TWENTY-SIXTH ANNUAL REPORT

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

School of Forest Resources
North Carolina State University
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EXECUTIVE SUMMARY

1. The 1981 cone and seed crop surpassed all previous orchard production records.

    a. Members of the Cooperative harvested 50.5 tons of genetically improved loblolly pine seed in 1981. This is enough seed to grow 808 million plantable seedlings.

    b. The Cooperative averaged 1.58 pounds of seed per bushel of loblolly cones. Champion International Corporation's Coastal Orchard in N. C. averaged 2.25 pounds of seed per bushel--an all time record.

    c. Significant improvement in insect control capability has resulted from aerial application of insecticides, the registration of Pydrin®, and population monitoring with synthetic pheromones.

2. Increased effort is being directed toward breeding the Cooperative's very broad genetic base.

    a. Over 3100 plantation selections have been graded for use in the Program.

    b. A total of 2156 second generation selections have been graded in Cooperative progeny tests.

    c. In a Special Advisory Committee Meeting, the Cooperative adopted an aggressive but realistic breeding schedule for the next cycle of improvement.

    d. The first second generation genetic test was planted in 1982.

3. Several Cooperative research initiatives are producing valuable results.

    a. First generation value gains have been estimated to be 18% for unrogued orchards and 32% for rogued orchards.

    b. Mature wood specific gravity is under substantial genetic control and is highly correlated with juvenile wood specific gravity.

    c. If dry weight per acre is the goal of selection, only a small gain in efficiency is realized if specific gravity is added to a selection index model emphasizing volume improvement.

d. The Pilodyn Wood Tester appears to hold promise as an aid in selecting to improve wood specific gravity in loblolly pine.

e. Second generation selections are producing more pollen catkins than first generation "pollen" parents when compared in young second generation orchards.

f. Eight field plantings of tissue cultured plantlets have been established.

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

5. The Cooperative welcomes Buckeye Cellulose Corporation as the newest member. 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 26th year of operation. The challenge ahead is to fully exploit the potential for improvement in future generations, a potential projected to be significantly greater than the benefit realized to date. Yet the environment in which we work to meet the challenge has become increasingly difficult.

The southern forest products industry is currently struggling through the most difficult economic period experienced since it became a fixture in the South following World War II. Housing markets are depressed due to record high interest rates. Pulp, paper, and board products have had recent price drops without a commensurate decrease in costs. Capital expenditures for forestry have greatly diminished or disappeared. Operating budgets have been cut drastically.

However, despite the difficult economic climate, members of the Cooperative have made a renewed commitment to the long term development of loblolly pine genetic resources. Ambitious, yet realistic goals have been set for accomplishing key breeding and testing schedules in the future. Program members have set their sights on the rapid development of future forest productivity potential.

The South is clearly emerging as the "woodbasket" of the nation and in fact for much of the world. Forest land productivity is the key, and increasing numbers of industrial leaders are recognizing this important fact. Currently, more capital is being directed into the southern region for expansion of the pulp and paper manufacturing capacity than at any time in the last 15 years. It has been estimated that over 60% of the new productive capacity of the industry will be located in the South.

In order to meet the challenge of producing raw materials at a reasonable price for current and expanded capacity, the forest land manager must successfully increase production per acre per year. That is the major goal of the Cooperative. We have made good progress to date, with value gains assessed between 18 and 32% and the production of 50.5 tons of improved seed in 1981. Expectations from future cycles of improvement are even more promising. The recognition of this success and future potential has provided impetus for recent decisions to push ahead aggressively. The Cooperative's spirit is alive and well.

SEED ORCHARD PRODUCTION

Cone and Seed Yields

The 1981 cone and seed crop surpassed all previous production records. For the three year period, 1977 through 1979, the Cooperative's loblolly pine orchards produced an average of 36,274 bushels of cones and 25.3 tons of seed per year. In contrast, the production in 1981 resulted in 64,145 bushels of cones and 50.5 tons of seed (Table 1). Compared to the previous record production period, production this year represents a 77% increase in bushels of cones and 100% for pounds of seed. Assuming 8000 plantable seedlings per pound of seed and 600 trees planted per acre, the 1981 harvest of genetically improved loblolly pine seed was sufficient to produce 808 million improved seedlings and to regenerate 1,347,000 acres of forest land. If it is assumed

Table 1. A comparison of total cone and seed yields for all conifers and loblolly pine in the Cooperative's three best production years and the 1981 record year.

	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

Cones awaiting seed extraction. A record 50.5 tons of loblolly seed were produced in 1981.

that each pound of loblolly pine seed harvested in 1981 has a net present value of $300, then the total value of this seed crop is 30.3 million dollars!

Other conifer orchards added almost 8000 bushels of cones and 4 tons of seed to the loblolly totals, bringing the all time record for genetically improved conifer seed production to 54.5 tons (Table 1). Good weather, good management, and hard work all contributed to the outstanding success of this year's seed harvest. We can not sufficiently stress the "hard work." The fall of 1981 presented orchard managers with their largest harvest ever and the shortest possible time for completing the task. Unusually hot, dry weather shortened the harvest season 2 to 3 weeks. Only through efficient organization and extraordinary effort was this large crop successfully harvested. Congratulations to all for a job well done.

Production statistics for loblolly and slash pine orchards in bushels of cones harvested and pounds of seed per bushel are shown for the last thirteen years in Table 2. The seed yield per bushel of cones for loblolly was the best ever. Yields from slash pine cones in 1981 were the third best on record.

In last year's report, it was noted that the impact of insect populations on cone and seed yields can be overwhelming when a large crop is followed by a small one. In 1981, the reverse trend was evident, a small crop in 1980 was followed by a huge crop in 1981. Insect populations were believed to be at only moderate strength as the 1981 crop was maturing. This phenomena, coupled with major improvements in insect control methods, contributed to the outstanding yields this year.

Table 2. Cone and seed yields of the Cooperative orchards for the last thirteen 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

A comparison of 1980 and 1981 yields for all conifer species is shown in Table 3. It was indeed a good year overall for seed production. Of particular note is the excellent production experienced for longleaf pine and Fraser fir. Both species have been rather poor producers in the past. Improvement was clearly evident this year.

The production information shown in Table 3 contrasts the best and worst years since 1974. It is a graphic illustration of the fact that lean years do and will occur. We have been fortunate to experience only one such lean year in the last five. The total conifer seed crop for 1981 was 522% larger than the very poor 1980 crop. Dramatic year to year variation in production can occur. Such variations have important implications with respect to the need for and size of seed inventories to be maintained.

Table 3. Comparison of cone and seed yields for 1980 and 1981, respectively the worst production year since 1974 and the best ever.

	Bushels of Cones		Pounds of Seeds		Pounds of Seed/ Bushel of Cones	
	1980	1981	1980	1981	1980	1981
Loblolly Pine Coastal Source	10381	43819	9944	66579	0.96	1.52
Loblolly Pine Piedmont & Mountain Source	4915	20326	5913	34454	1.20	1.70
Slash Pine	4171	4880	4418	4701	1.06	0.96
longleaf Pine	13	1457	2	2039	0.12	1.40
White Pine	547	658	195	298	0.36	0.45
Virginia Pine	352	591	259	480	0.74	0.81
Fraser Fir	33	148	78	336	2.36	2.27
Pond Pine	6	46	2	14	0.33	0.30
Shortleaf Pine	37	39	32	35	0.86	0.90
Total	20465	71964	20847	108936		

Cooperative members often inquire as to how their production statistics compare to others in the program. Summary information for the "average" Piedmont and Coastal source orchards is presented in Table 4. The information is based on all producing orchards in the Cooperative including 18 Piedmont orchards and 27 Coastal source orchards ranging in age from 8 to 24 years. The hypothetical "average" Piedmont and Coastal orchards produced 47.8 and

56.1 pounds of seed per acre, respectively. We traditionally plan required orchard acreage for Cooperators using 50 lbs. per acre for Piedmont orchards and 40 lbs. per acre for Coastal orchards. Many of the oldest orchards routinely produce bushels of cones and pounds of seed per acre well in excess of these expected or average values.

Table 4. A comparison of per acre production statistics for Piedmont and Coastal orchards eight years old and above.[1/]

	Piedmont Orchards	Coastal Plain Orchards
Bushels of cones per acre	28.8	37.1
Pounds of seed per acre	47.8	56.1

1/Based on information from 18 Piedmont orchards and 27 Coastal orchards.

For the first time in Cooperative history, the per acre production in Coastal orchards exceeded the Piedmont. Coastal orchards typically grow faster and maintain somewhat larger crowns than do Piedmont source orchards. It is suspected that this year when everything was "perfect" for cone and seed production, trees in the Coastal orchards made full use of the more extensive cone bearing surface grown over many years at the expense of cone and seed production. It was a most welcome event.

Individual Production Records

In the year when all previous Cooperative cone and seed production records were shattered, several individual orchard records were also set. The new records for bushels of cones per acre, pounds of seed per acre and pounds

Considerable effort is required to locate a suitable second generation seed orchard site. Shown is the site recently acquired by Kimberly Clark Corporation in Alabama.

of seed per bushel were all set at Champion International's orchard complex near Roanoke Rapids, North Carolina. The Champion Orchards, under the management expertise of Ray Brown, have set tough new standards against which future activities will be measured.

The production records set by Ray Brown and his capable staff are as follows:

Bushels of Cones per Acre - 146.8 (Piedmont Orchard)

Pounds of Seed per Acre - 293.6 (Piedmont Orchard)

Pounds of Seed per Bushel - 2.25 (Coastal Orchard)

To achieve such outstanding production requires a combination of superb orchard management, quality cone harvesting and efficient seed extraction methods. All of these obviously were applied to the Champion crop in 1981. It was estimated that the yield per bushel of cones for the Coastal orchard was in excess of 95% of the species full seed production potential.

Harvesting by Genetic Quality Class

The production of excellent cone and seed crops in four of the last five years has put many Cooperative members in a seed self-sufficiency situation. This is particularly true for the members that have older orchards with production capacity equal to or in excess of current seed needs. Most of these programs also have mature progeny testing programs. This means that we know which orchard parents produce the best, average and worst progeny. The progeny test data have been used to rogue inferior parents from the orchards. In addition, this information base is increasingly being used to classify orchard parents by genetic quality, thus providing the basis for planning and implementing a segregated harvest of the cone crop. An example of the production obtained by Catawba Timber Company with a segregated harvest plan is shown in Table 5.

The segregated harvest plan allows Catawba to increase the genetic gain from their program. They can meet all their seed needs from the best seed and place in inventory the remaining seed (classes #2 and #3) for use only if the best seed becomes unavailable. This is a seed inventory management system that has been referred to as BEST IN - FIRST OUT. The disease resistant (#4 orange tag) seed will be utilized as needed for regenerating tracts with a high hazard rating for fusiform rust. A segregated harvest plan is an excellant way to capitalize on the genetic information from the testing program.

Table 5. Production statistics for Catawba Timber Company's 1981 Cone Harvest showing the segregation into genetic quality classes.

Quality Class	Bushels Harvested	Lbs. of Seed	Lbs. of Seed/Bushel
#1 blue tag - best seed	694	1441	2.08
#2 reg tag - next best seed	314	604	1.92
#3 yellow tag - poorest seed	168	436	2.59
#4 orange tag - disease resistant	126	283	2.25
Total	1302	2764	2.12

Nitrogen Fertilization in Seed Orchards

Numerous studies have been published which show the advantages of managing the nutrient status of seed orchard soils. A general conclusion has been that summer fertilization with nitrogen will increase cone crops in succeeding years. However, with tight budgets and the increasing costs of fertilizer, labor and machine operation, questions continue to arise concerning the value of nitrogen fertilization. A recent study by the Virginia Division of Forestry has provided confirmation to our long standing advocacy of summer nitrogen treatment.

In Virginia's New Kent Seed Orchard, four different blocks received no summer application of ammonium nitrate for several consecutive years. The cones from these check plots were picked and counted separately by tree as were the cones from each tree in several rows immediately adjacent to the check plots. The results, in average number of bushels of cones per tree, are shown in Table 6 below.

Table 6. Comparisons of per tree production levels with and without nitrogen fertilization.

Orchard	No. of Trees		Avg. No. Bushels/Tree	
Block	Fertilized	Check	Fertilized	Check
P-1	59	91	0.71	0.38
P-2	50	52	1.04	0.44
CP-1W	64	58	0.48	0.43
CP-4	124	100	0.27	0.18

There was a clear advantage from fertilizing with nitrogen. The fertilized trees, on the average, produced about 75% more bushels of cones than the trees receiving no summer nitrogen. Differences like these would certainly justify the cost of purchase and application of ammonium nitrate. In the New Kent Orchard, which had relatively low production in terms of bushels per tree, the 75% increase would translate into an additional 16 bushels of cones per acre. This represents additional net present value of more than $7000 assuming seed yields of 1.5 lbs. per bushel and $300 per lb. of seed. Good orchard management practices have a worthwhile payback.

Insect Control

The depredation of the orchard cone and seed crops by insects continues to be a major concern of orchard managers. Members and staff of the Cooperative have continued to work closely with U. S. Forest Service scientists, and as a result, steady improvements in control capabilities are evident. Such control capability is critical for without it, the cone and seed insects would routinely destroy 50 to 70 percent of our seed crops each year.

A major break through has been made in the identification of the sex pheromones for all major southern pine cone worms (*Dioryctria*). Sex pheromones are volatile chemical compounds produced by the female when in the adult moth stage of their life cycle. The male moth can sense the pheromone with its antennae and uses this sensory perception as a means to locate females of its own species for mating. These pheromone compounds have now been produced synthetically and are being used in species specific sticky

Aerial spraying of Guthion® has proven to be an effective measure for reducing cone and seed insect damage.

traps. When baited with pheromones and placed in the top portion of several seed orchard trees, the traps effectively monitor insect population size. With such a monitoring system, orchards can be rated for hazard levels for each coneworm species. An effective hazard rating system allows the orchard manager to develop control strategies on a prescription basis. The orchard manager need only apply controls (insecticides) when the hazard rating suggests serious damage is likely. This can reduce insect control costs and lower environmental risks associated with insecticide use.

The efforts of Dr. Gary DeBarr and Dr. Jack Nord of the U. S. Forest Service have resulted in the registration of a new insecticide for use in seed orchard insect control. The insecticide, Pydrin®, is a synthetic pyrethroid compound. While more expensive than Guthion®, an insecticide with wide current use, Pydrin® can be used in concentrations one tenth as strong and will persist in the orchard environment three to four weeks longer than Guthion®. Pydrin® is toxic to insects but has rather low mammalian toxicity. It is a welcome addition to the collection of seed orchard management tools. We are hopeful that yet another insecticide will be registered in the very near future for orchard use.

Insect control strategies have frequently been frustrated by the cumbersome and costly nature of insecticide sprays applied with ground equipment. Too often such applications have been ineffective because of the difficulty of getting good spray coverage in the top portion of the orchard trees. It is in the top half of the tree that cone production is concentrated. Recent work by Dr. Larry Barber of the U. S. Forest Service has led to the development and registration of effective aerial application methods for Guthion® and Pydrin®. Studies have shown aerial applications to be cost effective and, in many cases, insect control was improved substantially. The spray coverage from aerially applied insecticides is much better in the top portion of the trees than it is with ground equipment, especially in older orchards with very large, tall trees. Aerial application methods allow an entire orchard of significant size to be sprayed in a brief, prescribed period. Control of an insect that recently became a serious problem, Dioryctria disclusa, requires that insecticide be applied throughout the orchard in a short 3 to 4 day period.

Lower Cost Grafting

Even though we are in our 26th year of operations, we are still not too "old" to learn new tricks. Such is the case for the devlopment of an improved grafting method. The method is known as wax grafting and the major advantage is substantially lower costs. It has been estimated that wax grafting will give satisfactory survival with a commensurate cost reduction of over 70%.

The wax grafting of pines was first demonstrated on an operational scale by personnel of the Mississippi Commission of Forestry, a member of the Western Gulf Tree Improvement Cooperative. Champion International and Union Camp were among the first in our program to work with this technique operationally. The technique uses a cleft or side graft made in the usual way, except that all needles are stripped from the scion. Once the graft union is wrapped with the grafting rubber, it is completely coated (sealed), bud and all, with melted parafin applied with a brush. Care must be taken not to apply parafin that is too hot, or plant tissues will be destroyed, and the graft will die. If the parafin is too cold, the coating will crack, and a tight seal will not be formed. The best temperature for the wax is between 175° and 200°F.

Once the graft is made and sealed with wax, the work is virtually completed. Covering the grafts with paper and plastic bags is eliminated, and tediuous after care is drastically reduced. As the scion begins to grow, it will break through the wax seal. The only after care needed is to prune back the rootstock branches and eventually remove the grafting rubber since once covered with wax it will not disintegrate from exposure to light. Results of a trial of this method by Union Camp Corporation are shown in Table 7.

Marvin Zoerb summarized the results by saying: "Eliminating the bags results in a large saving in both cost of grafting and aftercare. It also produces a faster growing, better formed graft. I'm not sure it will work in all areas or every year. We plan to use it on a larger scale in the future." Improvement such as this in even our most basic procedures continues to increase the Program's effectiveness.

Table 7. A comparison of graft survival using traditional methods, parafilm and melted parafin wax.

Method	No. grafted [1/]	Survival
Parafin Wax Only	116	82%
Plastic and Paper Bags	349	94%

[1/] Includes 58 clones with 2 grafts each for the wax and 6 grafts each with the conventional method.

SELECTION, BREEDING AND TESTING

The Cooperatives Genetic Base

The Cooperative recently completed a six year program designed to broaden the genetic base for advanced generation breeding. In excess of 3100 phenotypically superior loblolly pines growing in unimproved plantations were graded during this period. The average superiority of all 3100 selections over the check trees (5 next best crop trees in the stand) was nearly 18% for volume. These trees represent a substantial investment in future forest productivity by the members of the Cooperative.

The plantation selections are well distributed over the entire range of loblolly pine east of the Mississippi River. Lands being regenerated and managed by the Cooperative members are also widely distributed. Until research data suggests otherwise, plans are to utilize the new select trees within or very close to the geographic region in which they were selected. As a result of this constraint, it was of concern whether the plantation selection program provided a satisfactory base for each member of the program. Table 8 shows for each advanced generation orchard/breeding program in the Cooperative, the number of trees available to serve as part of that program's genetic base. Most geneticists believe that a genetic base of 200 to 300 individuals is satisfactory. It is clear then from Table 8 that each member of the Cooperative has an exceptionally broad base from which to draw. Several programs have well over 700 trees available, the fewest number for any single program is 348. The advantages of developing genetic resources in a cooperative manner are clearly evident.

Table 8. The availability of the 3100 new plantation selections to each Cooperator in the Program. For a satisfactory genetic base a minimum of 250 select trees per members is needed.

Company	Province	# of Trees Available
American Can	- Coastal Plain	732
Boise Cascade	- Piedmont - Coastal Plain	711 373
Brunswick	- Piedmont - Coastal Plain	671 348
Hiwassee	- Piedmont - Mountain	677
Catawba	- Piedmont	667
Champion (S.C.)	- Piedmont	667
Champion (N.C.)	- Piedmont - Coastal Plain	691 530
Champion (Ala.)	- Piedmont	724
Chesapeake	- Coastal Plain - Piedmont	610
Container	- Lower Coastal Plain	407
Continental Forest Ind. (Ga.)	- Piedmont - Coastal Plain	669 446
Continental Forest Ind. (Va.)	- Coastal Plain - Piedmont	610
Federal	- Piedmont - Coastal Plain	735 360
Georgia-Kraft	- Piedmont - Mountain - Coastal Plain	690 446
Georgia-Pacific (N.C.)	- Coastal Plain	530
Georgia-Pacific (Ga.-S.C.)	- Coastal Plain	479
Great Southern	- Lower Coastal Plain	407
Hammermill	- Coastal Plain	758
International Paper (S.C.)	- Coastal Plain	479

Table 8. - Continued.

Company	Province	# of Trees Available
International Paper (Miss.)	- Upper Coastal Plain - Lower Coastal Plain	599 475
Kimberly-Clark	- Piedmont	622
MacMillan-Bloedel	- Coastal Plain	732
Masonite	- Coastal Plain	475
N. C. Forest Service	- Piedmont - Coastal Plain	691 530
Rayonier	- Coastal Plain - Piedmont	348 669
Scott	- Lower Coastal Plain	407
S. C. Commission of Forestry	- Piedmont - Coastal Plain	667 479
St. Regis	- Lower Coastal Plain	407
Tennessee River	- Piedmont	700
Union Camp (Ga.)	- Coastal Plain	446
Union Camp (Va.)	- Coastal Plain	610
Virginia Div. of Forestry	- Coastal Plain - Piedmont	610
Westvaco (S.C.)	- Coastal Plain	479
Westvaco (Va.)	- Piedmont	610
Westvaco (Tenn.- Ky.)	- Piedmont	700
Weyerhaeuser (N.C.)	- Coastal Plain	530
Weyerhaeuser (Miss.-Ala.)	- Upper Coastal Plain - Piedmont	565

1/Each of the 3100 trees is counted as part of the genetic base for numerous cooperators.

Each year new second generation selections are located and graded in the progeny tests of Cooperative members. The Cooperative has accumulated a significant number of superior pedigreed selections following assessment of 4, 8 and 12 year-old tests. A listing by member of the total number of second generation selections that have been graded to date is given in Table 9. In the last year, 142 new trees were graded to bring the total to 2156. Approximately 60% percent or 1300 trees are currently rated useable in production orchards.

The plantation selections and the pedigreed second generation selections comprise the genetic base for future generations of improvement. Considerable energy and effort is now being directed toward the production of pollen and female flowers on grafts of these selections. The challenge of breeding these selected trees is now at hand.

Accelerated Breeding

In October of 1981, the Cooperative held a Special Advisory Committee Meeting in Hot Springs, Arkansas. The purpose of the meeting was to explore new technologies for stimulating flower production on young grafts, to consider the impact of this technology on the Cooperative's breeding plans and to adopt a realistic but agressive schedule for completing the next breeding cycle. This is the first time in twenty-six years that there was a need to hold a Special Advisory Meeting in mid-year. The meeting was well attended and much was accomplished.

Table 9. A listing of second-generation selections of loblolly pine in the Cooperative.

	Number of Selections
Hiwassee	162
Catawba	84
Union Camp (Va.)	115
Champion--Western Carolina Division	78
Chesapeake	105
Continental Forest Industries (Ga.)	97
Champion-- Eastern Carolina Division	124
International Paper	115
Weyerhaeuser (N.C.)	226
Weyerhaeuser (Miss.-Ala.)	61
Federal	106
Union Camp (Ga.)--Loblolly Only	55
Westvaco	151
Kimberly-Clark	139
Continental Forest Industries (Va.)	101
Georgia Kraft	84
N. C. Forest Service	10
American Can	54
S. C. Commission of Forestry	52
Tennessee River	82
Virginia Division of Forestry	120
Georgia-Pacific	7
Masonite	11
Container	4
Rayonier	5
Brunswick	5
MacMillan-Bloedel	2
Great Southern	1
Total	2156

The importance of accelerated breeding stems from the greater economic returns possible from tree improvement investments, when generations are turned over more rapidly. Once the value of and methods for shortening the breeding cycles were assessed, the Advisory Committee deliberated over a schedule appropriate for the Cooperative. The schedule adopted as our program goal is displayed in Figure 1. It is a very agressive yet realistic schedule. The plan calls for completing all breeding and test establishment for the next round of genetic testing within twelve years following grafting of a new selection. It is an aggressive plan in that it calls for completion of the test establishment work from 8 to 12 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. For members to meet this goal, it will require an extraordinary effort by all, and the use of portions and in some cases all of the new technology developed for early flower stimulation.

The response to this Special Advisory Meeting and the resulting planning decisions has been most gratifying. The members have set ambitious long term goals for the program and all have pledged to meet them. It was clearly a statement of renewed commitment to the development of our genetic resource potential. It was a commitment made with enthusiasm. The program staff has repeatedly been asked "to help us be among the leaders in accomplishing these valuable goals."

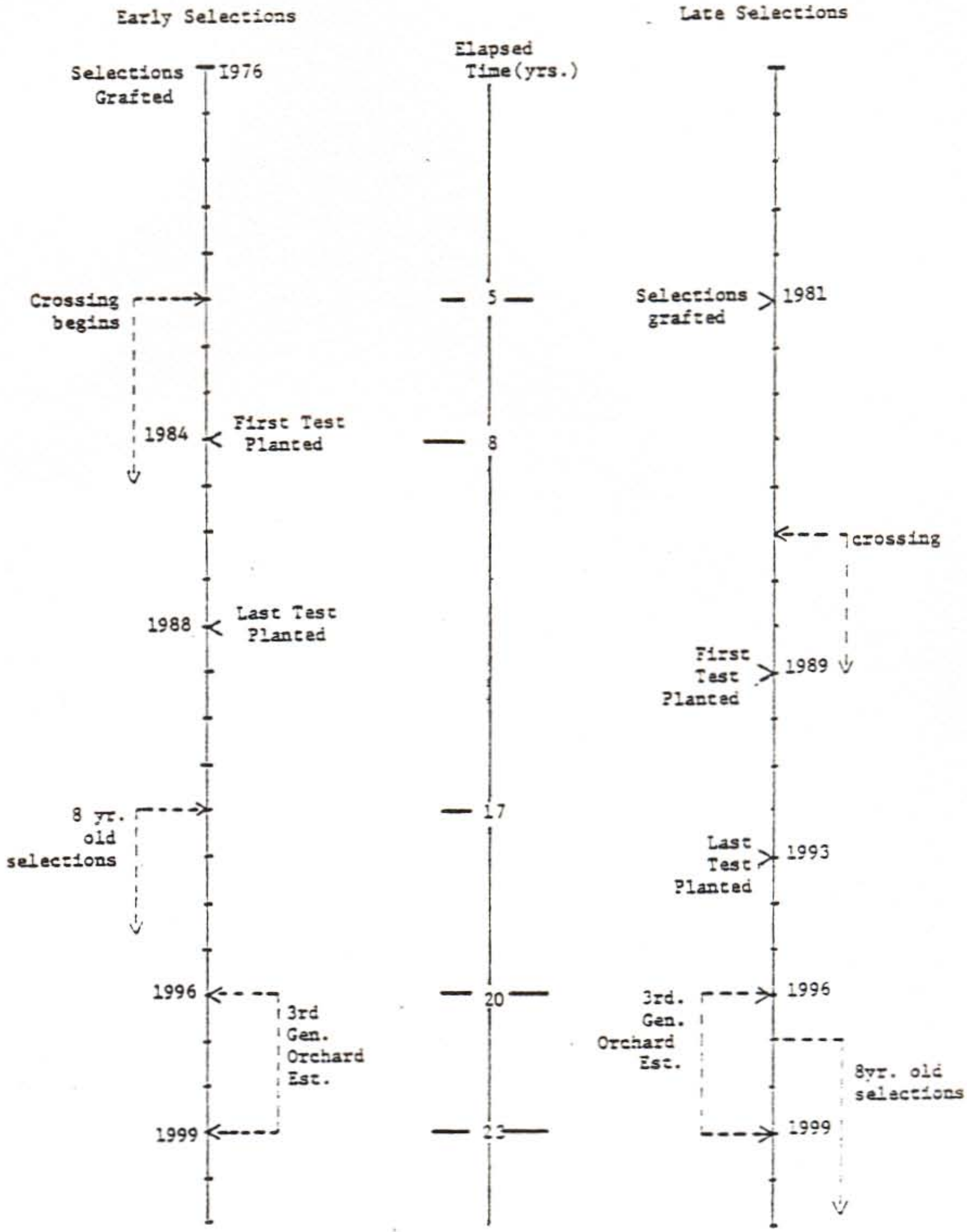
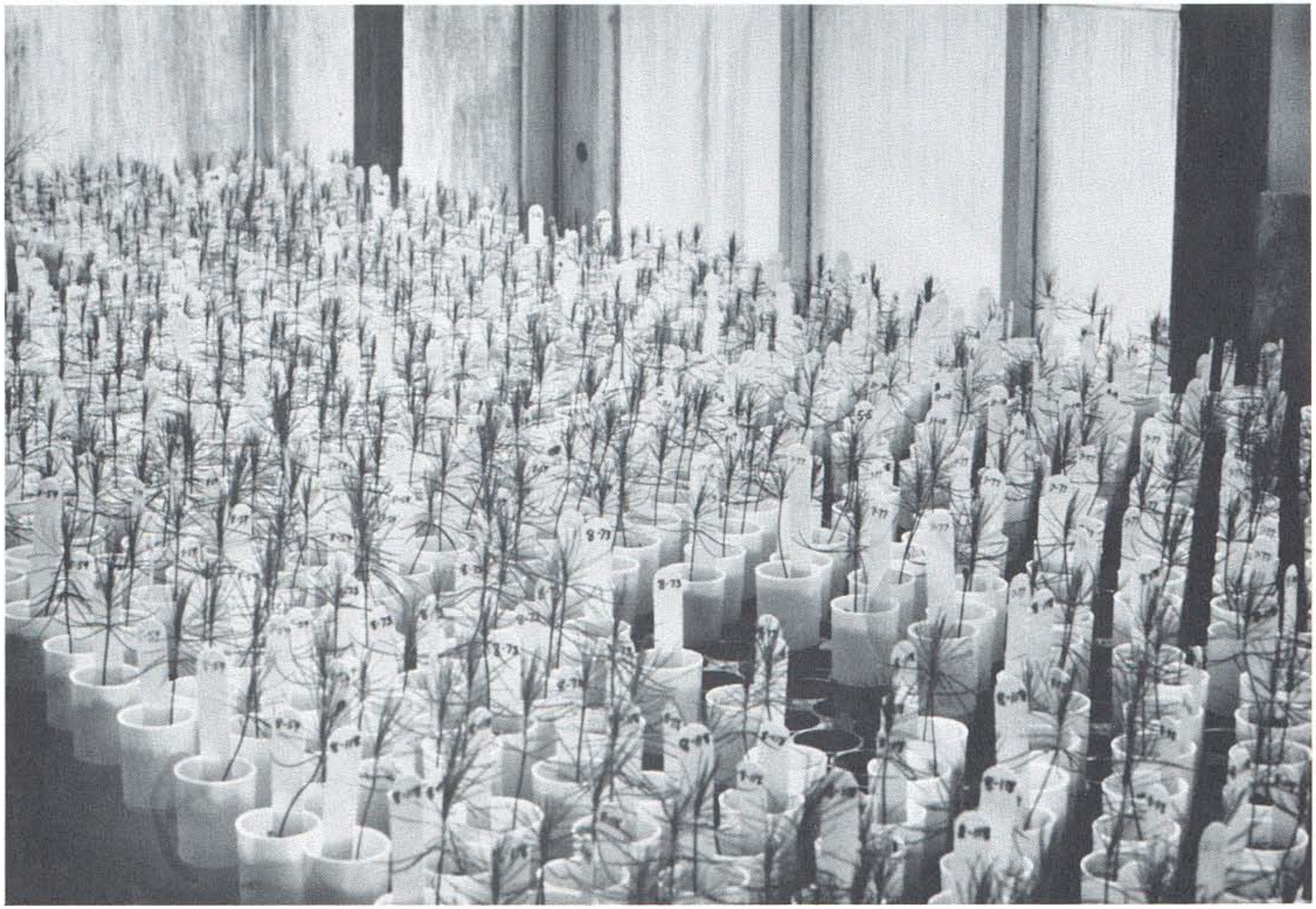


Figure 1. Breeding and Testing Goals for Plantation and Second Generation Selections.



Growing progeny seedlings in large (10 cu. in.) containers as shown can save 1 year and increase seed to seedling ratios.

Pollen Storage

The ability to store pollen over a relatively long period (2 to 4 years) will greatly enhance the efficient completion of the Cooperative's breeding workload. In support of the Cooperative's efforts to maintain a pollen bank for use with breeding second generation selections, several different pollen storage methods have been evaluated. Pollen from 10 clones ranging in initial germination percentage from 19% to 56% (mean = 43%) was stored in three ways: 1) Refrigerated vials, cotton stoppered, 2) refrigerated vials, screw cap, 3) frozen vials, screw cap. Readings were taken periodically over a four year period of storage as shown in Table 10. Pollen was initially packaged so that a new vial was removed for each clone at each sampling point. No vials were returned to the freezer or refrigerator after once being opened for germination tests.

The results in Table 10 indicate that loblolly pine pollen can be stored successfully for up to four years. Properly dried pollen (8-9% moisture) seems to store best if packaged in a vial with a screw cap and frozen.

Table 10. A comparison of three pollen storage methods over a 4 year period on pollen germination percent.

	Percent Pollen Germination [1/]		
Months Stored	Refrigerated Cotton Stopper	Refrigerated Screw Cap	Frozen Screw Cap
0	43.1	43.1	43.1
6	45.3	57.8	63.7
12	13.5	29.8	49.8
18	22.9	35.5	52.4
24	25.0	21.0	35.8
36	23.0	17.0	24.7
48	24.7	24.2	37.6

[1/] The vagaries of sampling error cause some unexplained variation in in the readings, however, the trends are of value.

A Wire girdle applied in February can stimulate male catkin production a year later. Care must be taken to support the weakened branch to avoid breakage.

Progeny Testing

The first generation progeny testing program is rapidly coming to a close. The last tests were nursery planted this spring and will be field planted in the winter of 1982-83. As we complete this task, it is appropriate to recognize the organization that has had the single largest testing program in the Cooperative--Union Camp. Under the capable leadership of Marvin Zoerb, Union Camp in 1982 alone, planted 25 new tests, comprised of 31,000 trees on 44 acres of land. This brings their total testing program to 206 tests that include 325,000 trees on 466 acres of land. The size of this workload relates to the number of species, geographic sources and orchards with which they are working. The enormity of this workload has not, however, in even the smallest way compromised the quality of effort. In site selection, test design and establishment, maintenance, and data collection, Union Camp has consistently been among the best in the Cooperative.

We are delighted to report that in the spring of 1982, Weyerhaeuser planted the first second generation genetic test. The next generation of improvement is underway! Weyerhaeuser along with International Paper Company planted the first progeny tests in the Cooperative for the first cycle of testing. Congratulations to Weyerhaeuser for getting off the mark two years ahead of schedule (see Figure 1) in the second cycle.

Screening for Rust Resistance

The U. S. Forest Service has been operating a Resistance Screening Center (RSC) for fusiform rust for a number of years. Recent improvements in the RSC's ability to simulate field test results (Figure 2a and b) have led to renewed interest in the center for aiding the development of fusiform rust resistance. Dr. Michael Carson, a recently completed Ph.D at N. C. State working on aspects of fusiform rust, stated that the four major advantages of the RSC screening relative to field testing are:

1) greater economies in the measurement of resistance.
2) greater precision in measuring resistance.
3) increased selection intensity opportunities.
4) early selection coupled with accelerated breeding allows generations to be cycled more rapidly.

The Cooperative staff will be working with those Cooperative members concerned with the development of specialty rust resistance programs in order to more fully exploit the potentials of the RSC. The opportunities are substantial.

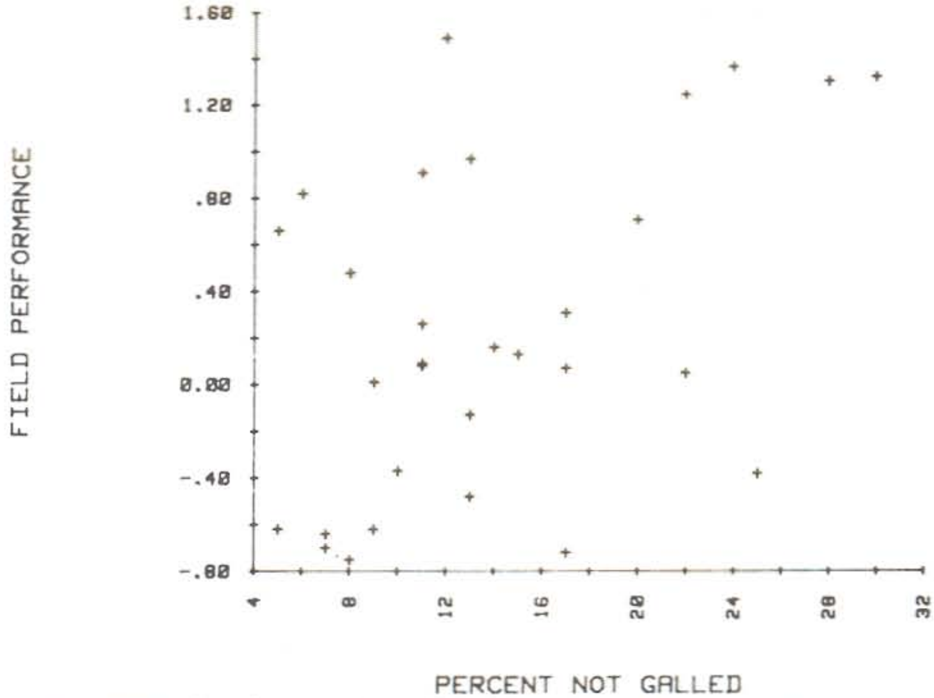


Figure 2a. Past practices at RSC utilized information on percent not galled only. Correlations with field results were poor.

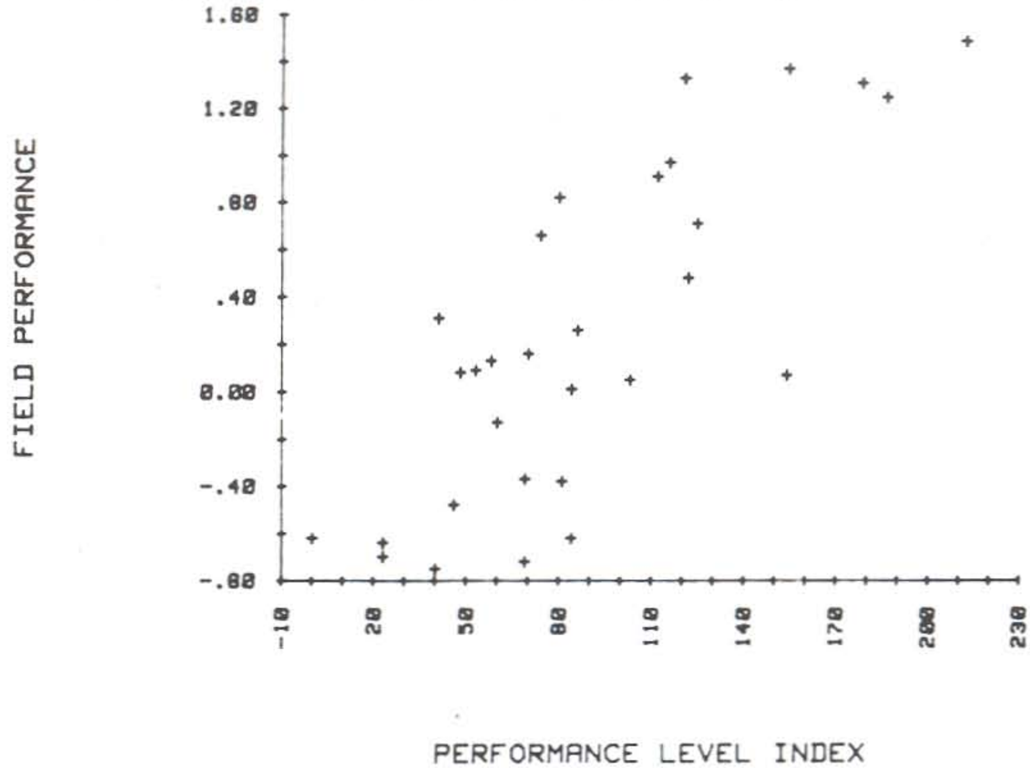


Figure 2b. Using information collected on rust symptom types in a performance index greatly improves the correlation with field results.

RESEARCH RESULTS AND ASSOCIATED ACTIVITIES

First Generation Gains

Gains from tree improvement activities ultimately reside in the improved productivity of forest lands. Determination of realized gains in productivity, especially those in yield per unit area, usually involve establishment of long-term studies with large block plots comparing improved and unimproved planting stock. Since in most programs selection for the next generation are made well before rotation age, breeding activities will have advanced to the second or third generation before realized gains from first generation orchards are accurately known. For planning purposes, however, economic and silvicultural decisions involving management of plantations from first generation improved stock must be made early in the program. Consequently, estimates of gain from tree improvement must often be made from studies not designed specifically for that purpose.

The N. C. State Cooperative's first generation progeny tests were established primarily for progeny testing and selection purposes. The row plots utilized do not permit direct comparisons of yield among families or between improved stock and unimproved check lots on a per acre basis. However, many tests have now been measured at four, eight, and twelve years of age and trends are evident in the relative performance of improved and unimproved stock over time. Many tests have reached a stage where gains from one generation of selection can be estimated from trees approaching one-half rotation age.

Average percentage gains in height growth for first generation loblolly pine progeny compared to unimproved checks are shown in Table 11. Gain

Table 11. Average percentage height gains for first generation loblolly pine seed orchard stock at different assessment ages.[1/]

	Age		
	4	8	12
Percentage Gain [2/]	3.14	4.06	2.84
Standard Error	.45	.52	.65
Range	-2.18 to 7.54	-.79 to 8.00	-3.49 to 6.89
No. Orchards	33	30	16

[1/]Gains are calculated as average performance of progeny test seedlings in comparison to unimproved check lots.

[2/]Percentage gains at all ages are significantly greater than 0 ($p < .01$). Gains at different ages are not significantly different from each other.

figures were computed by determining average gain for each loblolly pine seed orchard in the Cooperative, and then averaging across all orchards. Each orchard was treated as an independent estimate of gain. Percentage gains for any individual orchard may be biased to the extent that the tester mating system used does not represent what would be obtained with random mating in the seed orchard, and to the extent that the unimproved check does not accurately represent unimproved planting stock. However, when averaged across a number of orchards the bias should disappear.

Percentage gain estimates for height appear to remain constant at 3-4% regardless of test measurement age (Table 11). 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.

One way of interpreting the percentage gain figures for height shown in Table 11 is as a change in site index, or the expected height of the dominant and co-dominant trees in a stand at a base age. For example, if site index for unimproved stock is 60 feet (base age 25), then an equivalent site index using 3% improved stock from unrogued orchards would be 1.03 x 60 ft. = 61.8 ft.. Changes in yield resulting from tree improvement can then be estimated through use of growth and yield models. These models predict yield based upon initial plant density, site index, and plantation age or dominant tree height.

Predicted cord volume yields in unthinned plantations for unrogued and rogued first generation loblolly pine seed orchards at various ages on site index 60 ft.$_{(25)}$ land are shown in Table 12. Unrogued orchard stock was assumed to grow 3% faster in height than unimproved stock, changing site quality to an equivalent of site index 61.8 ft.$_{(25)}$. Stock from rogued orchards was estimated from progeny tests to grow 7% faster in height than unimproved stock changing site index to an equivalent of 64.2 ft.$_{(25)}$ (site index figures were rounded to 62 ft. and 64 ft. respectively). If an orchard were rogued strictly on height, estimated gains would be greater than 7%. In reality, orchards are rogued on a number of characteristics, including cone production, which reduces effective selection intensity for height. The 7% figure is probably realistic for many orchards.

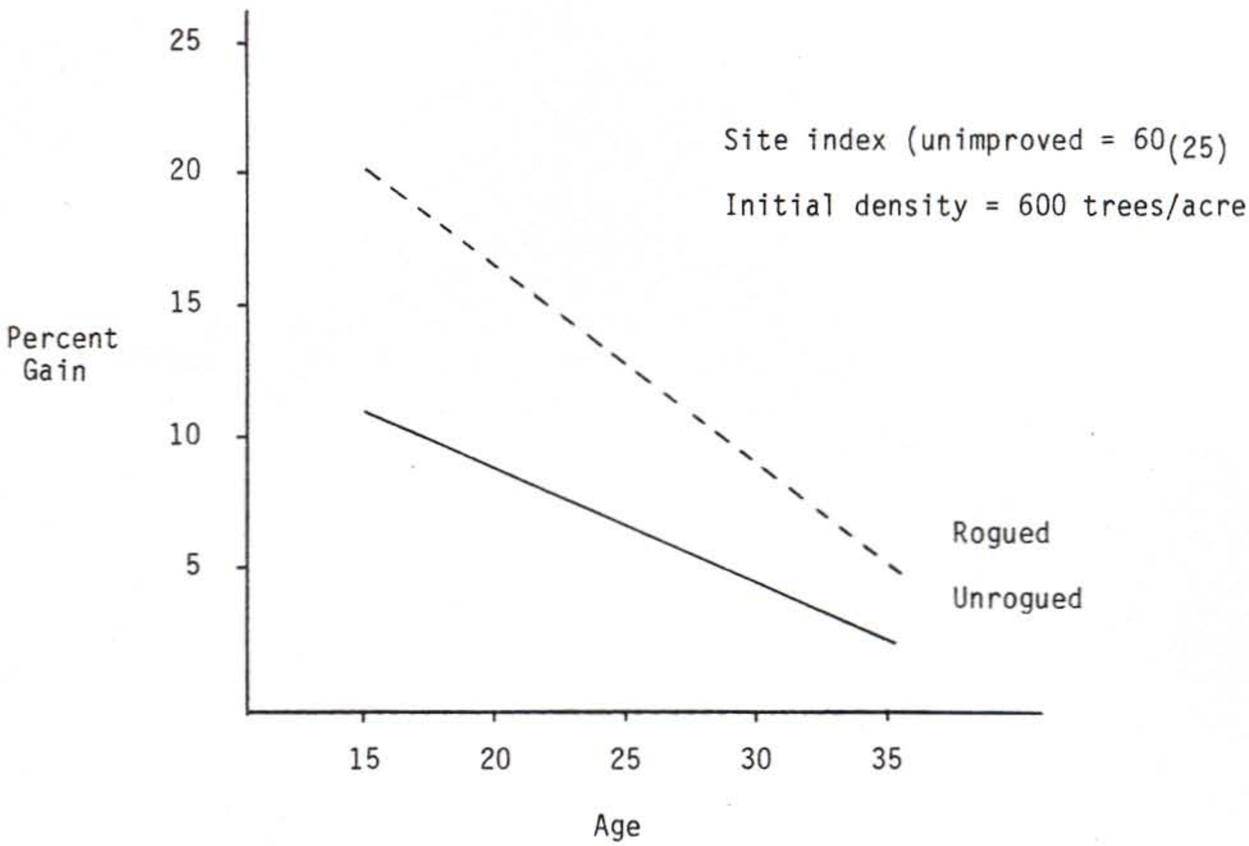
Table 12. Stand densities and cord volumes in unthinned loblolly pine plantations for site index 60 ft., 62 ft., and 64 ft.$_{(25)}$ at various ages.[1/]

	SITE INDEX					
	60 ft.		62 ft.		64 ft.	
Age	Trees/A	Cords/A	Trees/A	Cords/A	Trees/A	Cords/A
1	600	-	600	-	600	-
15	591	16.7	589	18.4	585	20.1
20	558	32.7	549	35.6	538	38.3
25	493	48.7	477	51.9	461	54.9
30	411	57.1	394	60.0	368	63.2
35	336	62.3	320	63.9	307	65.3

[1/]Site index $60_{(25)}$ = Unimproved stock; Site index $62_{(25)}$ = Unrogued orchard stock; Site index $64_{(25)}$ = rogued orchard stock; All cord volumes are total tree inside bark. Differences in yield for small changes in site index were calculated utilizing models developed by W. L. Hafley and W. D. Smith, Southern Forest Research Center, Department of Forestry, N. C. State University (as yet unpublished). We gratefully acknowledge their assistance.

Predicted percentage gains in cord volume (Figure 3) decline dramatically with increasing age in the unthinned stands depicted in Table 12. Gains for rogued orchard stock fall from 20% at age 15 to just under 5% at age 35. At age 25, a common rotation age on land of this site quality, percentage gains in volume are 6.4% for plantations from unrogued orchards and 12.7% from rogued orchards, with no salvage of lost mortality by thinning. Over time absolute gains in volume appear to be remaining nearly constant at 3 cords/acre after a plateau is reached at about age 20 (Table 12).

Figure 3. Influence of age on percentage volume gain in unthinned loblolly pine plantations utilizing first generation orchard stock.



One of the reasons for decreasing percentage gains in volume is an increasing volume figure on which the percentage is based. Examination of the stand data shows that another reason is increased mortality in stands planted with seed orchard stock because of more intense tree to tree competition resulting from more rapid stand development. When the trees are in a "free to grow" situation, there is little mortality and percent improvement in volume resulting from small changes in site index are large. Gains fall as competition sets in, more quickly on the better sites, and mortality begins to occur. Stands must either be planted at wide spacings and harvested before intense competition and associated mortality begin, or stands must be thinned to salvage mortality if the best return from tree improvement is to be realized. Stands of improved trees will develop faster, compete sooner and need thinning earlier.

Gains in volume production from genetics can be utilized by the forest manager in two ways. One would be to harvest timber when it reaches a given size; thus, genetic improvement would be realized as a reduction in rotation age. If this were the case, and rotation length for unimproved stock on site index 60 ft.$_{(25)}$ land were 25 years, then use of periodic annual increments generated from Table 12 would show that rotations could be reduced to 24 years with unrogued orchard stock, or to 23 years with rogued orchard stock.

Alternatively, the manager could decide to grow the stand for the same rotation length, and enjoy the benefit of harvesting more volume per acre, concentrated on fewer, but larger, more valuable stems. Gains in estimated dollar value for a 25 year rotation on site index 60 ft.$_{(25)}$ land with this alternative are shown in Table 13. Unrogued orchards yield an 18% increase in dollar value at age 25, while a 32% increase in value results from use of stock from rogued orchards, given the assumptions listed in Table 13. The large increases in value associated with small gains in volume are the result of more trees in the larger diameter classes.

Increases in stumpage values per acre shown in Table 13 are believed to be conservative. Growth rate was the only trait considered and important progress in the improvement of quality characteristics was ignored. Test

Table 13. 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	1680	--
Unrogued	1979	18%
Rogued	2216	32%

Assumptions:

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

results indicate large improvements have been made in quality traits, and that these genetic improvements have a marked impact on yield of both pulpwood and solid wood products. The impact of quality improvement is especially significant in stands harvested at young ages where the quality is a key factor in determining whether a log is merchandized for pulpwood or solid wood products.

There can no longer be any doubt that substantial genetic gains can be made in forest trees. These genetic gains translate into remarkable value improvements per acre. However, it is also apparent that genetic improvement will have a large impact on forest management strategies. This is because biological and economic gains can and will change dramatically during the life of a stand, and with different management practices.

Inheritance of Wood Specific Gravity

Studies investigating inheritance of wood specific gravity have dealt primarily with measurements taken on wood from young trees. Therefore, samples consisted largely or entirely of juvenile wood. Compared to mature wood, juvenile wood can be characterized as having lower specific gravity, shorter tracheids, thinner cell walls and a lower proportion of summerwood. The transition from juvenile to mature wood is a gradual process, but generally occurs in a zone from 7 to 11 rings from the pith in loblolly pine.

Because of dissimilarities in juvenile wood specific gravities, inheritance patterns for the two traits might be different. During the summer of 1979, a study was initiated to investigate the inheritance of mature wood specific gravity in loblolly pine. The test population was the Loblolly Pine Heritability Study, established jointly in 1960 by N. C. State University and International Paper Company on the company's Southlands Experiment Forest near Bainbridge, Georgia. The study is designed to investigate inheritance patterns in a nonselected natural loblolly pine population.

Wood samples were first taken from the open-pollinated study after 7 growing seasons. At that time, 8 mm. "bark to bark" increment cores were taken at breast height (4.5 feet) from 112 families, each planted in four replications. Seven trees were sampled per family plot. Unextracted juvenile wood specific gravity was determined for each sample tree.

During the 20th growing season, 12 mm. "bark to bark" increment cores were obtained at breast height from 45 families across all 4 replications of the study. Families sampled were chosen so that they were in common with the age 7 assessment. Because of sampling procedures and the thinning which was conducted at age 10, very few trees measured for specific gravity in the age 7 assessment were included in the age 20 assessment. Cores taken at age 20 were divided into juvenile and mature wood segments (using an arbitrary division at 10 rings from the pith) and specific gravity was determined for both juvenile and mature wood segments. A weighted breast height specific gravity was determined by averaging juvenile and mature wood values for each tree, weighted by the basal area represented by each segment.

Results indicate that breast height unextracted juvenile, unextracted mature, and unextracted weighted specific gravity are under substantial genetic control in this nonselected 20-year-old loblolly pine population. Calculated heritabilities were essentially the same for all traits, with $h^2 = 0.44$ for juvenile wood specific gravity, and $h^2 = 0.45$ for mature wood and weighted tree specific gravities. Genotype by location interaction effects were small. Genetic correlations were high, with $r_G = 0.88$ between juvenile and mature wood specific gravity. Equivalent heritabilities and the high genetic correlation indicate that substantial genetic gain can be made in mature wood specific gravity through selection for juvenile wood specific gravity. In advanced generation loblolly pine improvement programs, most selections are made at young ages (10-years-old or younger) before most trees begin to produce mature wood. The need to select for increased juvenile wood specific gravity in pines, especially for trees harvested at young ages has recently been emphasized. However, mature wood will still comprise a substantial proportion of wood harvested on rotations of 20 years or more. Selection to increase specific gravity of the juvenile wood component in loblolly pine will give a correlated increase in the mature wood component.

Several species of Larch (Larix) are being evaluated for fiber production on lands of Westvaco in West Virginia. Survival and growth through two years is promising.

Results of the age 20 specific gravity measurements compare quite favorably with measurements of juvenile wood specific gravity made at age 7 in the same genetic test. Heritabilities for juvenile wood specific gravity were similar at both assessments (h^2 = 0.40 at age 7 and h^2 = 0.44 at age 20), and genetic correlations between the age 7 measurement and the three specific gravity traits assessed at age 20 were high.

Wood specific gravity is one of the most heritable economically important characteristics in loblolly pine. Although it is more difficult to assess on large numbers of trees than other important traits such as height, stem straightness, or pest resistance, high heritabilities and considerable variation in wood specific gravity in loblolly pine indicate selection for the trait will result in substantial genetic gain.

Selection for Dry Weight Yield

In recent years considerable thought and effort has been given to using selection indexes as the selection method in forest tree improvement. Selection indexes can be constructed that include information from relatives, such as siblings in genetic tests, and from several traits to predict the aggregate genetic value of candidate trees. This technique predicts the value of a tree based on all the genetic and economic information available. Selection indexes are theoretically more efficient than other commonly considered means of selection and are one of the best ways to organize and interpret genetic information on a population. However, if either the genetic or economic information on traits of interest is in error, selection indexes can be considerably less efficient than other methods of selection in improving the total genetic quality of the population.

Although genetic parameters for important economic traits of loblolly pine are now generally known, the relative economic values of a unit improvement of the various traits of interest are poorly defined. Incomplete economic information has restricted the use of selection indexes in the Cooperative's loblolly pine improvement program.

Recently, several selection indexes were compared which had different selection criteria but the same goal of selection, the improvement of total dry weight of wood in loblolly pine. Total dry weight of wood is influenced by tree volume and wood specific gravity and is a major determinant of pulp yields from stands of loblolly pine. The Loblolly Pine Heritability Study was used as a source of data for this work. Measurements on height, d.b.h., volume, specific gravity, and total tree dry weight were made when the test population was 10 years of age.

Each of the selection index models considered had increased dry weight yield as the goal of selection. The gain in dry weight and efficiency of each selection model was compared to combined selection (selection on families and individuals within families for dry weight only). The proportion saved was one in one hundred for all models considered. The expected gain from combined selection for dry weight was 16.5 lbs. per tree which represents a 22% increase over the mean per tree dry weight of 76.8 lbs. This value was assumed to represent an efficiency of 1.00.

Expected gain (and efficiency) will generally increase as more information is included in a selection index. Thus, tree breeders with height, d.b.h., volume, specific gravity, and dry weight information available could combine all of these into a single index to increase gain in dry weight yield. Inclusion of other traits improves expected gain because of their correlation with dry weight yield. Correlated variables can be used to enhance selection, and therefore increase expected gain. Constructing multiple-trait indexes requires appropriate weighting for each of the traits that determine genetic worth. This means that relative weights must be assigned to height, d.b.h., volume, and specific gravity, as well as dry weight. These weights reflect the relative importance of each trait in changing dry weight yield.

It is apparent from Table 14 that efficiencies of selection for dry weight yield can be increased by including information on all traits into a selection index for dry weight yield, as long as dry weight and/or height are given substantial weight in the index. Greatest efficiency (1.20) was obtained when all weight was given to dry weight or when all traits were weighted equally. The least efficient index (0.49) resulted when all economic weight was placed on specific gravity because of the relatively low genetic correlation of wood specific gravity and total dry weight of trees.

Selection for dry weight yield gain is often done without the inclusion of specific gravity information because of the difficulty and expense of obtaining specific gravity data. As a result, selection is frequently for increased volume growth, even when the goal is dry weight improvement.

The most efficient form of selection to improve dry weight yield in this situation would be a reduced selection index, where information on the covariance of dry weight with measured traits are included in the index, even though dry weight itself has not been measured. When this type of index was constructed, it was found that selection for dry weight yield with the reduced selection index giving equal weights to height, d.b.h., and volume

Table 14. Expected response and efficiency of five traits selection indexes compared to combined selection (selection on the best individuals in the best families) for dry weight yield.

Relative Weights For Traits [1]					GENETIC GAIN Height (ft.)	D.b.h. (in.)	Volume ($ft.^3$)	Specific Gravity	Dry Weight (lbs.)	% Dry Weight [2]	Efficiency [3] in improving dry weight yield
1	1	1	1	1	2.8	.36	.61	.02	19.8	26%	1.20
1	0	0	0	0	2.8	.35	.60	.02	19.6	25%	1.18
0	1	0	0	0	2.2	.45	.73	-.02	15.5	20%	0.94
0	0	1	0	0	2.4	.45	.73	-.01	16.1	21%	0.97
0	0	0	1	0	1.0	-.11	-.15	.06	8.1	11%	0.49
0	0	0	0	1	2.8	.35	.59	.03	19.9	26%	1.20
1	1	0	0	0	2.8	.38	.64	.02	19.5	25%	1.18
1	1	1	0	0	2.8	.40	.67	.01	19.2	25%	1.16
1	1	0	1	0	2.8	.37	.63	.02	19.6	25%	1.18
-	-	-	-	1	-	-	-	-	16.5	22%	1.00

1/Relative weights are for individual values of height, d.b.h., volume, specific gravity, and dry weight, respectively. No weight was assigned to family values included in the indexes.

2/% Dry weight improvement calculated by dividing Dry Weight (lbs.) gain by the Stand Average which = 76.8 lbs.

3/Efficiency is the correlated response in dry weight as a % of gain for combined selection using dry weight as the criterion.

was nearly as efficient (1.17) as the best index which included individual measurements on all characteristics (Efficiency = 1.20).

These analyses indicate that if dry weight is the goal of selection, the small gains in efficiency to be had by measuring specific gravity and dry weight yield (1.20 vs. 1.17) are probably insufficient to warrant the expense of developing this information on individuals in the population. This is not meant to imply that dry weight should be the goal of selection, or that the sole impact of wood specific gravity on product quantity, or value is on dry weight yield. Wood specific gravity *per se* has important influences on quality of pulp and on the major strength properties of wood. The appropriate weight to give wood specific gravity relative to other traits in an advanced generation loblolly pine tree improvement program cannot be determined until the relative impact of a unit improvement on each trait in product value is known.

The Pilodyn Wood Tester

Many organizations in the Cooperative included wood specific gravity as a selection criterion in their first-generation loblolly pine improvement programs. It has been estimated that one generation of light selection for increased wood specific gravity improved yield of dry wood by approximately 2700 to 3000 lbs. per acre.

Compared to other traits, measurement of wood specific gravity in standing trees is costly in terms of manpower. Direct measurement of the trait involves extracting and processing increment cores. These considerations have made breeding for the trait difficult in advanced generation loblolly pine tree improvement, where several thousand progenies are measured annually by each Cooperator. Techniques allowing rapid and inexpensive assessment of specific gravity in standing trees would facilitate selection efforts for this important trait by allowing many more trees to be assessed which could increase selection intensity.

It has been proposed that the Pilodyn Wood Tester could be used to indirectly assess wood specific gravity. Originally developed to test soundness of wood poles in Switzerland, the Pilodyn is a handheld instrument which propels a spring-loaded needle into wood. Its use on living trees requires removal of a bark patch, followed by application of the instrument. Depth of needle penetration in mm. is read directly from the instrument. The needle will not penetrate as far as the density increases.

The staff of the Cooperative in conjunction with scientists and staff of International Paper Company's genetics research section near Bainbridge, Georgia evaluated the utility of the Pilodyn Wood Tester. A study was initiated during the summer of 1979 in which Pilodyn Wood Tester readings were taken on the same heritability study trees described earlier in this report, under the heading of Inheritance of Wood Specific Gravity. Three types of Pilodyn instruments were tested:

1. Six Joule - 2.0 mm. diameter needle width
2. Eighteen Joule - 2.5 mm. diameter needle width
3. Eighteen Joule - 3.0 mm. diameter needle width

The results shown in Table 15 were developed utilizing correlated gain analyses. Components of the analytical procedure include selection intensity, respective heritability estimates, genetic correlations, and estimates of phenotypic or total variation. In essence, what is being compared is indirect selection (Pilodyn) versus direct selection (specific gravity from cores). Gains from direct selection are usually greater than for indirect selection, but indirect selection can be a viable alternative if the characteristics for which improvement is desired (wood specific gravity) is difficult to measure and correlated response using an easily measured trait gives substantial gain.

The Pilodyn Wood Tester appears to hold promise as an aid in selecting to improve mature wood specific gravity in loblolly pine. Of the three Pilodyn instruments tested in this study, the 18-joule, 3.0 mm. Pilodyn gave the highest relative efficiency (83.6%) compared to direct selection for wood specific gravity. Although gains would be greater for direct selection, the time and money required to collect and laboratory process thousands of increment cores make intensive direct selection for wood specific gravity

Table 15. Gains and relative efficiency of selection for increased wood density in loblolly pine using increment core and Pilodyn needle penetration methods.

Selection Method	Gain in Specific Gravity[1/]	Efficiency[2/]
Wood Density - from increment cores	0.042	100%
6-joule 2.0 mm needle	0.033	77.1%
18-joule 2.5 mm needle	0.004	9.5%
18-joule 3.0 mm needle	0.035	83.6%

[1/]Selection intensity used was 1 in 100 saved.

[2/]Assumes that direct selection for specific gravity is 100% efficient.

prohibitively expensive in most cases. Additional studies are needed to determine the effectiveness of the Pilodyn in selection for improved wood specific gravity in younger trees which form the base population used for advanced generation loblolly pine improvement.

Pollen Parents in 2nd Generation Orchards

Extensive establishment of second generation orchards began during the mid-seventies. At that time virtually all the trees selected from progeny tests and recommended for use in these orchards were rather juvenile, five to seven years-old. It was thought that grafts of these young trees would be reluctant pollen producers. In first generation orchards, female strobili ("flowers") were often produced five to six years following grafting, while there was an additional two to three year delay before pollen was produced in any significant quantity. The concern with grafts of young, juvenile trees was that the onset of pollen production might be delayed as much as six to eight years beyond when female flowers were produced. The concern was the result of experiences with grafts of very young trees, one or two years from seed. To counter this potential problem in young second generation orchards the design called for inclusion of selected first generation clones (approximately 16% of the orchard ramets) to serve as "pollen parents" during the early years of seed production. It was hoped that grafts of sexually mature first generation parents would produce pollen earlier and in greater quantities than the sexually immature, juvenile second generation grafts. As several of the older second generation seed orchards began to flower, a study plan was developed to evaluate pollen production by the various parental types.

The data from this study, summarized in Table 16, provided a rather welcome surprise. It is apparent that no important delay in pollen production has been experienced. In fact, the juvenile second generation selections have produced more pollen at young ages than the so called "pollen parents." An additional year's data has been collected from several of these same orchards and from two new orchards just beginning to flower. While not completely summarized as this was written, it is clear that the additional data show the same results as evidenced in Table 16.

The "pollen parent" concept was concluded to have little utility. The elimination of first generation selections from second generation orchards will improve the genetic quality of the seed produced in young orchards and will reduce orchard establishment costs in the future.

Table 16. Pollen production on second generation selections and first generation selections occurring in even-aged (age from grafting) second generation orchard blocks.

		CATKIN CLUSTERS/TREE	
Orchard	Year	1st Gen.	2nd Gen.
Weyerhaeuser, N. C.	1980	41	94
Weyerhaeuser, N. C.	1981	100	262
Champion, S. C.	1981	30	141
Catawba, S. C.	1981	0	23

Potted grafts subjected to moisture stress and $GA_{4/7}$ treatments are producing flowers for the Cooperative's inbreeding study.

Wet Site Loblolly Pine

The Cooperative recently inherited a study, established by a former faculty member in the Department of Forestry, to determine whether loblolly pine grown from seed collected in stands growing on deep organic soils in the Coastal Plain would outperform collections from more typical mineral Coastal Plain soils. The study was planted in 1972 on two sites, one mineral soil and one organic soil on the Hofmann Forest in Onslow County, North Carolina. The objectives of the study were:

1. To determine whether the deep organic soil source would grow better on both mineral and organic soils, since both are basically wet, poorly drained sites.
2. To determine if either or both sources would respond to additions of Calcitic limestone and phosphorous.

Data were collected and analyzed following eight growing seasons in the field by graduate students Bruce Emery and James Hodges. Conclusions are summarized as follows:

1. On the mineral site, the mineral soil source outperformed the organic soil source in diameter growth and survival.
2. On the mineral site, the mineral soil source exhibited more than twice the fusiform rust infection of the organic soil source (26% vs. 10%).
3. No differences between the seed sources were detected on the organic site, possibly due to very low survival.

4. Both fertilizer amendments were associated with a response in diameter growth on the mineral site. There was a response to both fertilizers in diameter and height growth on the organic site.
5. No differences were detected for either percent survival or percent rust infection as a result of adding lime and phosphorous.

While these results are less than conclusive, the Cooperative has additional work underway in this area. Former graduate student Claire Williams (now employed by Weyerhaeuser) established six plantings comparable to the one summarized above. Three of the plantings are on organic soils, and three are on mineral soils. Each planting compares the performance of genetically improved seedlings derived from selections on organic soils against seedlings grown from selections on more typical mineral soils. As these plantings develop, it will enable us to quantify the suspected differences in the loblolly pine organic soil ecotype.

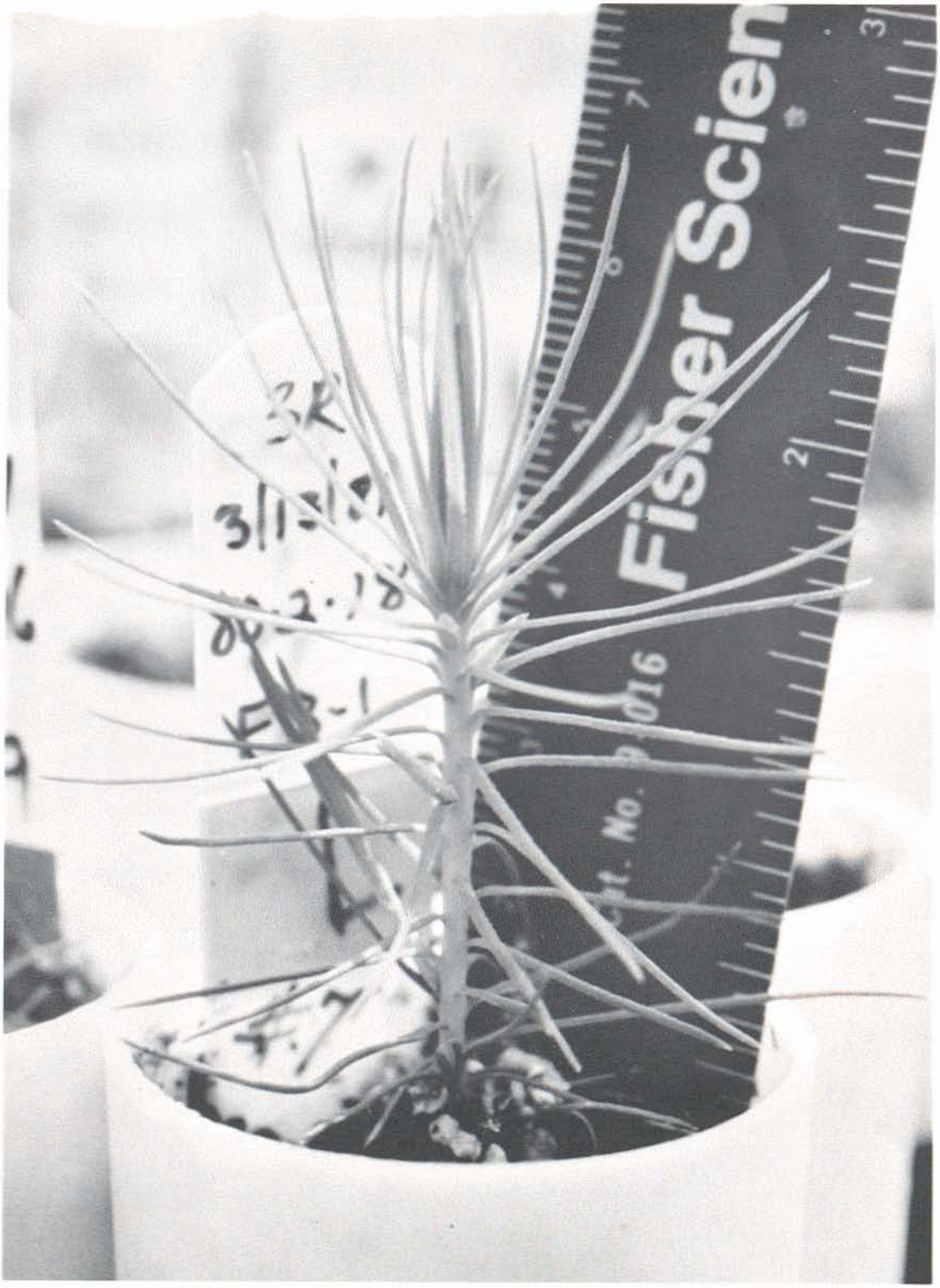
Tissue Culture

The Tree Improvement Cooperative has since its conception maintained a strong selection, breeding and testing program which constitutes the resource development segment of the program. The payoff or benefit segment of the program has utilized clonal seed orchards. This involves establishment of grafted select trees in one centralized intensively managed area where the best trees intermate with the best trees to produce genetically improved seed. This concept has been most successful producing large quantitites of significantly improved seed, however, it relies on a sexual propagation system, thus only a portion of the genetic gain possible is actually realized. It is apparent from recent research results that if an effective vegetative propagation system were available for loblolly pine, the improvement following any given cycle of selection might be doubled for certain economically important traits, e.g. growth rate.

In an effort toward developing the apparent potential of a vegetative propagation system, the Director and staff of the Cooperative sought ways to generate support for fundamental research in this area. We were fortunate to have an opportunity to join forces with a tissue culture research initiative in the Botany Department at N.C.S.U. under the direction of Dr. Ralph Mott and Dr. Henry Amerson. Together we were able to successfully organize the Special Project on Tissue Culture in January, 1979. The Project is currently supported by 12 industries, 11 of which are also members of the Tree Improvement Cooperative.

Over the three year period in which The Special Project has been in existence, the objectives have included:

1. Survey tissue culture potentials applied to tree improvement.
2. Refine existing tissue culture propagation techniques.
3. Produce tissue culture plantlets from embryo culture methods in sufficient numbers for field evaluation.
4. Use tissue culture systems to pioneer _in vitro_ selection schemes, initially concentrating on resistance to fusiform rust.
5. Produce plantlets from subcultured callus of mature trees.



A Tissue Culture plantlet grown for six weeks in the greenhouse. Secondary needles are already developing.

A greenhouse grown tissue cultured plantlet ready for field planting on lands of Federal Paper Board.

On balance, the results of this research initiative have been most encouraging. The embryonic culture system has been improved as studies demonstrated the importance of the media recipe for bud initiation and elongation. Shoot size, vigor, light and possibly age of tissue are important control factors for rooting of the tissue culture shoots. Currently 75-100% of the shoots produced can be rooted. Refinement of soil, watering and fertilization regimes in the greenhouse has increased survival upon transfer to soil from 30-50% in 1980 to 60-90% in 1981. Plantlets can now be grown in the greenhouse to field planting size in 4-6 months following transfer from the lab to soil. Eight field plantings have been established to date, and four more will be planted in 1982. An *in vitro* structural analysis of rust resistance has noted a strong tendency for necrotic regions to develop in association with the rust challenge to the plantlet. This appears to be a classic hypersensitive response that may operate to provide a form of resistance.

Graduate Student Research & Education

The education of graduate students and the research they conduct in conjunction with their degree program is a vital activity of the Cooperative. During the last year, 15 students have been working toward advanced degrees in close association with the Tree Improvement Cooperative. Six are working on Masters degrees and nine are involved in the Ph.D. program. In addition, John Talbert and J. B. Jett have recently made good progress toward completing their Ph.D., as has Steve McKeand who works with the tissue culture project.

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 in the last year.

The graduate students working with the Cooperative, the degree to which each aspires and the title 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
Mike Carson	Ph.D. (complete)	Genetic variation in rust symptom types with loblolly pine
Susan Carson	Ph.D. (complete)	Geographic variation in host-pathogen interactions with fusiform rust on loblolly pine
Bruce Emery	Ph.D.	Intensive roguing of seed orchards
John Frampton	Ph.D.	Genetic segregation of sympton types in fusiform rust
Albert Garlo	Masters (complete)	Vegetative propagation of Fraser Fir
Mike Harbin	Masters	Seed source studies involving Florida source loblolly pine
James Hodges	Masters	Genotype-fertilizer interaction studies of slash pine
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.	To be determined.
Joe Weber	Ph.D.	Geographic variation in natural stands of Fraser Fir
Lisa Wisniewski	Masters	Genotype by year interaction in fusiform rust

Program Staff

Faculty-level staff are well-known to Cooperators because of their frequent travel to work with Cooperative members in the field. Laboratory, secretarial and data processing staff are in most cases not nearly so visible, yet their work is of equal importance and they contribute vitally to the smooth and effective operation of the Cooperative. Program staff members are currently as follows:

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
Donna Miller
Judy Stallings
Jackie Evans

*Vernon Johnson - Coordinator
Laboratory & Field Technician
*Addie Byrd
*Rob Wilson[1/]

Donald Miller - hourly
Chuck Helms - hourly
Ricky Cantrell - hourly
David Ike - hourly
Dan Edwards - hourly
Greg Ferguson - hourly

*Individuals' time and financial support shared by Tree Improvement and one or more other Cooperative programs.

1/Rob Wilson left the Cooperative Staff on April 1, 1982 to become the Cooperative Contact Man for Hiwassee.

Support staff members were reduced by one and one-half positions during the last year. Upon completion of the plantation selection effort in the spring of 1981, the continuous demand for laboratory work (processing wood samples) stopped, and our needs became much more seasonal in nature. The hourly support staff listed are in most cases part-time student labor.

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 expected to be 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 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.

The Cooperative has been very fortunate to have a number of employees that have stayed with the program for many years through thick and thin. Time in service with the Cooperative ranges between 10 and 15 years for the following staff members: Addie Byrd (10), Bob Weir (11), Jerry Sprague (12), J. B. Jett (14), Alice Hatcher (14) and Vernon Johnson (15). The continuity that these people have contributed to the Program is valuable.

A short term progeny test of Virginia Pine established by the North Carolina Forest Service to evaluate Christmas tree quality. A split plot design was used with half the trees being sheared.

MEMBERSHIP OF TREE IMPROVEMENT COOPERATIVE

Organization	States Where Operating
American Can Company	Ala., Miss.
Brunswick Pulp Land Company	S.C., Ga., Tenn.
Bowaters	Catawba Timber Co.--S.C.,N.C., Va.,Ga. Hiwassee Land Co.--Tenn., Ga., Ala., 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.
Masonite Corporation	Ala., Miss.
North Carolina Forest Service	N.C.

MEMBERSHIP OF TREE IMPROVEMENT COOPERATIVE (CON'T)

Organization	States Where Operating
Rayonier, Inc.	Fla., Ga., S.C.
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.
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.

The membership of the Cooperative increased by one during the last year as Buckeye Cellulose Corporation in Ogelthorpe, Georgia became our newest member effective January 1, 1982. Buckeye has a long history of forestry research and active participation in research cooperatives, especially the Cooperative Forest Genetics Program at the University of Florida. With this history and the rapid start in our program that is already evident, we anticipate a long and mutually rewarding association. Welcome Buckeye!

The current membership of the Cooperative includes 25 forest based industries and the forestry organization 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

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