are not very efficient at nutrient uptake.

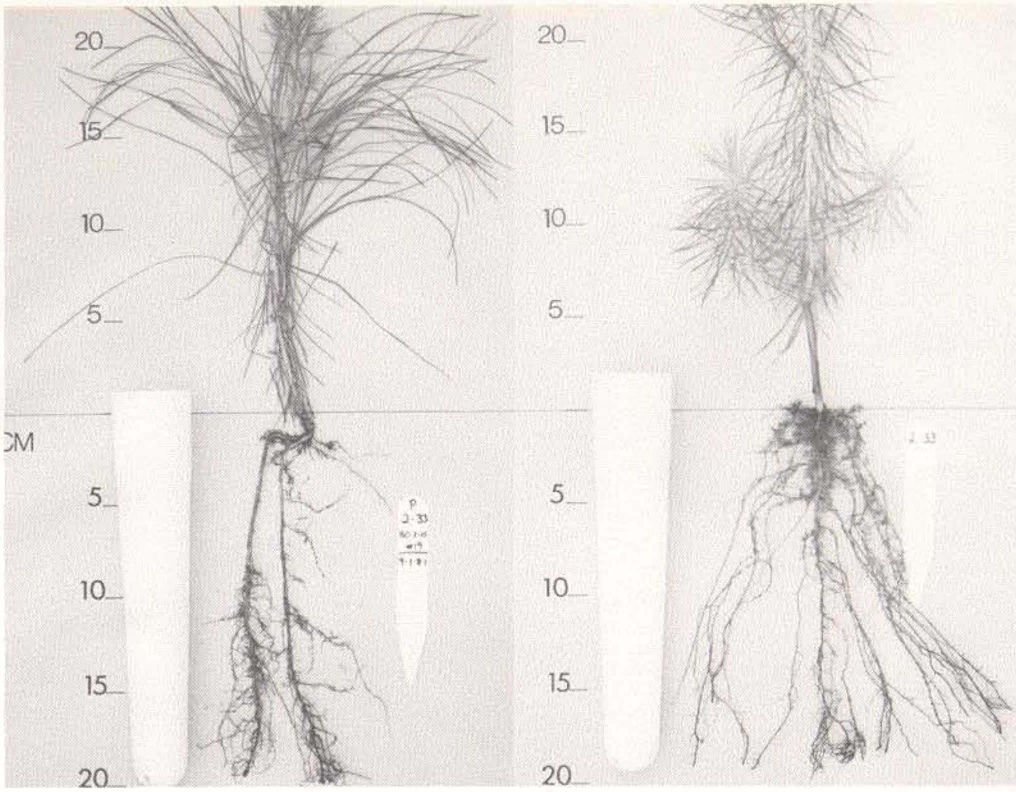


Figure 2. Plantlet (left), seedling (right) at 20 weeks of age. Notice the 2 thickened roots on the plantlet where much of the dry weight is concentrated.

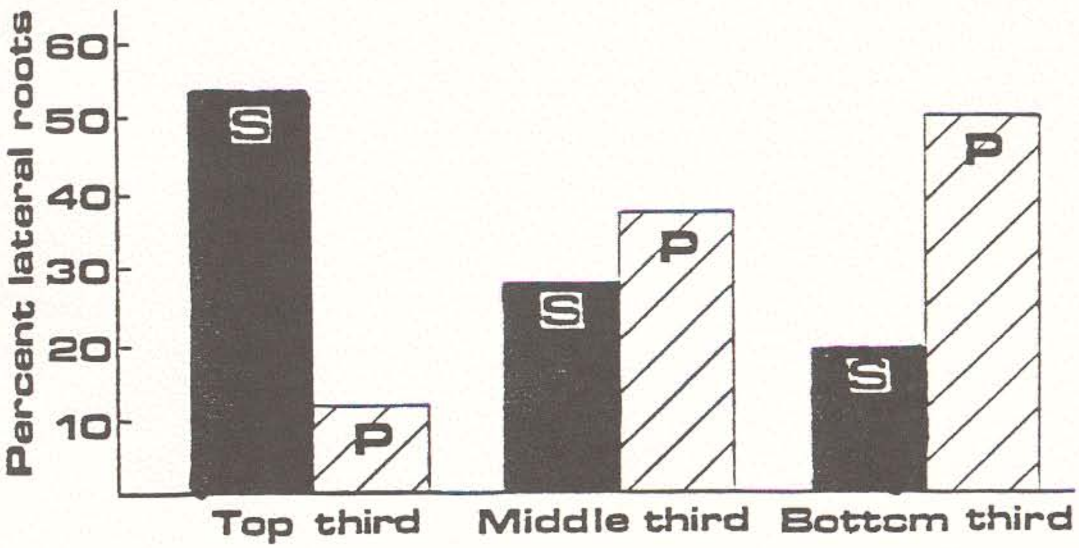


Figure 3. Position along main root (taproot) where dominant lateral roots originated in plantlets (P) and seedlings (S).

Table 12. Number of Dominant Lateral Roots for Plantlets and Seedlings at 6 and 20 Weeks of Age.

Age	Plantlets	Seedlings
6 Weeks	2.4	22.6
20 Weeks	10.3	18.3

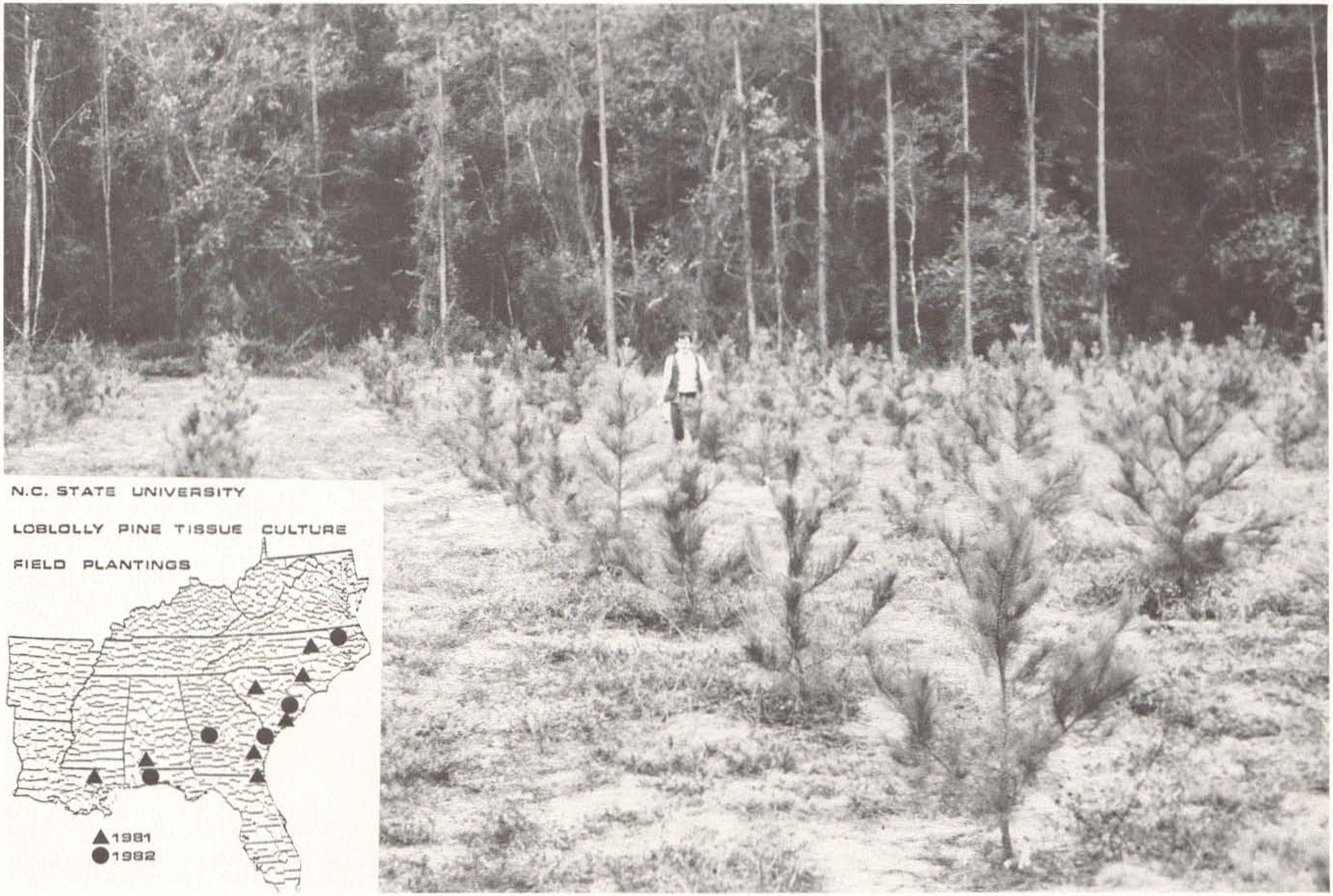
Plantlets produce fewer lateral roots than seedlings (Table 12). Thus plantlets have less root surface area for nutrient uptake. The tendency for plantlets not to form lateral roots can also be demonstrated in Figure 3. The majority of the plantlet roots originate in the bottom of the containers, whereas the majority of the seedling roots originate nearer the soil surface. Only after the plantlet roots are air pruned at the bottom of the container is lateral root development enhanced.

Another major emphasis in tissue culture has been a study to look at plantlet development in a nursery bed. Different root pruning treatments were studied to determine the effects on plantlet development. Root pruning increased the fibrousness of the root system by increasing the number of lateral roots. The growth of the plantlets in the nursery bed was excellent. Even though the plantlets were very small when planted in May (average 1/2 in. in height and 3.5 in. root length), the survival was 97% in the nursery bed. We are hopeful of using pine seedling nurseries for production of plantlets in future years.

The field testing phase of the tissue culture project also has progressed well. A total of 13 field plantings have been established which will yield long term results concerning the growth of plantlets in the field.

Tissue culture plantlets were successfully established in a nursery bed at Federal Paper Board's Nursery.

Plantlets grew quite well in the nursery and were lifted to determine root development patterns.



Tissue culture plantings have been established throughout the Southeast and will yield valuable information over the next few years.

Wide Cross Study

Results from the well known southwide seed source study and other work such as the Rayonier source trial for loblolly pine noted earlier in this report have all shown distinct patterns of geographic variation for growth, fusiform rust resistance, and other economically valuable traits. Clearly it is important to match geographic sources with planting locations. Such results raised curiosity about the potential of reaping further benefit from hybridization among geographic sources of loblolly pine which might combine desirable traits from different geographic races.

With this opportunity in mind, the Cooperative initiated a Wide Cross Study in 1968 as a means to measure the usefulness of trees originating from crosses of widely separated geographic regions. The mother trees for these crosses were all seed orchard parents selected in eastern North Carolina. Within region, crosses were made among these local trees. Intermediate crosses were made between the North Carolina trees and trees selected in Georgia and Alabama. Wide crosses were made between the North Carolina trees and trees selected in Texas and Louisiana. These three types of crosses and open pollinated seedlings from the parents used in the crosses were all planted on a coastal plain site in northeastern North Carolina.

Recently, graduate research assistant John Frampton analyzed the eight and twelve year measurements of the Wide Cross Study with the following results. The wide crosses produced 11.8 and 17.4 percent more volume per tree and 5.7 and 7.3 percent lower rust scores than the mean of the open pollinated seedlots of their parents at ages eight and twelve, respectively. At age 12, the intermediate crosses performed 0.73 and 7.2

percent better than the mean of the open pollinated seedlots of their parents for volume and rust, respectively. These data are direct evidence of hybrid vigor among certain geographic sources of loblolly pine. Apparently, sets of genes for fast growth and fusiform rust resistance from more southern geographic regions are capable of exhibiting dominance over genes for those same traits from North Carolina trees without altering adaptive ability for North Carolina environmental conditions.

A system to exploit these advantages could be devised to produce geographic hybrids for commercial outplanting. To mass produce such geographic hybrids, a technique of supplemental mass pollination could be employed with pollen from the desired distant geographic region. Seed not fertilized by supplemental pollen would still be of an appropriate within geographic region cross. When developed, techniques for mass production of vegetative propagules such as rooted cuttings or tissue culture could be used to produce hybrids for commercial planting stock.

Graduate Student Research and Education

The education of graduate students and the research they conduct in conjunction with their degree program is an important activity of the Cooperative. During the last year, 13 students have been working toward advanced degrees in close association with the Tree Improvement Cooperative. Five are working on Masters degrees and eight are involved in the Ph.D. program. In addition, staff member John Talbert is making good progress toward completing his Ph.D.. We are most happy to report that J. B. Jett, Associate Director, and Steve McKeand, Tree Improvement Specialist with the Tissue Culture Research Project, successfully completed their Ph.D. programs in the last year. Congratulations to Dr. Jett and Dr. McKeand are in order.

In addition to the work with students on their respective research programs, Cooperative staff members were invited to lecture many times in the past year in a variety of graduate and undergraduate courses. Numerous seminars on aspects of tree improvement were conducted by members of the staff.

The graduate students working with the Cooperative, the degree to which each aspires and the subject of their research project are listed on the following page. The student research projects encompass a wide range of subject matter, but in each case, the work is supportive of overall program research goals. Financial support for students comes from a variety of sources--The Tree Improvement Program, The School of Forest Resources, The N. C. State University Agricultural Research Service, The U. S. Forest Service, industry-sponsored fellowships, and foreign governments.

Student	Degree	Research Project
Robin Arnold	Masters	An economic analysis of rust resistance alternatives with loblolly, shortleaf and loblolly x shortleaf hybrids
Sheryl Brown	Masters	A detailed study of the pollination mechanism of loblolly pine
Cheryl Busby	Ph.D.	Developing a multi-trait selection index for loblolly pine
Bruce Emery	Ph.D.	Intensive roguing of seed orchards
John Frampton	Ph.D.	Genetic segregation of symptom types in fusiform rust
Mike Harbin	Masters	Seed source studies involving Florida source loblolly pine
Gary Hodge	Ph.D.	Cold tolerant loblolly pine
James Hodges	Masters	Genotype-fertilizer interaction studies of slash pine

of slash pine

Student	Degree	Research Project
Randy Johnson	Ph.D.	Genetic variation in nitrogen uptake and utilization in loblolly pine (joint student with Fertilizer Coop.)
Richard Sniezko	Ph.D.	Hybrid vigor resulting from outcrossing S_1 loblolly pines
Jarbas Shimizu	Ph.D.	Genotypic competitive effects in loblolly pine
Claire Williams	Ph.D.	Early Selection in loblolly pine
Lisa Wisniewski	Masters	Discriminate analysis used to classify rust resistance classes

Program Staff

Listed below are Cooperative program staff members. The program is fortunate to have such a dedicated and capable group working as a team. The faculty level staff and those listed under support staff work full time on Cooperative activities except where noted otherwise by an asterisk*. These laboratory and field technicians in all cases have joint appointments with Tree Improvement and one other cooperative program.

Faculty-Level Staff

Bob Weir - Director
J. B. Jett - Associate Director
Jerry Sprague - Liaison Geneticist
John Talbert - Liaison Geneticist

Associated Appointments

Floyd Bridgwater - U. S. Forest Service
Steve McKeand - Tissue Culture
Bruce Zobel - Professor Emeritus

Support Staff

Alice Hatcher - Coordinator
Data Processing & Secretarial
Rosina Rubes
Judy Stallings
Jackie Evans

*Vernon Johnson - Coordinator
Laboratory & Field Technician
*Addie Byrd
*Greg Ferguson

Two changes occurred in the ranks of the support staff during the last year. Ms. Donna Miller resigned in January and moved to Butler, Alabama to be with her new husband, Mike Williford, the contact man for American Can Company. We were pleased to have Ms. Rosina Rubes join the data processing staff as of mid-March. Greg Ferguson filled the vacancy in a research technician position created when Rob Wilson left to become contact man for Hiwassee. We welcome both Rosina and Greg to the Cooperative Program staff.

Once again, we have noted the associate appointments of three persons who make important contributions to the program. Dr. Floyd Bridgwater is employed by the U. S. Forest Service's Southeastern Forest Experiment Station and is assigned to the Forestry Department at N. C. State University. Floyd's research program has been developed in close coordination with the Cooperative, and the joint research initiatives are mutually beneficial to both organizations. Floyd is also working with several graduate students. Steve McKeand is a research assistant with the industry supported Special Project on Tissue Culture which is being largely conducted in the Department of Botany. Steve is responsible for the design and establishment of the greenhouse and field trials of rooted cuttings and tissue culture plantlets. Results of these trials will have a direct impact on opportunities for increasing genetic gain in future generations. Bruce Zobel continues to work half-time with the Forestry Department concentrating mostly on teaching and graduate student programs.

MEMBERSHIP OF THE 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., N.C.
Boise Cascade Corporation	S.C., N.C.
Buckeye Cellulose Corp.	Ga.
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., N.C.
Container Corporation of America	Ala., Fla.
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	Northern Region--Va., N.C. Southern Region--S.C., Ga.
Great Southern Paper Company	Ga., Ala., Fla.
Hammermill Paper Company	Ala.
International Paper Company	Atlantic Region--N.C., S.C., Ga. Gulf Region--Miss., Ala.
Kimberly-Clark Corporation	Ala.
MacMillan-Bloedel Corporation	Ala., Miss.
North Carolina Forest Service	N.C.
Rayonier, Inc.	Fla., Ga., S.C.

MEMBERSHIP OF THE TREE IMPROVEMENT COOPERATIVE (CON'T)

Organization	States Where Operating
Scott Paper Company	Ala., Fla., Miss.
South Carolina State Commission of Forestry	S.C.
St. Regis Paper Company	Ala., Miss., Fla., Ga.
Tennessee River Pulp and Paper Co.	Tenn., Ala., Miss.
Timber Realization Company	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.
Weyerhaeuser Company	N.C. Region--N.C., Va. Miss. Region--Miss., Ala.

During the last year, the Masonite Corporation through a vote of stockholders decided to divest themselves of their land base in Mississippi, Alabama, and other regions of the country. A limited partnership known as Timber Realization Company was formed to manage the divestiture. Tree improvement activities and membership in the Cooperative have been maintained by the partnership. We anticipate sale of a significant portion of the land and timber including the seed orchards in the near future. It is hoped and anticipated that membership in the Cooperative will be maintained by the new owner.

The current membership of the Cooperative includes 25 forest based industries and the forestry organizations of three states. Among the industry members, there are nine supplemental units bringing the total membership to 37 working units.

PUBLICATIONS OF SPECIAL INTEREST
TO MEMBERS OF THE COOPERATIVE

Amerson, H. V., S. E. McKeand, and R. L. Mott. 1981. Tissue culture and greenhouse practices for the production of loblolly pine plantlets. Proc. 16^{th} South. For. Tree Impr. Conf., Blacksburg, Va. p. 168-175.

Bridgwater, F. E. and D. L. Bramlett. 1982. Supplemental mass pollination to increase seed yields in loblolly pine seed orchards. South. Jour. App. For. 6:100-103.

Bridgwater, F. E. and I. F. Trew. 1981. Supplemental Mass Pollination. In: Pollen Management Handbook. USDA For. Serv. Agric. Handbook. No. 587. p. 52-57.

Bridgwater, F. E., J. T. Talbert, and S. Jahromi. 1982. Index selection for increased dry weight in a young loblolly pine population. Sil. Gen. (in press).

Bridgwater, F. E., J. T. Talbert, and D. Rockwood. 1982. Field designs for genetic testing of forest trees. Workshop on Progeny Test Methodology, Auburn, Ala. June, 1982, 14 p..

Bruno, A. and B. Zobel. 1982. Genetic base populations, gene pools, and breeding populations for Eucalyptus in Brazil. Sil. Gen. 30:146-149.

Duffield, J. W. 1981. Hybridization - then and now. Proc. 16^{th} South. For. Tree Impr. Conf., Blacksburg, Va. p. 1-5.

Dvorak, W. S., E. C. Franklin, and G. Meskimen. 1981. Genetic strategy for _Eucalyptus robusta_ Sm. in southern Florida. Proc. 16^{th} South. For. Tree Impr. Conf., Blacksburg, Va. p. 116-122.

Foster, G. S., F. E. Bridgwater, and S. E. McKeand. 1981. An analysis of systems for producing large numbers of vegetative propagules of forest trees. Proc. 16^{th} South. For. Tree Impr. Conf., Blacksburg, Va. p. 311-319.

Foushee, D. L., J. T. Talbert, B. J. Zobel, and K. O. Summerville. 1981. The effects of seed orchard fertilization on seed and seedling Characteristics of four longleaf pine families. South. Jour. App. For. 5:159-162.

Frampton, L. J., R. J. Weir, J. T. Talbert, and M. C. Harbin. 1983. Wide crossing to improve volume growth and fusiform rust resistance in loblolly pine (in press).

Franklin, Carlyle. (Ed.) 1981. Pollen Management Handbook. USDA For. Ser. Agri. Handbook. No. 587. 98 p.

Franklin, E. C., and F. E. Bridgwater. 1981. Genetics of fast growth and wood properties. TAPPI Nat. Meet., Chicago, Ill., March, 1981. 4 pp.

Gallegos, C. M., C. B. Davey, R. C. Kellison, P. A. Sanchez, and B. J. Zobel. 1982. Technologies for reforestation of degraded lands in the tropics. Office of Technology Assessment, Food and Renewable Resources, Congress of the United States, Washington, D. C. 133 p.

Garlo, A. S. 1982. Vegetative propagation of fraser fir seed orchard trees by rooted cuttings and grafting. M.S. Thesis, Dept. of Forestry, N. C. State Univ., Raleigh. 60 p.

Harcharik, D. A. 1981. The timing and economics of irrigation in loblolly pine seed orchards. Ph.D. dissertation, Dept. of For., N. C. State Univ., Raleigh, N. C. 86 pp.

Hatcher, A. V., and R. J. Weir. 1981. The design and layout of advanced generation seed orchards. Proc. 16th South. For. Tree Impr. Conf., Blacksburg, Va. p. 205-212.

Hatcher, A. V., F. E. Bridgwater, and R. J. Weir. 1981. Performance level-a standardized score for progeny test performance. Sil. Gen. 30:184-187.

Jett, J. B. 1983. The impact of irrigation and supplemental nitrogen fertilization on the development of a young loblolly pine seed orchard. Ph.D. dissertation, Dept. of For., N. C. State Univ., Raleigh. 38 p.

Jett., J. B., and J. T. Talbert. 1982. (Abstract) The inclusion of wood specific gravity in the development of advanced generation seed orchards. Proc. 6th N. Am. For. Biol. Workshop. Edmonton, Alberta. Aug., 1980, p. 138.

Jett, J. B. and J. T. Talbert. 1982. The place of wood specific gravity in the development of advanced-generation seed orchards and breeding programs. South. Jour. Appl. For. 6:177-180.

Kellison, R. C. 1981. Characteristics affecting quality of timber from plantations, their determination, and scope for modification. World Forestry Congress, Japan. 11 pp. (In press).

Kellison, R. C. and R. C. Purnell. 1982. Genetic improvement of southern hardwood--an update. For. Farmer. (In press). 12 p.

Kellison, R. C. and J. R. Sprague. 1981. Forest genetics for tomorrow's southern pine forest. Pulp and Paper 55:187-191.

Lambeth, C. C., B. J. Zobel, and R. W. Stonecypher. 1982. Interaction of Douglas-fir full-sib families with temperature, nutrients, and moisture in a phytotron: the effect of predicting field performance. Proc. 7th N. Am. For. Bio. Workshop, Lexington, Ky. (in press).

Lowerts, G. A., and R. C. Kellison. 1981. Genetically controlled resistance to discoloration and decay in wounded trees of yellow poplar. Sil. Gen. 30:98-101.

McCall, E. Y. and R. C. Kellison. 1981. The effect of pollination, pollen tube growth, and tree nutrient status on conelet abortion in open-pollinated longleaf pine. Proc. 16th South. For. Tree Impr. Conf., Blacksburg, Va. p. 267-275.

McKeand, S. E. 1981. Loblolly pine tissue culture: current and future uses in southern forestry. N. C. State Univ., School of Forest Res. Tech. Rept. No. 64. 50 p.

McKeand, S. E. and W. F. Beineke. 1981. Sublining for half-sib breeding populations of forest trees. Sil. Gen. 29:14-17.

McKeand, S. E. and R. J. Weir. 1982. Tissue culture in forestry: a current prospective (in press).

McKeand, S. E. and L. A. Wisniewski. 1982. Root morphology of loblolly pine tissue culture plantlets. Proc. 7th N. Am. For. Bio. Workshop, Lexington, Ky. (in press).

Miller, L. K. and R. J. Weir. 1982. Effect of two differing temperature regimes on the expression and heritability of several seedling characteristics of Fraser fir (Abies fraseri), (in press).

Mott, R. L. 1981. Tissue culture propagation of conifers: current and future. Proc. 16th South. For. Tree Impr. Conf., Blacksburg, Va. p. 160-167.

Mott, R. L., and H. V. Amerson. 1981. A tissue culture process for the clonal production of loblolly pine plantlets. Technical Bulletin No. 271. N. C. Ag. Res. Ser. 14 pp.

Paschke, J. L., G. R. Johnson, Jr., and W. E. Gardner. 1981. Genetic aspects of nursery management for sweetgum seedling uniformity. Proc. 16th South. For. Tree Impr. Conf., Blacksburg, Va. p. 279-287.

Perry, T. O. and W. L. Hafley. 1981. Variation in seedling growth rates - their genetic and physiological bases. Proc. 16th South. For. Tree Impr. Conf.. Blacksburg, Va. p. 288-301.

Pousujja, Reungchai. 1981. Potential and gain of a breeding program using vegetative propagation compared to traditional systems. Ph.D. dissertation, Dept. of Forestry, N. C. State Univ., Raleigh, N. C.

Skoller, D. L., F. E. Bridgwater, and C. C. Lambeth. 1983. Fusiform rust resistance of select loblolly pine seedlots in the laboratory, nursery, and field. South. Jour. App. For. (in press).

Sniezko, R. A. 1981. Genetic and economic consequences of pollen contamination in seed orchards. Proc. 16th South. For. Tree Impr. Conf. Blacksburg, Va. p. 225-233.

Sprague, J., and E. B. Synder. 1981. Extraction and drying of southern pine pollen. In: Pollen Management Handbook. USDA For. Ser. Agri. Handbook. No. 587. p. 33-36.

Sprague, J. R., J. T. Talbert, J. B. Jett, and R. L. Bryant. 1982. Utility of the Pilodyn in selection for mature wood specific gravity in loblolly pine. For. Sci. (in press).

Talbert, J. T. 1981. One generation of loblolly pine tree improvement: results and challenges. Proc. 18th Can. Tree Imp. Assoc. Meeting, Duncan, B. C. p. 106-120.

Talbert, J. T., and J. B. Jett. 1981. Regional specific gravity values for plantation grown loblolly pine in the southeastern United States. For. Sci. 27:801-807.

Talbert, J. T., F. E. Bridgwater, and C. C. Lambeth. 1981. Genetic Testing Manual. N. C. State University-Industry Pine Tree Improvement Cooperative. 37 p.

Talbert, J. T., J. B. Jett, and R. L. Bryant. 1982. Inheritance of wood specific gravity in an unimproved loblolly pine population: 20 years of results. Sil. Gen. (in press).

Talbert, J. T., F. E. Bridgwater, J. B. Jett, and S. Jahromi. 1982. Genetic parameters for wood specific gravity in a control-pollinated genetic test. TAPPI R & D Conference, Asheville, N. C., August, 1982, p. 179-182.

Talbert, J. T., R. J. Weir, and R. D. Arnold. 1983. Loblolly pine tree improvement an attractive forestry investment. Proc. Sou. For. Econ. Workers Workshop, Mobile, Ala. (in press).

Talbert, J. T., R. A. Wilson, and R. J. Weir. 1982. Utility of first-generation pollen parents in young second-generation seed orchards. Proc. 7th N. Am. For. Bio. Workshop, Lexington, KY. (in press).

Weir, R. J., J. P. van Buijtenen, and R. E. Goddard. 1982. What not to do or Robert's Rules of Disorder in progeny testing of forest trees. Workshop on Progeny Test Methodology, Auburn, Ala.

Weir, R. J., R. G. Pearson, and W. D. Smith. 1982. Utilization of pine thinnings. Proc. Workshop on Thinning Pine Plantations, Long Beach, Miss. (in press).

Weir, R. J., J. T. Talbert, and S. E. McKeand. 1982. Trends in loblolly pine tree improvement in the Southern United States. Proc. Symp. on Management of Loblolly Pine Ecosystems, Raleigh, N. C. p. 102-114.

Williams, C. G. 1981. Differences in seedling root morphology between two edaphic sources of loblolly pine (Pinus taeda L.) in eastern North Carolina. M.S. Thesis, Dept. of For., N. C. State Univ., Raleigh, N. C. 54 p.

Williams, C. and F. E. Bridgwater. 1981. Screening loblolly pine for adaptability to deep peat sites: A seedling study of two edaphic seed sources from eastern North Carolina. Proc. 16th Sou. For. Tree Imp. Conf., Blacksburg, Va. p. 143-148.

Zobel, B. J. 1981. The effect of genetic improvement of pine on regeneration methods. In Artificial Regeneration of Southern Pines - Decision Making the Regeneration Process, Clemson Univ. 4 pp.

Zobel, B. J. 1981. Fast Growth Plantations in the Tropics and Subtropics of South America. (In press - Forest Farmer).

Zobel, B. J. 1981. Making forests productive--overcoming perceived constraints. Banff Center/IRPP National Resources Conf., Canada. 9 pp. (Mimeo).

Zobel, B. J. 1981. Vegetative propagation in forest management operations. Proc. 16th South. For. Tree Impr. Conf., Blacksburg, Va. p. 149-159.

Zobel, B. J. 1982. Changing quality of the world timber supply (to be presented at the International Academy of Wood Science Conference, September, 1983).

Zobel, B. J. 1982. Developing fusiform resistant trees in the Southeastern United States. Proc. 3rd Int. Conf. on Genetics of Host-Parasite Interactions in Forestry, Wagninen, Holland (H. M. Heybroek, B. R. Stephan, and K. von Weissenberg, eds.), p. 417-426.

Zobel, B. J. 1982. Loblolly pine - in restrospect. Proc. Symp. on Management of Loblolly Pine Ecocsystems, Raleigh, N. C. p. 1-6.

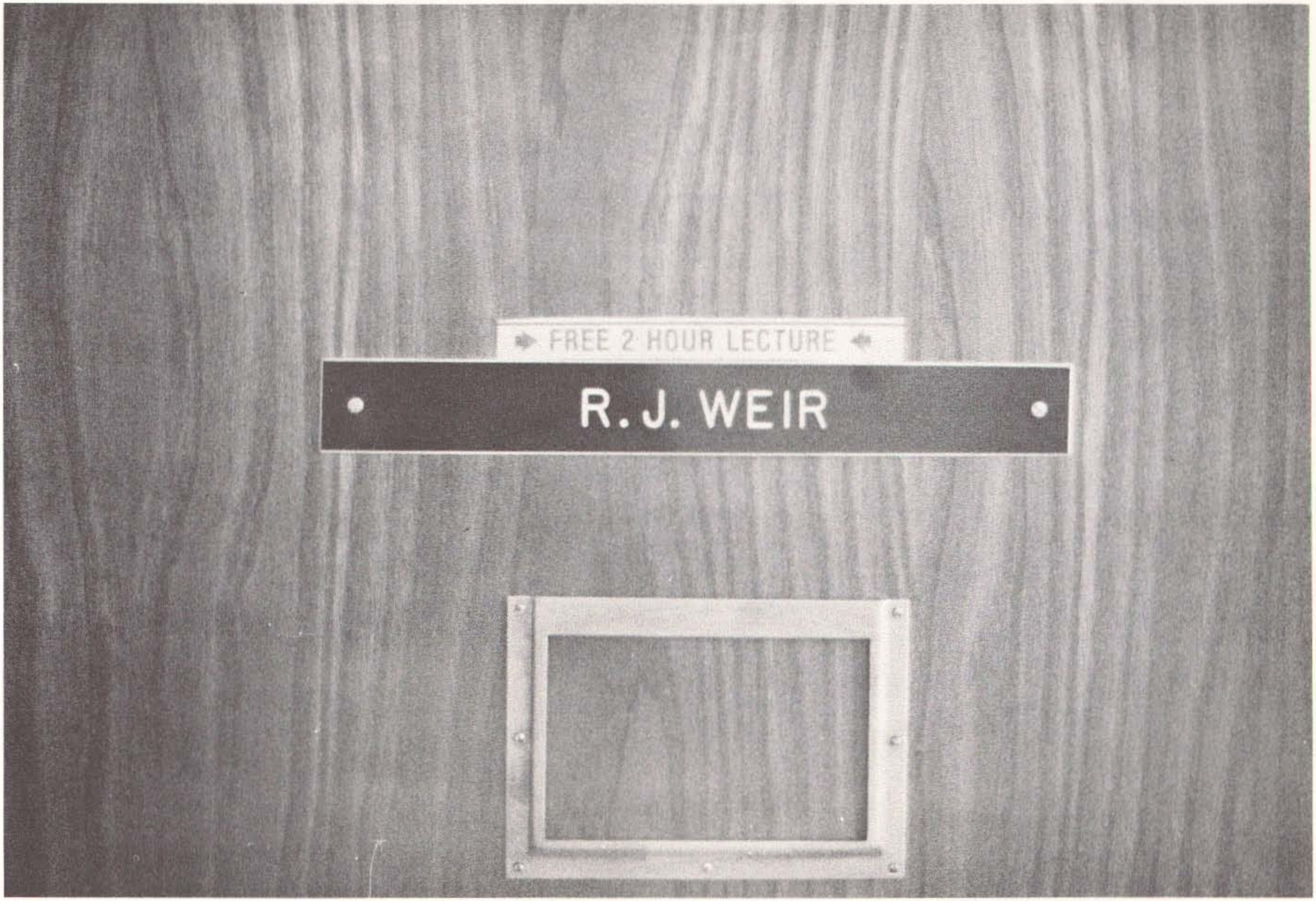
Zobel, B. J. 1982. Research and development in forest biology in Canada. Can. For. Congress, Toronto. p. 68-73.

Zobel, B. J. 1982. The necessity for tree improvement in forestry plantations in Venezuela. Venezuela Forestal (in press). 12 p.

Zobel, B. J. 1982. The world's need for pest-resistant forest trees. Proc. Int. Workshop on the Genetics of Host-Parasite Interactions in Forestry, Wagninen, Holland (H. M. Heybroek, B. R. Stephan, and K. von Weissenberg, eds.), pp. 1-8.

Zobel, B. J. and J. T. Talbert. Applied Tree Improvement. John Wiley and Sons (in press).

Zobel, B. J., E. Campinos, Jr., and Y. K. Ikemori. 1983. Selecting and breeding for desirable wood. TAPPI 66:70-73.



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