THIRTY-SECOND ANNUAL REPORT

N. C. STATE UNIVERSITY-INDUSTRY
COOPERATIVE TREE IMPROVEMENT PROGRAM

COLLEGE OF FOREST RESOURCES
N. C. STATE UNIVERSITY
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THIRTY-SECOND ANNUAL REPORT

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

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EXECUTIVE SUMMARY

1. Three Cooperative Research studies were established or initiated during the past year:

    a. Breeding began for the Plantation Selection Seed Source Study.

    b. The Inbreeding Study was planted at 10 locations, five in the Piedmont and five in the Coastal plain.

    c. Grafting was completed at three of four Dwarfing Rootstock Study locations.

2. Progress reports for six additional research projects reveal that:

    a. The vast majority of loblolly pine families exhibit average stability over a wide range of site quality.

    b. Florida source loblolly performance is similar to the south Atlantic Coastal plain source and both were better than the lower gulf source at five years of age.

    c. Subsoiling treatments have a minimal effect on seed quality and size.

    d. Better quality progeny test seedlings are grown in large containers. Subsequent first year growth in the field is enhanced by early season planting.

    e. Sub-lethal doses of herbicides will inhibit seed orchard turf growth. Continued work to improve methodology is warranted.

    f. Fraser fir seedlings from low elevation sources outgrew those from the high elevations after four years in the field.

3. The 1987 harvest of cones and seeds was the largest in program history:

    a. Cooperative members harvested 93.3 tons of improved loblolly pine seeds.

    b. Second generation loblolly seed orchards produced 10 tons of seeds or approximately 11% of the total harvest.

    c. Nine seed orchards in the Cooperative exceeded two pounds of seed per bushel of cones harvested.

4. The Cooperative's advanced generation breeding program includes over 4000 selections being bred in 670 six-parent half diallels that will be planted in 1340 individual tests. Good progress is being made in this work with over 11% of the total tests planted.

5. A total of 12 graduate students are working in association with the Cooperative on M.S. and Ph.D. programs.

INTRODUCTION

The North Carolina State University -Industry Cooperative Tree Improvement Program has completed 32 years of activity. In an environment of true cooperation members have shared over three decades of challenging experiences and rewarding accomplishment. With a firm commitment to common goals and relatively stable financial support we have made remarkable progress in genetic resource development. Focused research has led to greater understanding, improved methodology, and substantial gains in efficiency and therefore value returns. Rapid technology transfer has been a hallmark of the Cooperative. Genetic gains of 7 to 12 percent for growth with comparable improvements in quality traits have been realized in seed harvests sufficient to reforest 12.6 million acres of commercial forest land. This Cooperative has become an outstanding example of a beneficial partnership among industry, governments, and university, and now serves as a model for similar endeavors throughout the nation and the world.

Through these years the Cooperative has matured. The membership has grown from the original 11 charter members to 28 members operating 40 distinct tree improvement centers throughout the southeastern U. S. Tree improvement, which began as a high risk proposition accompanied with substantial uncertainty, is now a functional component of operational forest regeneration activities. Research and development issues are far more complex than in the developing years of the Cooperative.

The maturing process is inevitable and can be a positive influence on the future direction and potential of the Cooperative. Yet it is not necessarily easy to negotiate. The membership of the Cooperative is more diverse, partly because there are more members, but also because members have more diverse missions and therefore different expectations from the Cooperative. Recognizing that this is a part of our future, a process of reconsideration, discussion, and planning was initiated during the past year. A special Advisory Committee Meeting, held in October of 1987, was instrumental in defining the issues of concern. It was, however, merely a beginning as the membership endorsed the preparation of a strategic plan for the Cooperative. The Program staff, in concert with a specially appointed steering committee, has begun the strategic planning work. The strategic plan will be a constructive vehicle to strengthen our ability to meet the complex challenges that are ahead. Three decades of progress and cooperation make a solid foundation for a productive future.

RESEARCH

Substantial progress was made on several research projects during the past year. Field activities were at a hectic pace for the Plantation Selection Seed Source Study, the Inbreeding Study, and the Dwarfing Rootstock Study. All three are in some phase of establishment or initiation. Research projects which have progressed to a point of meaningful results include: the Stability of Loblolly Pine Families in the Southeastern U. S.; The Florida Loblolly Provenance Trial; The Impact of Orchard Subsoiling on Seed Quality; An Evaluation of Container Size and Date of Planting for Loblolly Pine Containerized Seedlings; Seed Orchard Turf Management; and, Fourth Year Results of a Fraser fir Provenance Study.

One objective in these and other studies underway is to establish trials which provide both applied, short-term results and an opportunity for more basic, long-term research. We are fortunate to have gained in the Forestry Department this past year a research physiologist, Dr. Leslie Tolley-Henry. We are hopeful that research with her and other scientists at N. C. State University, such as Dr. Henry Amerson, will be directed toward understanding some of the genetics-physiology relationships of loblolly pine.

Plantation Selection Seed Source Study

Breeding for the Plantation Selection Seed Source Study was initiated in the spring of 1988. Results from this study will be used to evaluate the patterns of variation among and within sources of the plantation selection population. Seven pollen mixes were made with 40 plantation selections from each testing region. The 40 parents were chosen to represent the age and geographic distribution among plantation selections in each region. Each of the pollen mixes are being used to breed 20 females in their respective region.

Overall, good progress in the pollination work for this study was made by cooperators this spring, In some areas we experienced a rather poor flower crop which limited the breeding to some extent. Additional pollen was collected to supplement next year's pollination work. We are hopeful that the pollination work for this study can be completed in the spring of 1989. Seed resulting from this pollination work will be used to establish field trials throughout the Southeast.

Inbreeding Study

The inbreeding study was established in field trials during the spring of 1988. A total of 10 Cooperative members each established one field planting of the study. There were five sites established in the Coastal Plain of North Carolina and South Carolina, and five Piedmont sites were established in North Carolina, South Carolina, and Georgia. During the winter over 20,000 seedlings were grown in the greenhouse at N. C. State University and distributed to Cooperative members for the field plantings. We were successful in getting almost every cross (including 18 of 20 selfs) established in the trials.

The Inbreeding Study was designed with the following objectives:

1. To determine the response to related matings in improved loblolly pine.

2. To characterize family differences in sensitivity to inbreeding

The deleterious effects of self pollination on the subsequent performance of the resulting offspring are well known. With selfs, inbreeding depression for growth in excess of 25% is not uncommon. However, little information is available as to the effects of less severe levels of inbreeding. If matings among full-sibs or half-sibs result in no appreciable depression in growth, then we can increase selection intensity and therefore genetic gain. An additional concern with inbreeding is whether families exhibit the same or different responses to varying levels of inbreeding. A strong interaction between families and inbreeding levels would exclude a general prescription for use of related individuals in seed orchards. The results of this study will guide future breeding decisions and orchard designs.

Parents used in the Inbreeding Study were all second generation selections. Ten family sets were created from matings among Coastal Plain selections and 10 were derived from breeding Piedmont selections. Matings were done in a manner to create four levels of inbreeding. The four inbreeding levels being tested result from matings among:

Selfs	-- 50%	inbred
Full sibs	-- 25%	inbred
Half sibs	-- 12.5%	inbred
Unrelated	-- 0%	inbred

Over 20,000 seedlings for the Cooperative Inbreeding Study were grown in Raleigh this past winter. Five Coastal and five Piedmont sites were established in the field during the spring of 1988.

We have summarized results for seed germination from the four inbreeding levels studied (Figures 1A & 1B). There was no strong inbreeding depression for seed germination for filled seed (all seeds were "floated" in water before sowing and floaters were discarded). However, the non-inbred seeds (unrelated crosses) had the best germination in both the Coastal and Piedmont groups.

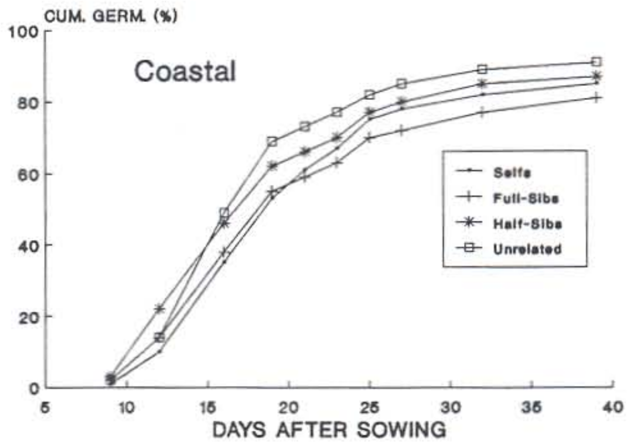
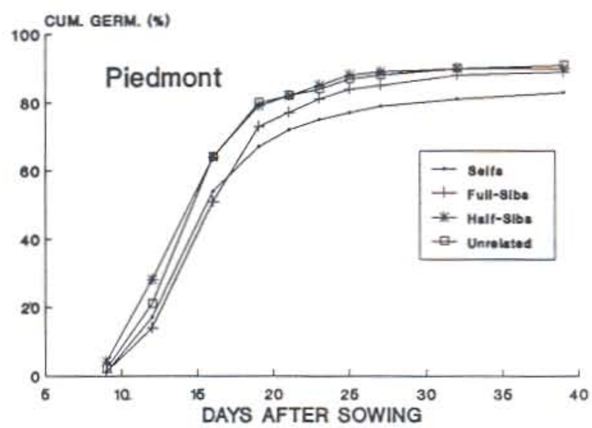


Figure 1A.

Cumulative seed germination in the Coastal Plain provenance for four inbreeding levels.

Figure 1B.

Cumulative seed germination in the Piedmont provenance for the four inbreeding levels.



Dwarfing Rootstock Study

In many horticultural fruit and nut crops, the use of selected rootstocks in orchards is standard practice. Desirable characteristics, including reduced tree size, precocious flowering, increased fruit yield and quality, disease resistance, and cold tolerance can be imparted to the scion by the rootstock. The most economically important traits are probably those affecting tree size and fruit yield.

In forest trees relatively little work has been done to develop rootstocks with desirable characteristics. The potential to screen among loblolly pine genotypes for various rootstock characteristics has been demonstrated. Craig McKinley of the Texas Forest Service found differences among four loblolly rootstock families which affected the growth of scions. Ron Schmidtling of the U. S. F. S. showed that rootstocks of different pine species influence precocity, growth, and survival of loblolly pine scions. From the horticultural research, it has been determined that low vigor rootstocks impart their low vigor (slower growth) to scion clones. If forest trees are similar, it would seem likely that slow growing genotypes would be good candidates for dwarfing rootstocks in loblolly pine. The effect of low vigor on flowering is unclear. Some studies show little relationship between the level of rootstock vigor and flowering, while in others dwarfing rootstocks were associated with precocity. It is difficult to draw general conclusions from horticultural studies of rootstock effects on scion growth. Scion rootstock interactions seem to be the rule rather than the exception.

With these horticultural and forestry experiences with rootstocks and scions in mind, we have designed a study with the following objectives:

1. Determine morphological, physiological, and genetic characteristics of root and shoot contributions to growth and development.

2. Determine which rootstock families contribute desirable characteristics such as growth reduction, increased flowering, seed yield, seed quality, and compatibility to various scion clones.

A total of four installations of the Dwarfing Rootstock Study are planned. The locations are in Alabama, Georgia, South Carolina, and North Carolina. Three of the four installations were grafted in February and March, 1988. The fourth site will be grafted during the spring of 1989. The first objective is being evaluated by grafting fast and slow growing scions onto fast and slow growing rootstock families in all possible combinations. This portion of the study should provide insight into the relative contributions of shoots and root systems to tree growth and development. To evaluate the second objective, seedlings from 20 very poor growing first-generation crosses are being evaluated as rootstocks and compared to five fast growing, full-sib rootstock families. We hope to find some families which will be valuable to seed orchard managers for third generation seed orchards. The two objectives are interrelated since it would be most useful if a genotype's potential as a rootstock could be predicted from various growth, morphological, or physiological characteristics.

Grafting was completed on three of the four Dwarfing Rootstock Studies in 1988. Shown is the installation at Hiwassee's orchard near Oak Park, Georgia.

Stability of Loblolly Pine Families in the Southeastern U. S.

Eight-year data from 21 of the Good General Combiner Tests established in the mid to late 1970's were analyzed to determine the amount of genotype by environment (G x E) interaction present among 43 open-pollinated families of loblolly pine. The 21 tests, located in Coastal Georgia, Florida, Alabama, and Mississippi (Figure 2), were selected because of good family representation from the same latitudinal area. The tests represented a range of site qualities for growth and fusiform rust infection. Average test heights ranged from 17.7 to 30.8 feet and rust infection levels from 13% to 73%.

A stability analysis was conducted to determine which of the 43 families responded to site changes in a predictable manner. If a family increased in size in direct proportion to site quality it has average stability.

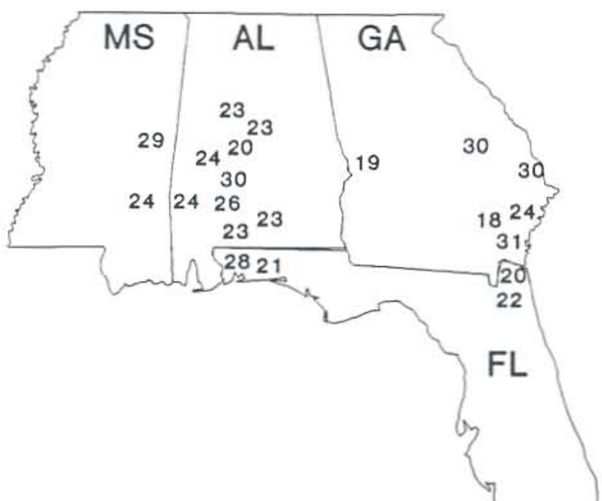


Figure 2.

Locations of trials used in stability analyses. Numbers indicate the average height (feet) of trees at each site.

Families which grew better than expected on the better sites were considered unstable but responsive to shifts in site quality. If a family did not respond to site changes then it was considered very stable for performance. Similar analyses were performed for fusiform rust resistance where overall percent rust infection in the stand was used as the indicator of site quality.

Of the 43 families tested, only 8 had regression coefficients significantly different from the expected value of 1.0 for volume, and 6 were different from 1.0 for % rust-free trees (Table 1). The majority of families showed average stability (as measured by the slope of the regression line -- coefficient $b_i = 1.0$) and were predictable in their response to site as measured by the high R^2 values. Simply stated, the overwhelming majority of families changed performance in direct proportion to changes in site quality.

To illustrate the patterns of stability in these tests, the response of three families for volume are plotted in Figure 3. Family 03007 represents the 35 of 43 families which were of average stability for stem volume. Family 07056 represents the four families which were not stable for growth (i.e. $b_i > 1.0$). This kind of instability is very desirable, performance improves more than for most families as the sites improve in quality. Family 01064 is a family which was stable (i.e., performed almost the same regardless of site quality). Unfortunately family 01064 was stable but a poor performer.

Table 1: Family means for volume and percent rust-free trees, number of tests, estimated regression coefficients (b_i) and the coefficients of determination (R^2).

Family	Origin[1]	# Tests	Volume (dm^3) Mean	b_i	R^2	% Rust-Free Trees Mean	b_i	R^2
01014	P,GA	8	31.40	0.91	0.95	55	1.24	0.92
01064	P,GA	12	21.33	0.56**	0.81	53	1.44*	0.87
01523	P,SC	7	39.16	1.03	0.88	50	1.18	0.85
02008	C,VA	8	36.19	0.96	0.97	68	1.00	0.88
02040	C,VA	19	25.17	0.85	0.87	50	1.23	0.81
03007	P,SC	13	34.01	0.98	0.94	75	0.82	0.80
03036	P,SC	14	28.92	0.91	0.96	57	1.28*	0.92
04006	C,VA	9	35.72	1.00	0.95	52	1.32	0.89
04018	C,VA	19	29.96	0.95	0.93	56	1.23	0.75
05005	C,GA	10	38.92	1.21	0.92	57	1.36	0.74
06009	P,NC	11	34.75	0.88	0.91	40	1.32	0.75
06020	P,NC	19	30.61	0.97	0.96	57	1.28	0.82
06022	C,NC	8	31.61	0.72*	0.88	57	1.13	0.71
07002	C,SC	8	38.29	1.41*	0.92	50	0.83	0.57
07034	C,SC	11	44.39	1.11	0.82	65	1.13	0.74
07056	C,SC	19	41.73	1.34*	0.93	64	0.99	0.74
08001	C,NC	20	32.02	1.13*	0.97	63	1.06	0.76
08059	C,NC	20	33.01	1.00	0.94	65	1.20	0.79
08061	C,NC	20	34.82	1.15**	0.97	56	1.39**	0.89
08068	C,NC	21	30.69	1.02	0.94	65	0.97	0.79
08076	C,NC	16	39.43	1.13	0.95	63	1.22	0.78
08102	C,NC	7	32.80	1.05	0.96	34	1.07	0.72
08509	C,AL	10	29.34	0.80	0.88	57	1.41	0.72
09017	P,NC	11	38.05	1.07	0.94	63	1.02	0.93
10002	C,GA	7	36.24	0.98	0.83	65	0.38	0.30
10005	C,GA	13	40.58	1.23*	0.96	67	0.59	0.46
10006	C,GA	8	38.01	1.08	0.93	75	0.70*	0.83
10010	C,GA	7	36.64	1.11	0.80	53	0.91	0.51
10014	C,GA	14	34.40	1.12	0.90	40	0.85	0.80
10046	C,GA	6	34.16	0.93	0.94	58	1.05	0.65
11009	C,SC	10	39.31	1.24**	0.95	82	0.84	0.58
11010	C,SC	8	42.39	1.15	0.90	81	0.73	0.57
11016	C,SC	14	34.08	1.18	0.93	74	0.74	0.50
11061	C,SC	7	34.44	1.23	0.94	59	1.08	0.41
15042	P,GA	16	30.96	1.01	0.93	73	0.60	0.65
17004	C,AL	9	37.49	0.98	0.93	56	1.52**	0.93
17005	C.AL	7	36.68	1.03	0.97	72	1.18	0.92
17016	C,AL	20	27.66	0.93	0.93	53	1.21*	0.88
17019	C,AL	6	38.78	1.09	0.92	70	0.89	0.54
17037	C,AL	11	30.91	0.96	0.82	61	1.00	0.74
19016	C,AL	8	25.24	0.72	0.80	33	1.23	0.70
19017	C,AL	7	33.60	0.97	0.93	49	1.41	0.85
19024	C,AL	8	26.04	0.88	0.94	43	1.08	0.81
Check		21	31.64	0.76	0.63	63	1.15	0.79
Overall Mean			34.13			59		

[1] Origin: Province (P=Piedmont, C=Coastal Plain), State.
*, ** Significantly different from 1.0 at the 5% and 1% level, respectively.

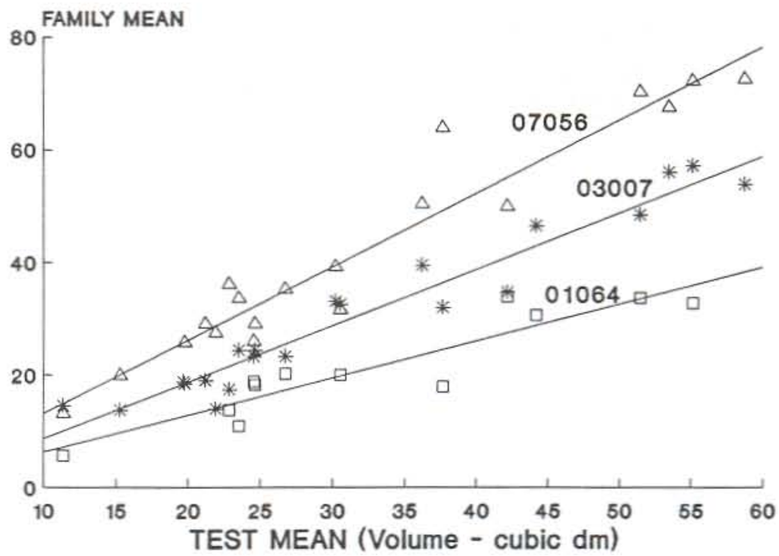


Figure 3.

Regression of three family means for volume on the environmental index (test means).

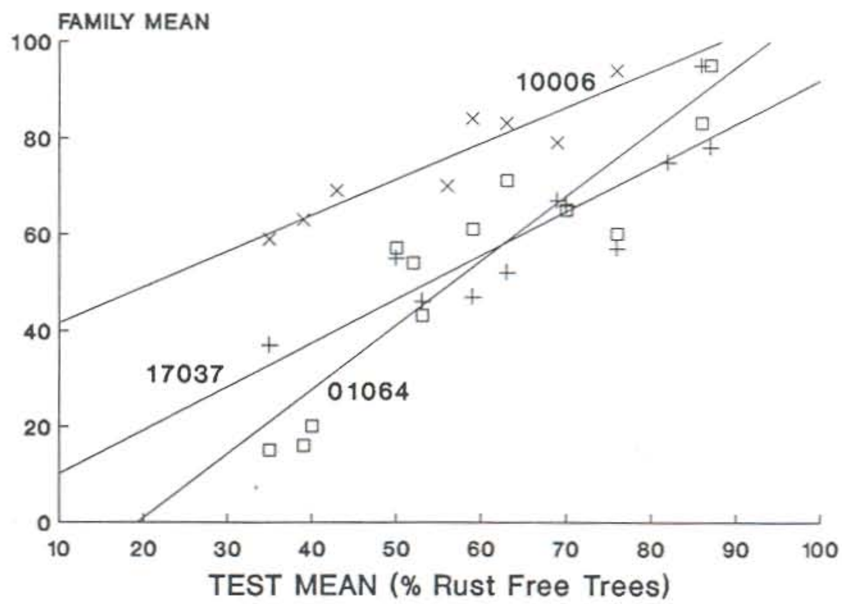


Figure 4.

Regression of three family means for % rust-free trees on the environmental index (test means of % rust-free trees).

Very similar patterns for rust resistance were seen (Figure 4). Most families (37 out of 43) responded as 17037 responded, rust infection was in direct proportion to the amount of rust in the test. Family 10006 is the type of family we prefer. It was well above average for percent rust-free trees in all tests, and it had relatively more rust-free trees as the percent rust-free trees in the test decreased.

Although significant genotype by environment interaction was detected for this population of loblolly pine, the biological and economic significance is not great. The performance of families on poor sites was generally predictive of families on good sites. An important implication to the breeding and testing program is that families need not be tested over environmental extremes to determine breeding values. Our use of uniform, agricultural sites for testing is concluded to be an acceptable practice. We can determine the breeding value for most families on relatively good sites, and correctly infer the breeding value for poorer sites.

Florida Loblolly Provenance Trial

In 1982 and 1983 the Florida loblolly provenance trials were established by members of our Cooperative and by members of the University of Florida Cooperative Forest Genetics Research program. An objective of this study was to thoroughly evaluate the potential of the Marion County (MC) and Gulf Hammock (GH) (from Levy Co.) sources of loblolly pine in the southern Atlantic Coastal Plain and Lower Gulf regions of the Southeast.

There are several situations unique to the Florida sources of loblolly pine. The first is the relatively small base population of selections in both Cooperatives. Fewer than 120 trees have been selected which is too small a base for advanced generation breeding. There also seems to be little opportunity to expand the breeding base by acquiring new selections from the Florida sources. One objective of the study was to determine if improved sources of loblolly pine from the Florida sources could be included in the advanced generation improvement program with the Lower Gulf and South Atlantic Coastal Plain sources.

A second complexity of the Florida source is that despite a very restricted range in peninsular Florida, the MC and GH sources evolved on very different soil types. Marion County is typified by sandy soils (Quartzipsamments) in the inland areas while Levy County has wet, marl type soils (Aqualfs) with high pH's nearer the Gulf Coast. Differences such as these are ideal for the formation of edaphic races of loblolly pine which might respond to different soil types. A second objective of the trials was to determine if differences existed between the MC and GH sources.

A total of six trials (Figure 5) have been retained in the study through age 5. Each trial was established with open-pollinated families from the following sources of loblolly pine:

Marion County, FL
Gulf Hammock, FL
Southern Atlantic Coastal Plain (ACP)
Lower Gulf Coastal Plain (LG)

A total of 15 families represented each source in the study, although not every family was planted in each trial. Based on the 5-year results (Table 2), the Southern Atlantic Coastal Plain, Marion County, and Gulf Hammock sources are very comparable for growth, rust resistance and survival. The straightness of the Marion County and Gulf Hammock sources was slightly inferior to the Southern Atlantic Coastal Plain and Lower Gulf sources. Based on these early results, it appears that the Southern Atlantic Coastal Plain,

Table 2. Source means for different traits at age five years combined over six test locations in the Florida Loblolly provenance trials.

Source	Height(ft)[1]	Straightness Score[2]	%Rust	%Survival
Southern Atlantic Coastal	17.3[a]	3.2[c]	41[b]	86[a]
Gulf Hammock, Florida	17.8[a]	3.4[ab]	42[b]	84[a]
Marion County, Florida	17.3[a]	3.6[a]	40[b]	87[a]
Lower Gulf	15.5[b]	3.3[bc]	49[a]	85[a]

[1]Trait means followed by the same letter are not significantly different at $p \leq = .05$.

[2]Straightness measured on a 1-6 scale, 1 = straight and 6 = crooked.

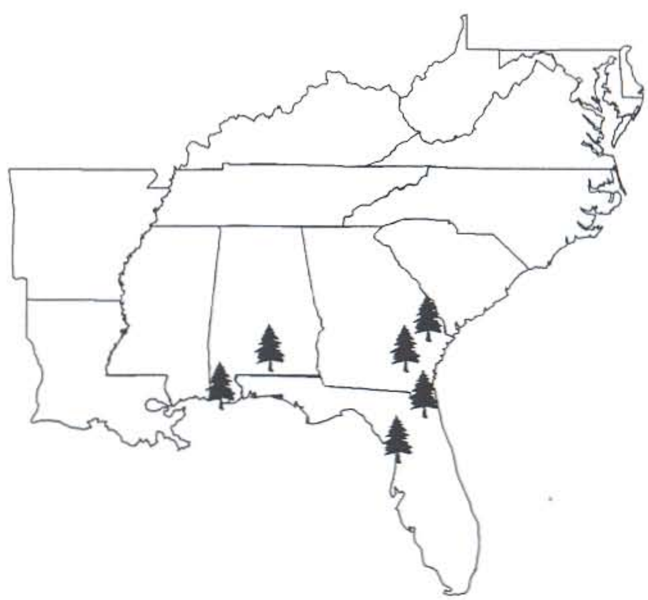


Figure 5.

Location of the six trials in the Florida loblolly provenance tests.

Marion County and Gulf Hammock sources could be combined into one region for advanced generation breeding. This breeding population would be restricted to the deep South. We have seen from the Cooperative's Good General Combiner tests (see the 1986 Annual Report) that Marion County and Gulf Hammock sources perform very poorly when moved north of coastal GA and the Lower Gulf.

There appears to be little consistent difference between the Marion County (sandy soil origin) and the Gulf Hammock (wet, marl soil origin) sources for any of the traits (Table 2).

The poor growth and rust performance of the 15 Lower Gulf families was surprising. They averaged about 2 feet shorter and had 7-9% more fusiform rust than the other three sources. However, these trials are still very young, and the long-term adaptability of the sources can be determined only with measurements through at least half rotation.

Another possible reason for the poor performance of the Lower Gulf source compared to the others is that the 15 families from the Lower Gulf were not representative of all families in the source. This apparently was not the case. In all four sources, the 15 families ranged from good to poor based on first-generation clone evaluations, with no apparent bias from sampling.

The Impact of Orchard Subsoiling on Seed Quality

Results of a subsoiling study evaluating frequency and intensity of subsoiling on cone yields and tree growth were presented in the 29th Annual Report. A follow-up study, evaluating the impact of subsoiling on seed yields per cone and seed quality, was conducted by Dr. Dan Struve, Ohio State University, and the Cooperative staff.

Three of the five original subsoiling treatments were included in the seed quality study: (1) Subsoil-1 where a single rip was made on opposite sides of a tree approximately 5 feet from the tree trunk; (2) Subsoil-3 was three parallel rips on opposite sides of the tree. The first rip was 5 feet from the trunk with the second and third cuts each approximately 5 feet further out; (3) Subsoil-0 consisted of the non-subsoiled control. The first series of rips were made in 1981. Beginning in 1983 the subsoil treatments were repeated on the sides of the trees not previously subsoiled. All subsoiling was done in late-July through August.

A random sample of 15 to 20 healthy cones were collected from two ramets per clone for each of 10 clones in each subsoil treatment during October 1984. Extracted seed from each ramet were cleaned, counted and sized into three categories: (1) small seed - passed through 3.9 mm seed screen; (2) medium seed - retained on a 3.9 mm. seed screen; and (3) large seed - retained on a 4.7 mm. screen. Germination tests were conducted in accordance with Association of Official Seed Analysts rules. Where possible four 100 seed lots were used in the germination tests.

Table 3. Seed yield per cone of loblolly pine under three subsoiling treatments.

Subsoiling Treatment[1]	Mean No./Cone[2]		
	Total Seed	Sound Seed	Sound Seed
Subsoil-0	76[a]	51[a]	67[a]
Subsoil-1	85[ab]	56[a]	66[a]
Subsoil-3	92[b]	62[a]	67[a]

[1] Subsoil-0 = control, no subsoiling,
Subsoil-1 = 1 rip on opposite sides of the tree
Subsoil-3 = 3 parallel rips on opposite side of the tree.

[2] Means followed by the same letter are not significantly different ($p \leq .05$).

Table 4. Average number and percentage (in brackets) of small, medium, and large sized sound seed/cone in loblolly pine for three subsoiling treatments.

Subsoil Treatment[1]	Mean No.[2] and (%) Sound Seed/Cone Small	Medium	Large
Subsoil-0	1.6a(3%)	37.2a(74%)	11.7a(23%)
Subsoil-1	3.5a(6%)	40.4a(71%)	12.9a(23%)
Subsoil-3	6.5a(10%)	42.0a(67%)	13.7a(22%)

[1] Subsoil-0 = control, no subsoiling
Subsoil-1 = 1 rip on opposite sides of the tree
Subsoil-3 = 3 parallel rips on opposite sides of the tree.

[2] Means followed by the same letter are not significantly different ($p \leq .05$).

Results indicate that cones from Subsoil-3 treatment had the greatest number of total seed per cone (Table 3). Although Subsoil-3 also had the greatest number of sound seed per cone, differences among the three treatments were not significant (Table 3). Subsoil treatments did not have any apparent effect on the number or percentage of small, medium, or large seed per cone (Table 4).

By day 16 of the germination test the effects of subsoiling treatments were evident (Table 5). The Subsoil-3 treatment had the highest mean daily germination although no statistical differences were detectable. Seeds from trees in the Subsoil-3 treatment also had the highest germination value. This is understandable since the germination value is a function of mean daily germination. At the end of the test the cumulative germination of the control (Subsoil-0) was highest although differences among treatment were small. Apparently if subsoiling influences germination it enhances germination speed.

A completely satisfactory explanation of these results is not evident. Subsoiling may have resulted in a better growing environment, hence improved tree vigor thereby enhancing seed quality. It is obvious that much more information is needed relative to basic tree physiology and its reaction to subsoiling before we can really understand this important orchard management tool. A better understanding should allow managers the opportunity of maximizing potential benefits from subsoiling.

Table 5. Mean germination and daily germination for seeds collected from 10 loblolly pines receiving three subsoiling treatments.

Subsoil Treatment[1]	Mean Daily Germination[2]	Germination Value[4,3]	Mean Cumulative Germination
Subsoil-0	2.89[a]	16.4[ab]	79.1[a]
Subsoil-1	2.71[a]	13.8[b]	74.6[b]
Subsoil-3	3.51[a]	18.6[a]	78.6[a]

[1] Subsoil-0 = control, no subsoiling
Subsoil-1 = 1 rip on opposite sides of the tree
Subsoil-3 = 3 parallel rips on opposite sides of the tree.

[2] Means followed by the same letter are not significantly different ($p \leq .05$).

3. Germination value = PV x MDG

where: PV = peak value = germination percent ÷ days

MDG = mean daily germination

4. Czabator, F. J. 1962. Germination value: an index combining speed and completeness of pine seed germination. For. Sci. 8:386-396.

An Evaluation of Container Size and Date of Planting for Loblolly Pine Containerized Seedlings

As the number of diallel and open-pollinated tests increase each year, program members seek to economize and increase efficiency. Several cooperators have been interested in using small containers (less than 7 in^3) for growing seedlings to ease test establishment. The large 10 in^3 RL Super Cells®, most people have used, can be difficult to plant especially in heavier soils.

One concern about using a smaller container has been that growth might be reduced in the first year. Small containers might also be less "forgiving", if planting had to be delayed due to inadequate soil moisture in the field.

In 1987 a study was undertaken to determine the effect of container size on early test growth and development. Three types of containers were used:

RL Super Cells® - 9.9 in^3
RL Stubbies® - 6.3 in^3
RL Pine Cells® - 2.9 in^3

Stratified seeds from a Piedmont N. C. seed orchard mix were sown in the containers in late December, 1986 and the seedlings remained in a greenhouse until they were planted in early May, June, or July. In each of the three months a portion of the seedlings were planted in large boxes (4' x 5' x 18") filled with 60% course sand, 30% peat moss, and 10% mineral soil. In one box, trees were watered when soil moisture tension reached 30 centibars (wet treatment) and in the other box at 60 centibars (dry treatment). Rain was excluded from the boxes with a plastic canopy (note picture on the following page). At the time of planting each month, the height of each tree was measured. At the end of the growing season in October, final heights were measured.

Container Size - Date of Planting Study

Top - Seedlings established in the wet (right) and dry (left) treatment boxes under the plastic canopy.

The most obvious result from the study was the lack of success with the small (2.9 in^3) containers. The initial survival in the greenhouse was very poor (48%) for the small containers compared to 98% for the Stubbies® and 100% for the Super Cells®. The reason for the poor survival was inadequate watering which should not have happened, but it indicates how sensitive the seedlings in the small containers can be. Even those that did survive did not grow well (Figure 6). In fact, the trees were not large enough to be planted in the boxes and were dropped from the rest of the study.

The growth in the greenhouse for the seedlings in the Stubby® and Super Cell® containers was enough to develop plantable seedlings. The Super Cell® trees were approximately one inch taller each month than the Stubby trees (Figure 6). Although the size differences were small in the greenhouse, the more rapid growth of the seedlings in the large containers could be important for field planting. They were large enough to field plant two weeks before the seedlings in Stubbies®. This provides a larger window for planting time.

The size of the trees at the end of the growing season was affected by all three factors in the study; month of planting, soil moisture treatment (wet vs. dry), and container size (Super Cell® vs. Stubby®). The most important factor was the month of planting. The overall means for final stem height for each planting date were:

May - 1.65 feet
June - 1.51 feet
July - 0.84 feet

Trees planted after early June had minimal growth regardless of container size or soil moisture treatment (Figure 7). As expected, soil moisture had a significant impact on growth. Trees in the wet treatment averaged 1.49 feet tall as opposed to 1.19 feet for trees in the dry treatment.

Wet - 1.49 feet
Dry - 1.19 feet

Figure 6. Height of trees at time of planting each month for the Container Size - Planting Date Study.

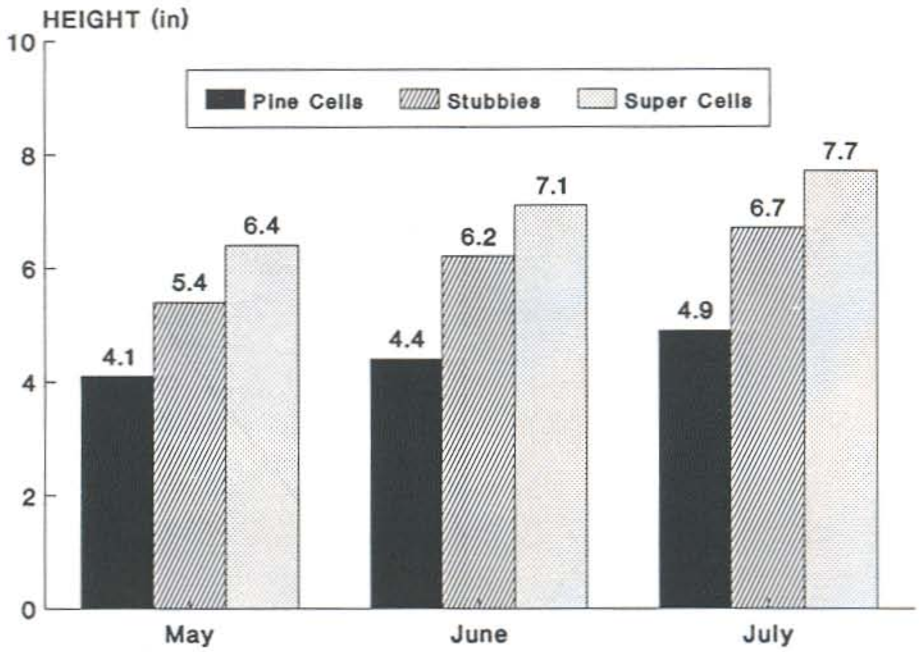
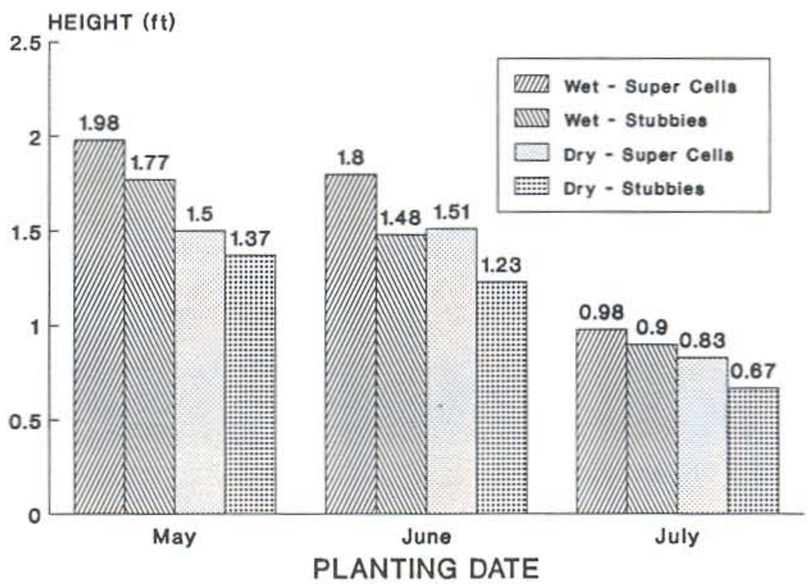


Figure 7. Final heights of trees in October for the Container Size - Planting Date Study



The differences were largest for trees planted early in the season:

May	Wet	- 1.87 feet
	Dry	- 1.43 feet
June	Wet	- 1.64 feet
	Dry	- 1.37 feet
July	Wet	- 0.93 feet
	Dry	- 0.75 feet

An important aspect of the soil moisture treatments was that the soil mix was thoroughly saturated with water at the time of planting. The water stress was imposed after the trees were planted. This simulated field conditions where tests are planted only when soil moisture is high. Any moisture stress would then occur primarily after planting.

Water requirements varied by planting date with the May planted trees requiring the most water since the trees were the biggest. A typical watering cycle after two months in soil for the May trees was every 5-6 days for the wet treatment and every 10-15 days for the dry treatment.

The seedlings grown in RL Super Cells® in the greenhouse were always bigger in October than those grown in Stubbies®. Overall means were:

Super Cells®	- 1.43 feet
Stubbies®	- 1.24 feet

There was no significant interaction between container size and moisture treatment for any of the different planting dates. The big containers were not relatively better than smaller containers in the dry soil treatment compared to the wet treatment for any date. Our suspicion that the large containers would be most valuable under dry conditions was not borne out by this study. However, seedlings grown in the Super Cells® were invariably larger and had a better appearance than those produced in the Stubby® containers.

There are several conclusions we have drawn from this study:

1. Containers the size of the 10 in^3 RL Super Cells® still appear to be best to use for growing test seedlings. They were always the largest and best quality trees in the study.
2. While the seedlings in the Stubbies® were acceptable, there seems little justifiction to use them. They were never as large as the Super Cell seedlings.
3. Under no circumstances should very small containers (< 5 in^3) be used for testing. The poor survival and growth of trees in the Pine cells make this obvious.
4. Seedlings should be planted in the field as early as possible. Planting in April-May in most regions of the Cooperative (when danger of frost is past) is best. Do not sow seeds in the greenhouse in February and intentionally schedule field planting 4 months later in June or July.

<u>Seed Orchard Turf Management</u>

There continues to be considerable interest among seed orchard managers in methods of reducing turf management costs. During April, 1987 a study was initiated with Union Camp Corporation to evaluate the use of sub-lethal doses of herbicides to stunt or reduce turf growth.

Five treatments were evaluated:

1. Roundup®-- .19 lbs. a.i./acre.-Applied in April.
2. Roundup®-- .38 lbs. a.i./acre.-Applied in April.
3. Roundup®-- .76 lbs. a.i./acre.-Application was split with .38 lbs. a.i./acre applied in April and .38 a.i. lbs/acre applied in July.
4. Oust® -- .02 lbs/acre.-Applied in April.
5. Control -- No herbicides applied.

The treatments were replicated four times in each of three seed orchards located approximately 60 miles west of Savannah, Ga. Bahaia grass was the predominant turf species in the Tar City orchard. The Virginia-second generation loblolly orchard and the Savannah second-generation loblolly orchard had a mixed ground cover of native weeds and grasses. The effectiveness of treatments in reducing turf growth was evauluated by mowing strips within each treatment plot using a standard lawn mower with a grass catching attachment. The grass clippings were weighed each month May through August for each treatment plot.

Results indicate that there were important differences between treatments at two of the three locations for May and June (Table 6). By July the influence of the herbicide treatments had become non-significant and this is well illustrated in Figure 8 for the Tar City orchard. Two questions immediately come to mind: 1) has the species composition shifted by mid-season or 2) have the treatments simply lost effectiveness? Since no attempt was made to monitor species composition, it is unknown whether the turf species involved had shifted from early-season to late-season grasses and weeds. Possibly the existing turf recovered from the herbicides and resumed normal growth. The lack of response to the one treatment with a

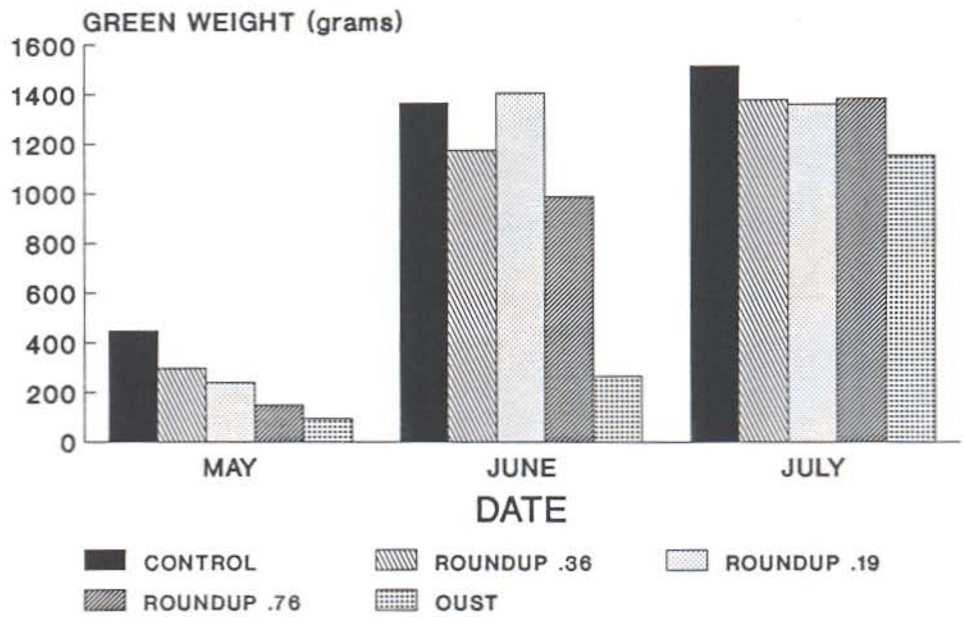
Table 6. Probability levels associated with herbicide treatment effects by orchard and sampling date.[1]

	May	June	July	August
VA. 2nd Gen.	.08	.53	.86	.34
Tar City	.0002*	.0001*	.78	---[2]
Sav. 2nd Gen.	.003*	.01*	.12	.97

[1] Probability values followed by an asterick indicate statistically significant treatment differences ($P \leq .05$).

[2] No sampling was done in this location at this date.

Figure 8. Mean clipping weight for herbicide treatments Tar City Orchard.



mid-season application may point to either a failure of the Roundup concentration or to the timing of the second application.

At both the Tar City and Savannah second generation seed orchards Oust proved to be the most effective herbicide evaluated (Table 7). At the Savannah second-generation site the control treatment produced an average of 71 percent more grass clipping weight than did the Oust® plots in May and June. Similarly, the control treatment produced 79 percent more grass weight than the Oust® treatment during the same period in the Tar City orchard.

Based on results from the 1987 growing seasons it is apparent that future work must be directed at evaluating different rates of herbicide applied at the beginning of the growing season and later during mid-season. A single application is obviously inadequate to provide growth retardation of the turf for the entire growing season. It is also very important to monitor species composition of the treatment plots. Understanding the species composition at mid-season would perhaps allow a better choice of treatments to extend growth reduction.

We anticipate that a cost effective sub-lethal herbicide treatment can be found. Future work might include studies to extend the practice to additional orchards in different regions having different turf species composition. If the favored treatment involves a soil active herbicide such as Oust® then follow up studies to monitor possible impacts on the seed orchard trees would be warranted.

Table 7. Mean Green Weight (g) of grass clippings per sample strip per treatment by orchard and month.

	Treatments[1,2]	May	June	July	August
	C	303^{b}	549^{bc}	637^{a}	372^{a}
Savannah 2nd	O	56^{a}	218^{a}	634^{a}	366^{a}
Gen. Seed Orch.	R1	145^{a}	500^{abc}	530a	402^{a}
	R2	320^{b}	786^{c}	884^{a}	384^{a}
	R3	141^{a}	385^{ab}	633^{a}	378^{a}
	C	447^{c}	1364^{c}	1515^{a}	
	O	95^{a}	267^{a}	1153^{a}	
Tar City Slash	R1	240^{b}	1407^{c}	1361^{a}	
Seed Orchard[3]	R2	297^{b}	1174^{bc}	1378^{a}	
	R3	148^{ab}	986^{b}	1383^{a}	
	C	298	275	602	656
Virginia 2nd	O	241	406	796	783
Gen. Seed Orch.[4]	R1	309	208	698	644
	R2	279	260	700	527
	R3	414	333	650	680

[1] Treatment code: C = control; O = Oust .02 lbs a.i./acre; R1 = Roundup .19 lbs a.i./acre. R2 = Roundup .36 lbs a.i./acre.; R3 = Roundup .76 lb. a.i./acre. Applied April and July;

[2] Means followed by the same superscript letter are not significantly different ($p \leq .05$).

[3] Clipping sample weight were only taken for 3 months at this orchard site.

[4] No significant differences existed among treatments for any month at this location.

Fourth Year Results of a Fraser Fir Provenance Study

Fourth year measurements were taken during 1987 on the Fraser Fir provenance study originally reported in the 30th Annual Report. This study consists of open-pollinated Fraser fir progeny grown from seed collected at different elevations from five natural mountain sources and outplanted at three locations in western North Carolina. The planting sites vary in elevation with the Bald Mountain site at 5100 feet, Purchase Knob at 4400 feet, and Crossnore at approximately 3000 feet elevation. This range in elevation spans the bulk of elevations encountered in commercial plantings of Fraser fir in North Carolina.

Highly significant differences were found for total tree height among the various provenances. When data from all tests were combined, the tallest provenance, Richland Balsam - 5500' elevation, out grew the poorest provenance, Clingman's Dome - 6000' elevation, by approximately 24 percent (Table 8).

Table 8. Mean total height after four growing seasons for provenances in the Fraser fir provenance study.

Provenance	Source Elevation (Ft)	Total Height[1]
Richland Balsam	5500	3.54 a
Clingman's Dome	5500	3.51 a
Clingman's Dome	5000	3.46 ab
Mount Rogers	5000	3.30 abc
Roan Mountain	5500	3.28 abc
Mount Mitchell	6000	3.18 bcd
Roan Mountain	6000	3.10 cde
Mount Mitchell	6500	2.94 de
Clingman's Dome	6000	2.86 e

[1]Means followed by the same letter are not significantly different ($p \leq .05$).

In addition to significant provenance differences, there was a detectable planting location by provenance interaction. An evaluation of provenance performance by planting location seems to indicate that most of the performance changes were associated with the Crossnore planting (Table 9). There was particularly strong agreement in rank of provenance performance between the two high elevation plantings but provenance performance changed order in the low elevation planting.

Table 9. Mean total height by planting location for Fraser fir provenances following four growing seasons.[1]

Purchase Knob		Bald Mountain		Crossnore	
Prov.[1]	Mean Total Ht.(ft.)	Prov.	Mean Total Ht.(ft.)	Prov.	Mean Total Ht.(ft.)
RB55	3.35	CD50	3.05	RB55	4.72
CD55	3.18	RB55	3.02	CD50	4.63
MR50	3.18	MR50	3.02	CD55	4.59
CD50	3.05	RM55	2.99	MM60	4.10
RM55	2.85	CD55	2.89	MR50	4.10
MM60	2.79	MM60	2.76	CD60	4.00
RM60	2.69	RM60	2.66	RM55	3.97
MM65	2.69	MM65	2.59	RM60	3.90
CD60	2.59	CD60	2.53	MM65	3.67

[1]Provenance/elevation code: Provenance --RB = Richland Balsam, CD = Clingman's Dome, MR = Mount Rogers, RM = Roan Mountain, MM = Mount Mitchell. Elevation --50 = 5000', 55 = 5500', 60 = 6000' and 65 = 6500'.

At all three locations there was a distinct pattern of the 5000 and 5500 foot elevation sources out performing the 6000 and 6500 foot provenances (Table 10). The average height of the 5000'-5500' sources was 3.40' as compared to 2.99' for the 6000-6500' sources when combined over locations.

Table 10. Mean total height by seed source across all planting locations and by individual planting location of the Fraser fir provenance study after four growing seasons.[1]

Elevation (ft.)	Locations Combined	Bald Mountain	Purchase Knob	Crossnore
5000	3.42[a]	3.02[a]	3.12[a]	4.33[a]
5500	3.38[a]	2.98[a]	3.11[a]	4.32[a]
6000	3.05[b]	2.65[b]	2.70[b]	3.99[b]
6500	2.94[b]	2.60[b]	2.69[b]	3.65[b]

[1]Means followed by the same letter are not significantly different ($p \leq .05$).

These results indicate that Fraser fir from lower elevation seed sources have faster growth. It is anticipated that the height growth advantage of the lower elevation sources will be even more important at market time (about age 8) because tree value is determined by height and grade.

The intensive culture studies are designed to evaluate the impacts of rapid tree growth on genetic variance estimates. Buckeye's planting near Americus, Ga. typifies the growth after 1.5 years.

SEED ORCHARD PRODUCTION

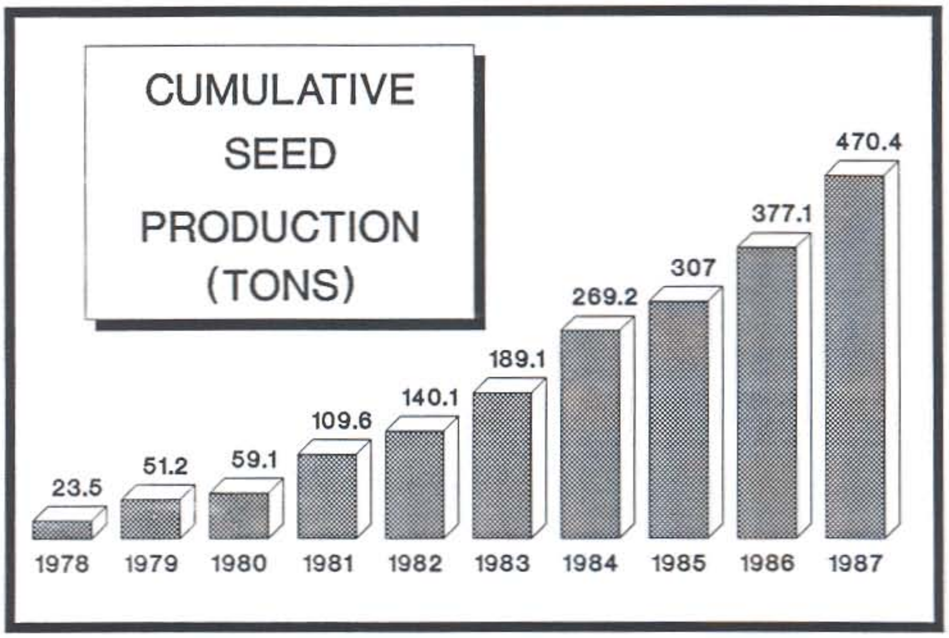
Cone and Seed Yields

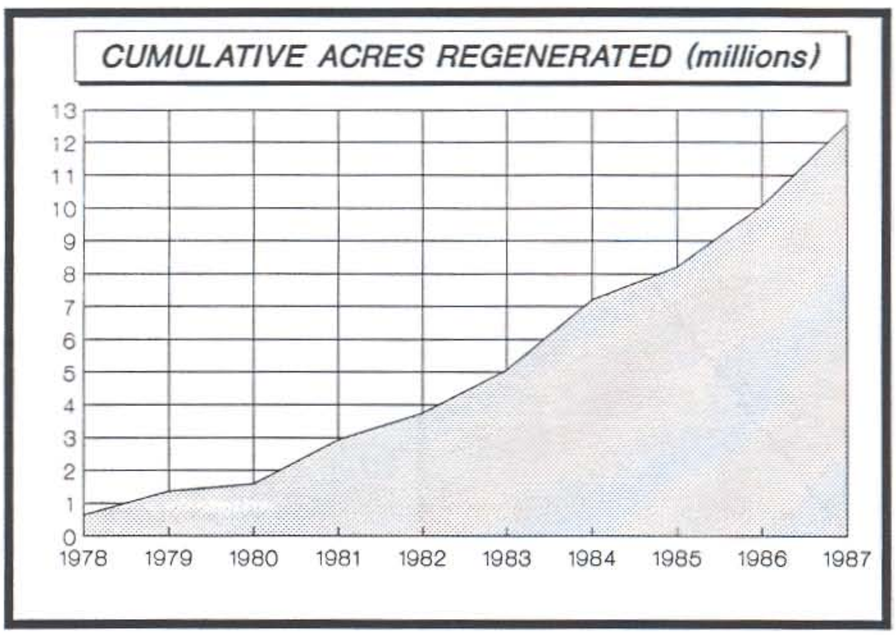
The 1987 harvest of cones and seeds from loblolly pine orchards was the largest in program history (Table 11). Over 112,000 bushels of cones were harvested from which 93.3 tons of genetically improved seeds were extracted. This harvest is sufficient to produce an estimated 1.49 billion plantable seedlings, twice the annual seedling needs (700 million) of the Cooperative membership. If all of these seedlings were used in regeneration programs, approximately 2.5 million acres could be planted with genetically improved loblolly pine.

The cumulative production profile depicted on the following page illustrates that Cooperative program members are impacting the forests of the South, and the nation in a major way through planting genetically improved loblolly pine.

Table 11. Production of cones, seeds and seedlings from Cooperative members' loblolly pine seed orchards over the last 10 years, including an estimate of acres that could be regenerated with improved seedlings if all seed were used.

Harvest Year	Bushels of Cones	Tons of Seeds	Millions of Seedlings	Millions of Acres Regenerated
1978	37,977	23.5	376	0.63
1979	38,693	27.7	443	0.74
1980	15,296	7.9	127	0.22
1981	64,811	50.5	808	1.35
1982	44,761	30.5	488	0.81
1983	68,447	49.0	784	1.31
1984	105,239	80.1	1,281	2.14
1985	52,155	37.8	605	1.01
1986	84,953	70.1	1,122	1.87
1987	112,822	93.3	1,494	2.50
Totals	625,154	470.5	7,528	12.61


CUMULATIVE
SEED
PRODUCTION
(TONS)
23.5
51.2
59.1
109.6
140.1
189.1
269.2
307
377.1
470.4
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987


CUMULATIVE ACRES REGENERATED (millions)
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987

Cooperative members have enjoyed outstanding seed crops in nine of the last ten years; only in 1980 was the harvest poor. This is a track record of consistent and high production that has had a positive impact on the tree improvement programs of individual members. The top executives that evaluate forestry operations and approve program budgets may not be conversant in the technical complexities of genetic improvement, but they do realize that without seed production success, the very best selection, breeding, and testing program has minimal value.

Our outstanding seed production has been realized as a direct result of seed orchard research and development that has been possible because of the participation and support of the entire membership. Individually members have committed their resources to properly implement the management techniques derived from this research. Cooperative research focused on high priority needs, rapid technology, and timely commitment of sufficient resources for effective implementation are strengths of the Cooperative Program.

In Table 12, the 1987 cone and seed harvest statistics are contrasted with those of 1986 for several conifer species of interest. Seed yields from first generation loblolly pine orchards increased an average of 32 percent over last year's levels. An extrememly heavy harvest of slash pine seed produced over four times the amount harvested in 1986. In 1987 the pounds of slash pine seed produced per bushel of cones (1.39) may be an all time high for this species. An excellent harvest of longleaf pine cones and seed resulted in nearly a four fold increase over last year. Cone and seed harvests for Virginia and white pine were down substantially compared

Table 12. Cone and seed yield comparisons for 1987 and 1986.

	Bushels of Cones		Pounds of Seeds		Pounds of Seed per Bushel of Cones	
Species	1987	1986	1987	1986	1987	1986
Loblolly Pine:						
Coastal 1.0 gen.	66,601	54,075	111,633	90,363	1.68	1.67
Piedmont 1.0 gen.	32,139	21.412	54,599	35,335	1.70	1.65
Coastal 2.0 gen.	10,010	6,594	14,781	10,136	1.48	1.54
Piedmont 2.0 gen.	4,072	2,872	5,687	4,425	1.40	1.54
Slash Pine	24,689	8,460	34,390	7,651	1.39	0.90
Longleaf	8,288	2,111	9,210	2,444	1.11	1.16
Virginia	200	462	210	376	1.05	0.81
White Pine	300	3,557	50	2,294	0.17	0.64
Fraser Fir	260	144	740	389	2.85	2.70
Totals	146,559	99,687	231,300	153,413		

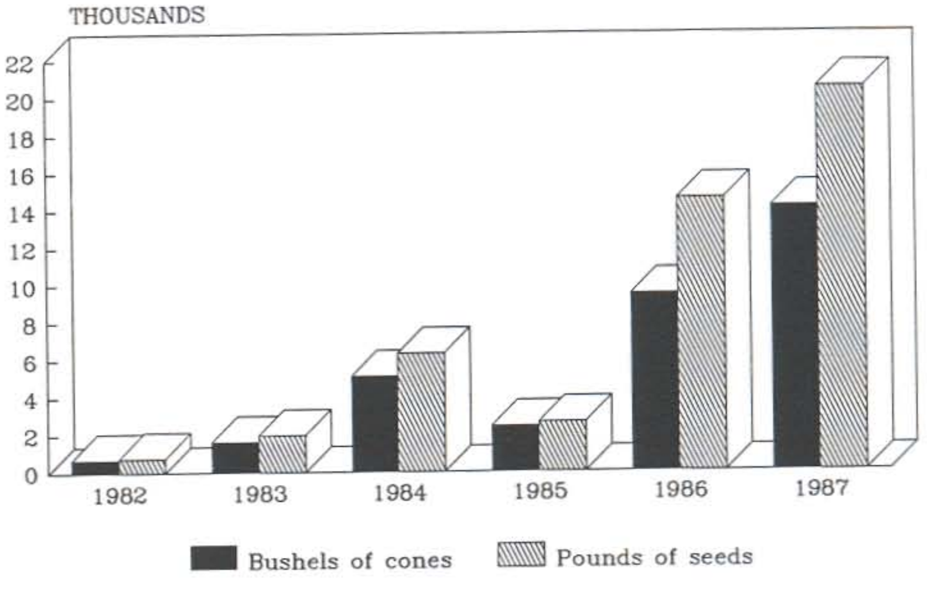
to the previous year, while the Fraser fir seed production by the North Carolina Forest Service was nearly twice the 1986 harvest. All three of these species have wide use in the rapidly expanding Christmas tree industry. The total harvest of conifer cones increased 47%, and the total seed produced was up 51% over the 1986 crop.

The N. C. Forest Service had excellent grafting success (79%) with longleaf pine in 1987. Grafting onto vigorous rootstocks (top) in a nursery bed seemed to do the trick. Transplanting to the seed orchard (bottom) went well this winter.

Second-Generation Orchard Yields

Second-generation loblolly pine seed orchards produced 49 percent more cones and 41 percent more seed in 1987 than the previous best year, 1986. This reflects the ingrowth of many young second-generation orchard acres to full production status. In 1987, more than 10 tons of second-generation seed were harvested representing approximately 11 percent of the total 1987 loblolly pine seed harvest. The rapid increase in annual second-generation seed orchard production is evident in the chart shown below. In the last six years, second-generation orchards have produced enough seed to grow 370 million seedlings and to regenerate 620 thousand acres of highly productive plantations.

SECOND GENERATION
SEED ORCHARD YIELDS



Production Leaders

It is a pleasure to once again recognize those programs and orchard managers who set standards for excellence in seed production. Orchard production measured in terms of pounds of seed per acre is the most informative statistic. However, we continue to have interest in seed yield per bushel since this reflects seed orchard efficiency. In the last year there were nine seed orchards in the Cooperative that exceeded two pounds of loblolly seed per bushel of cones. Congratulations are extended to the seven seed orchard managers who made the "two pound honor roll" in 1987. The orchards exceeding the two pound production efficiency level and their yield statistics are listed in Table 13 below.

Table 13. Seed orchards exceeding two pounds of seed per bushel of cones harvested in 1987.

Cooperator	Orchard Type	Generation	Acres	Age	Lbs./Bu.
Champion(NC)	Coastal	1.0	21	25	2.54
N. C. Forest Service	Coastal	2.0	10	6	2.49
Weyerhaeuser(NC)	Piedmont	1.0	11	26	2.37
Champion(NC)	Piedmont	2M5	32	36	3M43
EM AM Armm. of For.	Coastal	1.0	31	20	2.24
Int. Paper Co.(SC)	Piedmont	1.0	9	20	2.11
Weyerhaeuser(NC)	North Coastal	1.0	33	27	2.10
Federal	Piedmont	1.0	9	27	2.07
Westvaco(SC)	Coastal	1.0	38	21	2.03

The best yield in the Cooperative for 1987 was Champion International's first generation coastal orchard under the capable management of Marc Davison. This 21 acre, 25 year-old orchard located in Tillery, North Carolina produced 1239 bushels of cones from which 3150 pounds of seed were extracted. This sets a new Cooperative record of 2.54 pounds of seed per bushel of cones. Marc had previously held the record (1985 and before) but was beaten in 1986 by Marvin Cribb of International Paper Company. It appears that Marc enjoys first place since he quickly set a new record for pounds of seed per bushel of cones. Congratulations to Marc and Champion International. Surpassing the previous record of 2.42 pounds per bushel, and ranking a close second this year at 2.49 pounds per bushel, was the very young North Carolina Forest Service coastal second-generation orchard managed by Gene Turner. Congratulations to Gene and the North Carolina Forest Service for their excellence.

Congratulations are also extended to International Paper Company (Marvin Cribb), South Carolina Commission of Forestry (Booth Chilcutt), Westvaco (Dave Gerwig) and Weyerhaeuser-N.C. (Gary Oppenheimer) for making the two pound honor roll for the second straight year with one or more of their seed orchards. Weyerhaeuser-N.C and Champion-N.C. are noted for each having two orchards on the honor roll. Finally we congratulate Federal Paper Board for making the two pound honor roll with their Piedmont first generation orchards. This orchard is managed by David Sparkman and Maxie Maynor.

Effective orchard management practices implemented in a timely fashion have allowed Cooperative members to realize production efficiences that were previously a rare event. Congratulations to all the Cooperative's production leaders.

SELECTION, BREEDING AND TESTING

A major focus of the Cooperative continues to be the breeding and testing of plantation selections and second generation selections. The 3300 plantation selections are being bred in approximately 550 six-parent disconnected half diallels that will be planted in 1100 progeny tests. A total of 720 second generation selections are being bred in 120 six-parent disconnected half diallels that will be planted in 240 progeny tests. A total of over 4000 selections are being bred in 670 diallels to be planted in 1340 individual tests. This is indeed a major undertaking!

Each Cooperative member has made a substantial commitment to this huge task. It is one example of true cooperation that exemplifies the benefits of the Cooperative. Cost sharing among members in the breeding and testing work facilitates the development of a very broad and diverse genetic base while at the same time sustaining a high level of genetic resource development intensity.

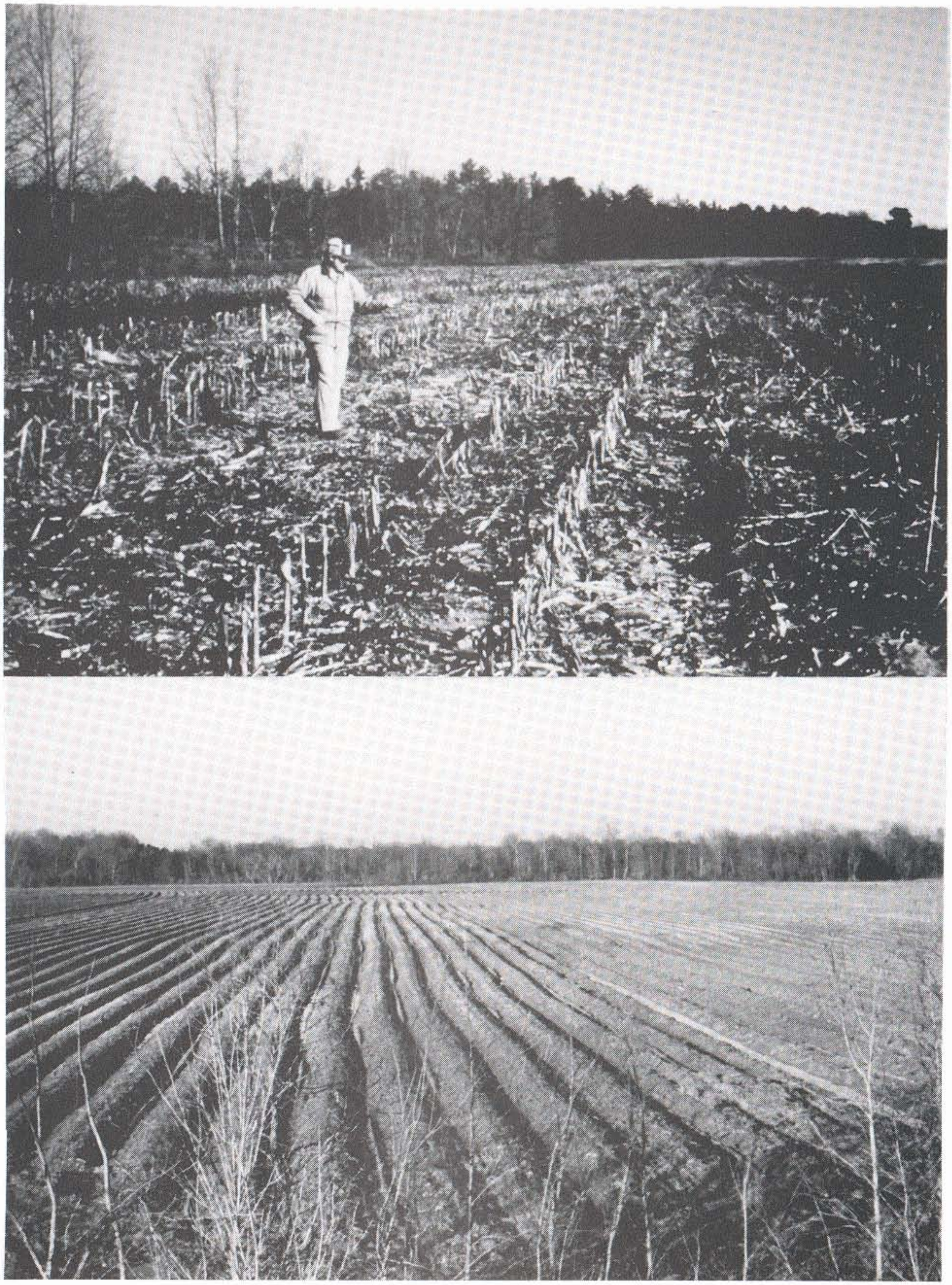
During the 1988 spring pollination season, excellent progress continued to be made. Numerous Cooperators completed the breeding work for plantation diallels. An example of this excellent progress was highlighted in a recent report from Bill Guinness. Bill noted that "after the 1988 cone harvest 86% of their crosses should have 300 or more seed stored and ready for progeny test planting. This includes all 36 plantation diallels that Catawba and Hiwassee are breeding". We have estimated that nearly 150 advanced generation progeny tests have been successfully planted through the spring of 1988. This represents 11% of the total testing work load. In the next three years the focus will shift from breeding to testing, as we anticipate a dramatic increase in annual test establishment work.

Outdoor containerized grafts have proven very successful even at the northern fringe of the loblolly range. Mike Harbin with Chesapeake Corp. in Va. inventories conelets from recent pollinations.

Numerous reports of individual members progress in the breeding work were made during the last year, at the advisory meeting, contact meeting, two short courses, during visits with individual members. In these reports the breeding progress of the Cooperative as a whole was rated outstanding. However, it was apparent that a few member units (six of 41) for varied reasons had experienced difficulty in making satisfactory progress. The Cooperative staff has worked closely with these members during the last year and extraordinary effort has been put forth by each of these members. The results of this effort are reported in Table 14. Outstanding progress was made for the most part despite sporadic flower production throughout the Southeast this spring. We remain optimistic that with a good flower crop in the next year or two that all members will be able to meet their breeding and testing obligation on schedule.

Table 14. Breeding progress in 1988 for members applying extra effort to meet the program schedules.

Organization	Area	% Complete Thru 1987	Accomplished in 1988	% Complete Thru 1988
Champion NC	Piedmont	32%	28%	60%
	Coastal	28	32	60
N. C. F. S.	Piedmont	70	20	90
	Coastal	35	55	90
Federal	Piedmont	26	29	55
	Coastal	26	19	45
S.C. Comm. of For.	Piedmont	36	39	75
	Coastal	16	24	40
Champion S. C.	Piedmont	26	54	80
Champion Ala	Piedmont	18	26	44



Even in the Piedmont excellent, uniform progeny test sites can be found as illustrated by these sites on Catawba's (top) and Hiwassee's land (bottom).

ASSOCIATED ACTIVITIES

Graduate Student Research and Education

The education of graduate students and the research they conduct as part of their degree program continues to be an important activity of the Cooperative. During the past year, 12 graduate student programs have been conducted in association with the Tree Improvement Cooperative. Eight were directed toward Masters degrees and four were involved in Ph.D programs. Of special note is the completion of degree programs by three students in 1987-1988: Claudio Balocchi, Ruy Lima and Ray Moody.

The graduate students working in association with the Cooperative, the degree to which each aspires and the subject of their research project are listed on the following page. Student research projects encompass a wide range of subject matter related to tree improvement. Financial support for students comes from a variety of sources -- The Tree Improvement Cooperative, the College of Forest Resources - Department of Forestry, the North Carolina State University Agricultural Research Service, The U. S. Forest Service, various fellowship programs and foreign governments.

The number of very qualified applicants for admission to graduate studies in tree improvement continues to be high. During the last year we admitted 11 students. It is anticipated that only six new students will actually enroll during the fall, the others will not attend in most cases because financial support was not offered. A substantial number of applicants to our graduate studies program are from foreign nations. This results from two primary factors, 1) the employment opportunities for domestic graduate students are few and 2) the strong international recognition of our tree breeding research and development success.

Student	Degree	Research Project
Roger Arnold	Masters	An evaluation of the DRIS approach for identifying mineral nutrient limitations on flowering and cone production in Fraser fir
Claudio Balocchi	Masters	Efficiency of genetic test designs for Pinus radiata in Chile - completed 1987.
Claudio Balocchi	Ph.D.	Evaluation of breeding strategies for Pinus radiata in Chile
Ann Margaret Hughs	Masters	Seed quality studies in Fraser fir
Ruy Lima	Masters	Family stability for wood properties of Pinus oocarpa - completed 1987
Mary Frances Mahalovich	Ph.D.	Modeling the genetic consequences of positive assortative mating
Ray Moody	Masters	Pollen vigor studies - completed 1987
Bailian Li	Ph.D.	Genetic variation of nitrogen use in loblolly pine
Yecai Liu	Masters	Undecided (New student)
David Porterfield	Masters	An evaluation of interspecific hybrids of P. clausa x P. virginiiana and P. rigida x P. clausa
Jim Richmond	Ph.D.	Genetic variation among populations of pine cone worms
Lan Zheng	Masters	The stability of wood specific gravity of loblolly pine in diverse geographic areas

Tree Improvement Shortcourses

In August and January the program staff conducted two tree improvement shortcourses for the benefit of member personnel. The second course was needed because the demand for attendance far exceeded our initial expectations. A total of 75 people from 21 member organizations participated in the two courses, each of which was conducted over a four-day period. The positive feedback received from attendees indicated that the courses were effectively focused on priority activities of the Cooperative Program. Topics covered in each of the shortcourses are listed below:

GENETICS

- Genetic Basis for Tree Improvement
- Selection and Genetic Gain
- Mating Designs and Breeding Strategies
- Emerging Technologies

BREEDING

- Cooperative's Breeding Schedule and Progress
- Flower Stimulation
- Pollen Handling
- Control Pollination

TESTING

- Growing Containerized Seedlings
- Progeny Test Site Selection
- Progeny Test Design, Layout and Establishment
- Progeny Test Maintenance
- Progeny Test Measurement
- Selection in Progeny Tests

SEED ORCHARDS

- Seed Orchard Establishment
- Seed Orchard Management
- Cone and Seed Harvest
- Seed Orchard Roguing

We especially want to express our gratitude to Bill Guinness and Jake Clark of Catawba Timber Company and to Dave Gerwig and his staff from Westvaco for hosting field workshops as part of these shortcourses. They were very well done and contributed substantially to the success of the effort.

During the past year program staff members also taught selected sessions in two other shortcourses held at N. C. State University. One was a genetics shortcourse for U. S. Forest Service seed orchard managers. The second was a shortcourse on fast grown plantations for the tropics and subtropics conducted by the department of forestry at N. C. State University. Approximately 50 people attended these two shortcourses.

Program Staff

Cooperative program staff members and their primary responsibilities are depicted in the organizational chart on the following page. The Cooperative staff work full time on Cooperative activities, except for limited teaching commitments by Drs. J. B. Jett and Steve McKeand; Mr. Charles Echerd has split responsibility as a research technician with the Tree Improvement Cooperative and the Tissue Culture Research Program. Not shown on the organization chart are the following associated appointments:

Dr. Floyd Bridgwater - U. S. Forest Service Research
Dr. John Frampton - Tissue Culture Program
Dr. Bruce Zobel - Professor Emeritus

During the last year, one change in the program staff occurred. Judy Stallings resigned to accept employment with a new industrially supported textiles program on campus. Judy has been replaced by Ms. Jean Pittman. Jean was a secretary with North Carolina State University's Sociology and Anthropology Department for five years. We are pleased to welcome Jean to the program.

COOPERATIVE TREE IMPROVEMENT PROGRAM
ORGANIZATIONAL CHART - MAY, 1988

DR. ROBERT J. WEIR
DIRECTOR

DR. J. B. JETT
ASSOCIATE DIRECTOR

- MR. VERNON JOHNSON
  AGRI. RES. TECH. II
- MS. ADDIE BYRD
  RESEARCH TECHNICIAN II
- MR. CHARLES ECHERD
  AGRI. RES. TECH. I
  (1/2 TIME)

Activities:

-Seed Orchard research and operations

-Lab. and field research and management

DR. STEVEN E. MCKEAND
GENETICIST

- MR. JERRY SPRAGUE
  TREE IMP. SPECIALIST
  (1/2 TIME)

Activities:

-Breeding and testing research and development

MS. ALICE V. HATCHER
MANAGER, INFO. SYSTEMS

- MR. JERRY SPRAGUE
  D.P. SPECIALIST
  (1/2 TIME)
- MS. JEAN PITTMAN
  SECRETARY IV
- MS. JACKIE EVANS
  SECRETARY
  (HOURLY)

Activities:

-Data Processing

-Office Management

-Budget Management

MEMBERSHIP OF THE TREE IMPROVEMENT COOPERATIVE

Organization	States Where Operating
Alabama Forestry Commission	Ala.
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 Corp.	Alabama Region--Ala., Tenn., Miss. East Carolina Region--N.C., Va. West Carolina Region--S.C., N.C., Ga. Florida Region--Ala., Fla., Ga.
Chesapeake Corporation of Virginia	Va., Md., N.C.
Container Corporation of America	Brewton--Ala., Fla. Fernandina Beach--Fla., Ga.
Federal Paper Board Co., Inc.	N.C., S.C.
Mead Paper Board Company	Ga., Ala.
Georgia Forestry Commission	Ga.
Georgia-Pacific Corporation	Northern Region--Va., N.C. Southern Region--S.C., Ga.
Great Southern Paper Company	Ga., Ala., Fla.
James River Corporation	Ala., Miss.
International Forest Seed Company	Miss., Ala., Fla., Ga., S.C.
International Paper Company	Atlantic Region--N.C., S.C., Ga. Gulf Region--Miss., Ala.
Kimberly-Clark Corporation	Ala.
Leaf River Forest Products Co.	Ala., Miss.
MacMillan-Bloedel Corporation	Ala., Miss.
N. C. Divison of Forest Resources	N.C.

Organization	States Where Operating
Packaging Corporation of America	Tenn., Ala., Miss.
Rayonier, Inc.	Fla., Ga., S.C.
Scott Paper Company	Ala., Fla., Miss.
South Carolina State Commission of Forestry	S.C.
Union Camp Corporation	Savannah Div.--Ga., S.C., Franklin Div.--N.C., Va. Alabama Div.--Ala.
Virginia Department of Forestry	Va.
Westvaco Corporation	South--S.C. North--Va., W.Va.
Weyerhaeuser Company	N.C. Region--N.C., Va. Miss. Region--Miss., Ala.

Membership in the Tree Improvement Cooperative now totals 28 organizations. The 28 member organizations operate 28 base units and 11 supplemental units for a total of 40 active tree improvement programs. During the last year, Continental Forest Investments terminated their tree improvement work. They have sold their forest land, sold the nursery and lastly closed the door and turned out the lights on tree improvement. While other programs have been absorbed through merger and acquisition this is the first member in thirty-two years to actually leave the program. We were pleased however to welcome the Georgia Forestry Commission to membership in the Cooperative effective July 1, 1987. The Georgia Forestry Commission annually grows 100 million loblolly seedlings in their nurseries. It is clear that their future success in tree improvement in association with the Cooperative will have a substantial impact on forest productivity in Georgia.

A final change in membership worthy of note is the break up of Georgia Kraft. We are happy to welcome Mead Corporation to the Cooperative. In a sense they have always been a member since Mead owned 50% of Georgia Kraft. However with the break up of the shared ownership arrangement, Mead takes over the tree improvement program and nurseries along with a land base of approximately 500 thousand acres. Following this change all Georgia-Kraft employees working with the Cooperative are in place with Mead so the transition has been smooth and progress continues uninterrupted.

PUBLICATIONS OF SPECIAL INTEREST TO MEMBERS OF THE COOPERATIVE

Amerson, H. V., L. J. Frampton, Jr., R. L. Mott, and P. C. Spaine. 1988. Tissue culture of conifers using loblolly pine as a model. pp. 117-137. In: J. Hanover and D. Keathley (eds.) Genetic manipulation of woody plants. Plenum Press, New York.

Bramlett, D. L. and F. E. Bridgwater. 1987. Effect of a clonal row design on the seed yields of loblolly pine. In: Proceedings of the 19th S. For. Tree Improvement Conf., College Station, Texas, June 16-18, 1987. pp. 253-260.

Bridgwater, F. E. 1987. Tree Improvements, silviculture and forest management interactions in loblolly and slash pines and their potential use in young tree improvement programs. In: Proceedings of Simposio Sobre Silviculture Y Mejoramiento Genetico De Especies Forestales, Buenos Aires, Argentina, April 6-10, 1987. Sponsored by Centro De Investigaciones Y Experiencias Forestales, Tomo III, pp. 1-9.

Bridgwater, F. E., D. L. Bramlett, and F. R. Matthews. 1987. Supplemental mass pollination is feasible on an operational scale. In: Proc. of the 19th S. For. Tree Improvement Conf., College Station, Texas, June 16-18, 1987. pp. 216-222.

Bramlett, D. L. and F. E. Bridgwater. 1986. Segregation of recessive embroyonic lethal alleles in a F_1 population of Virginia pine. pp. 401-409. In: IUFRO Conf. Joint Mtg. of Working Parties on Breeding Theory, Progeny Testing and Seed Orchard. Williamsburg, Va.

Bridgwater, F. E. and F. T. Ledig. 1986. Selecting for super trees. J. For. 84:53-56.

Bridgwater, F. E. and A. E. Squillace. 1986. Selection indexes for forest trees. p. 17-20. In: Southern Coop. Ser. Bull. No. 309. Advanced Generation Breeding of Forest Trees. Proc. of a Workshop on Advanced Generation Breeding. Current Status and Research Needs, June 6-7, 1984. Baton Rouge, LA.

Bridgwater, F. E. and C. G. Williams. 1986. Early testing and juvenile selection in loblolly pine. Proc. of the 30th N.E. For. Tree Impr. Conf., July 22-24, 1986, Univ. of Maine, Orono. (In press).

Brown, S. D. and F. E. Bridgwater. 1987. Observations on pollination in loblolly pine. Can. J. For. Res., 17:299-303.

Foster, G. S. and F. E. Bridgwater. 1986. Genetic analysis of fifth-year data from a seventeen parent partial diallel of loblolly pine. Silvae Genetica 35:118-122.

Frampton, L. J., Jr. 1986. Field performance of loblolly pine tissue culture plantlets. pp. 547-553. In: Proc. IUFRO Conf. Joint Mtg. of Working Parties on Breeding Theory, Progeny Testing and Seed Orchard. Williamsburg, Va.

Sniezko, R. A. and B. J. Zobel. 1986. Seedling height and diameter variation of various degrees of inbred and outcross progenies of loblolly pine. Silvae Genetica (In press).

Struve, D. K., J. B. Jett, and D. L. Bramlett. 1986. Production and harvest influences on woody plant seed germination. In: Proc. XXII International Hort. Congress, 83rd Annual Meeting of the Amer. Soc. Hort. Sci., August 10-18, Univ. California, Davis.

van Buijtenen, J. P. and F. E. Bridgwater. 1986. Mating and genetic test designs. p. 5-10. In: Southern Coop. Ser. Bull. No. 309. Advanced Generation Breeding of Forest Trees. Proc. of a Workshop on Advanced Generation Breeding. Current Status and Research Needs, June 6-7, 1984. Baton Rouge, La.

Weir, R. J. and R. E. Goddard. 1986. Advanced generation operational breeding programs for loblolly and slash pine. p. 21-26. In: Southern Coop. Ser. Bull. No. 309. Advanced Generation Breeding of Forest Trees. Proc. of a Workshop on Advanced Generation Breeding. Current Status and Research Needs, June 6-7, 1984. Baton Rouge, La.

Williams, C. G. 1987. The influence of shoot ontogeny on juvenile-mature correlations in loblolly pine. For. Sci. 33:411-422.

Wisniewski, L. A. 1987. The effect of cytokinins and root system parameters on the maturation of loblolly pine. Ph.D. Thesis, N. C. State Univ., Raleigh, NC. 91 p.

Wisniewski, L. A., L. J. Frampton, Jr., and S. E. McKeand. 1986. Early shoot and root quality effects on nursery and field development of tissue cultured loblolly pine. HortScience 21:1185-1186.

Wisniewski, L. A., S. E. McKeand and H. V. Amerson. 1987. The effect of root pruning on the maturation of loblolly pine (Pinus taeda) tissue culture plantlets. Abstr. for Amer. Soc. Plant Phys. Ann. Mtg. (In press).

Zobel, B. J. 1986. Advances in forestry in South America and their effect on competition with the southern United States. Tappi 69:34-36.

Zobel, B. J. 1987. Forestry in the developing countries - an overview. Bei Jie, Beejeing, China, Sci. and Tech. Review. 4 p.

Zobel, B. J., G. van Wyk, and P. Stahl. 1987. Growing exotic forests. John Wiley & Sons, NY. 508485 p.