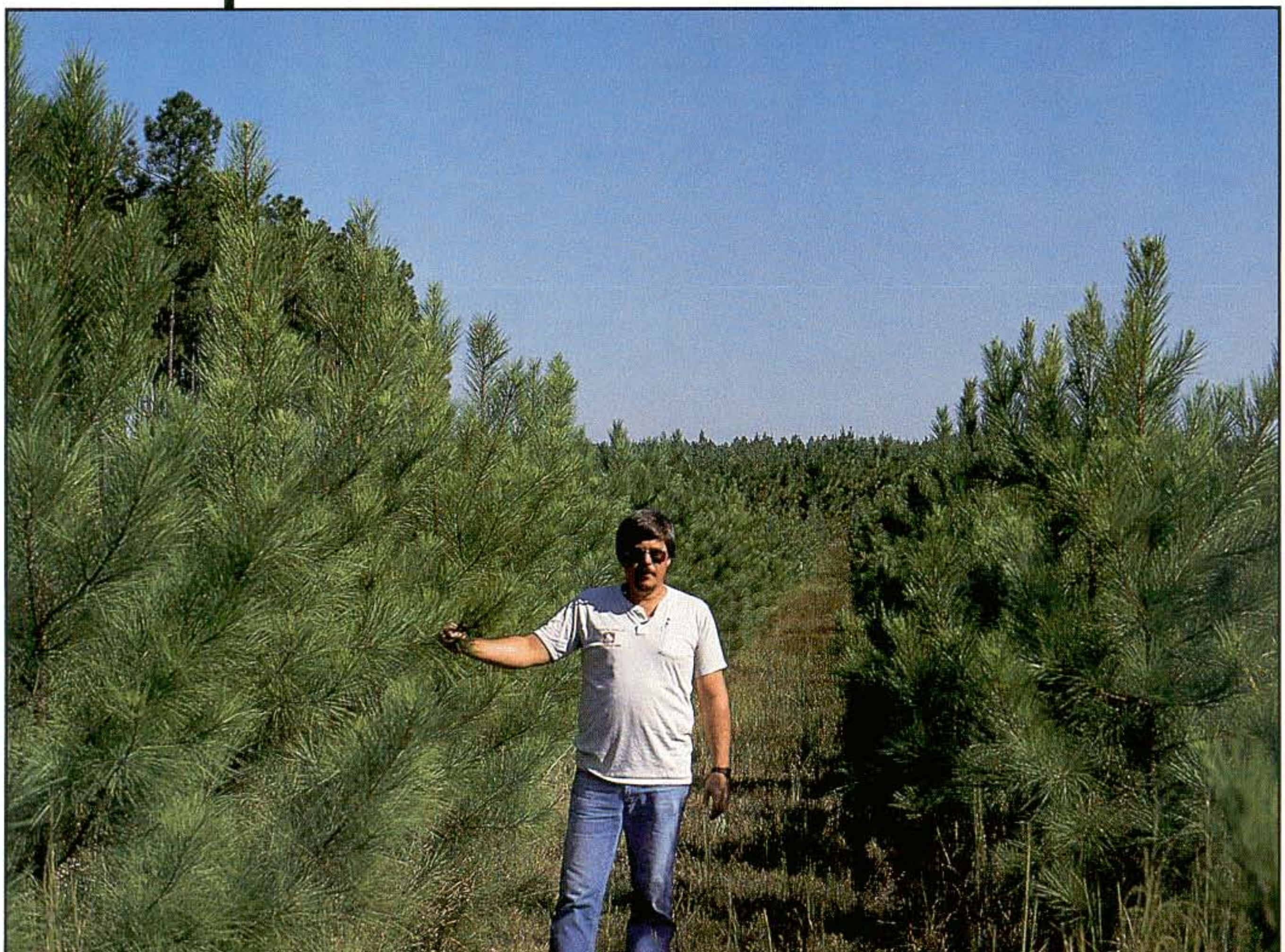
NORTH CAROLINA STATE UNIVERSITY
INDUSTRY COOPERATIVE TREE IMPROVEMENT PROGRAM



College of Forest Resources
N.C. State University
Raleigh, North Carolina

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EXECUTIVE SUMMARY

Two important research projects were initiated by the Cooperative this past year:

* Graduate student Jorge Vasquez, working jointly with the N. C. State University Forest Nutrition Cooperative and the Tree Improvement Cooperative, is investigating the variation in foliar nutrient concentration among families and provenances of loblolly pine. Results are expected in late 1992.

* Graduate student Kevin Harding is investigating age trends in the genetic parameters of wood properites for 26- to 28-year-old loblolly pine from the Heritability Study. Field sampling work was completed in the spring of 1992; sample preparation and x-ray densitometric scanning will commence in early summer.

Progress reports for research:

* Age three results from the Piedmont loblolly Inbreeding Study indicate that inbreeding results in reduced growth and that a significant interaction exists between clones and inbreeding levels. Age 6 measurements are scheduled for 1994.

* In a preliminary analysis of the Early Diallel Measurement Study, a majority of the diallels show a decrease in heritability at age two followed by an increase at age three.

Breeding and testing of the Cooperative's nearly 4000 plantation and second generation selections is quickly coming to a close. Currently, 90% of the crossing and 40% of the plantings are complete. Wrap up plans for this cycle of breeding are scheduled for this summer.

The Cooperative's loblolly pine seed orchards recorded a moderate seed crop in the fall of 1991.

* Cooperators harvested 38.8 tons of seed, a 27% increase over the previous year.

* Second generation orchard collection was a record high 12 tons of seed, almost one third of the total loblolly collection for 1991.

* For the first time, average lbs./bushel yield for the second generation orchards equaled that of the first generation.

* For the first time in years, not a single orchard achieved a yield of 2.0 lbs./bushel. However, several clones consistently seem to produce above the 2.0 mark.

The Seed Orchard Pest Management Committee (SFTIC) has accomplished much since its inception:

* The Furadan label has been revised to maintain the registration of Furadan for limited forestry use.

* Seed orchards have been reclassified from forestry to terrestrial non-food crops.

* A regional Cooperative study to evaluate the efficacy of Capture in seedbug control in loblolly and slash pine seed orchards has been completed. Results indicate that Capture effectively controls cone and seed insects. Hopefully, this will result in registration of Capture for seed orchard use.

Through joint efforts of the forest products industry and N.C. State University, a loblolly and slash pine rooted cutting project was initiated in January, 1992. Research will be focused in five primary areas of investigation to provide a better understanding of adventitious root initiation and development, and to hopefully refine a useful rooted cutting technology that will allow the full potential of clonal forestry to be realized.

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INTRODUCTION

The North Carolina State University - Industry Cooperative Tree Improvement Program has completed 36 years of continuous operation. With a firm foundation in cooperation, the member organizations and the University have, in partnership, sustained forest genetics research and development programs at over 40 regional centers in eight southeastern states. **Work conducted at the University and at each of the tree improvement centers has made a remarkable impact on forest productivity in the region.** The cumulative investment in genetic improvement over the 36 years exceeds 75 million dollars, and the additional wood and higher quality raw material produced from this investment is estimated to exceed 1.5 billion dollars of marginal present value in the standing forests of the region.

Despite this accomplishment, the potential for additional genetic improvement in the future is strong. We have only begun the process of "domesticating" loblolly pine for plantation forests. Multiple recurrent cycles of selection, breeding, and testing are on the horizon and offer substantial opportunity for additional value improvement to be derived from improving growth rate, pest tolerance, tree and stand quality, and overall environmental adaptability.

It becomes a significant challenge to maintain our momentum amidst conflicting business and societal pressures on the forestry enterprise. Changes such as increased recycling, environmental awareness, and foreign competition, are on balance desirable and will in the long run improve the world in which we live. Yet change is often a challenge to accommodate, particularly for a research and development program that is sensitive to the competition for scarce economic resources during these dynamic times. To prosper in this climate of change we must conduct effective planning for the future while maintaining the level of accomplishment from current activities. We are doing this.

Members of the program have intensified their efforts in breeding and testing and will soon wrap up the current work that provides the foundation for third cycle seed orchards. Second cycle orchards have produced the largest seed crop in their history, thus enhancing the productivity and value of plantations now being established. Research work has intensified and results becoming available will guide the resource development work for several decades into the future.

Very important to our future success has been the intense planning work completed during the past year. We have revised the Strategic Plan for the Cooperative. This document provides a comprehensive discussion of our current research and development work and provides the focus for work in the next three to five year period. Critical to our future is the completion of the Cooperative's Third Cycle Breeding Strategy. The breeding strategy, to be presented at the Advisory Committee Meeting, provides a means to increase benefits and lower costs in future generations. The management of a hierarchy of breeding populations is a key element of the proposed future strategy. Elite populations will be utilized to maximize short term gain, a Mainline Population will allow continued improvement for many cycles, while Genetic Diversity Archives will allow us to respond constructively to the uncertainties of the very distant future. Together these planning activities provide a strong basis for future development. Our future is promising, our effort is substantial, and we are eager to get on with the task of continued genetic improvement of loblolly pine.

RESEARCH

During the past year, two research studies were initiated by graduate students, preliminary results of two Cooperative research studies were obtained and a major research project on rooted cuttings was initiated in close alliance with the Cooperative. Jorge Vasquez is investigating the variation in foliar nutrient concentration among families and provenances of loblolly pine for his Master's Thesis. Kevin Harding's dissertation will consist of an investigation of age trends in genetic parameters of wood properties. Three year results are reported from the Piedmont Loblolly Inbreeding Study. Preliminary results from the Early Diallel Measurement Study are presented. The Rooted Cutting Project, and its association with the Cooperative, is briefly described.

AGE TRENDS FOR GENETIC PARAMETERS OF WOOD PROPERTIES OF 26- TO 28-YEAR-OLD LOBLOLLY PINE

Graduate student Kevin Harding has undertaken an investigation of age trends in the genetic parameters of wood properties. Key objectives of the project will be:

(1) To determine the extent of juvenile/mature correlation between early age assessments of wood properties.

(2) To develop a reliable method of identifying the transition age between juvenile and mature wood properties using x-ray densitometric techniques.

(3) To establish the extent of genetic variation in the age of transition and its genetic correlation with other important traits.

Full-sib families to be sampled will be from the control-pollinated plantings of the N. C. State University-International Paper Company Heritability Study established in 1963, 1964 and 1965 near Bainbridge, GA. Traits to be studied include a range of measurements of within and between growth ring specific gravity, earlywood/latewood percentages, juvenile/mature wood transition characteristics and mean juvenile/mature wood properties. Genotypic and phenotypic correlations among and between these traits and growth traits, as well as additive and dominance genetic variance components, will be estimated. A complete chronological history of the genetic relationships between several important growth and wood properties traits will be possible at the completion of this project. This investigation should provide loblolly pine breeders in the southern United States with a useful selection guide to optimize genetic gains for both wood and growth traits.

Field sampling work will be completed in the spring of 1992. Sample preparation and x-ray densitometric scanning will commence in the early summer of 1992.

FAMILY VARIATION IN FOLIAR NUTRIENT CONTENT

Graduate student, Jorge Vasquez, working jointly with the N. C. State University Forest Nutrition Cooperative and the Tree Improvement Cooperative, is investigating the variation in foliar nutrient concentration among families and provenances of loblolly pine. Fertilization of forest plantations has been used extensively to improve tree nutrition. To date, virtually all fertilizer prescriptions have been based upon average genotypic responses. However, there is a lack of information on how much genetic variation there is in foliar nutrition in older field trials or what impact this variation will have on actual prescriptions. The fact that provenances and families may respond differently to fertilization requires an understanding of the genotypic variation in order to apply optimal levels of nutrients according to the specific requirements of the genotypes, thus increasing the gains from individual family blocks.

Foliar nutrient concentration has been identified as an important diagnostic variable to predict growth responses to fertilization. The proposed research will help incorporate genetic information into fertilizer prescriptions for specific families.

The objectives of the study are:

(1) Determine the genetic variation in foliar macro- and micronutrient concentration and nutrient ratios in 10-year-old loblolly pines.

(2) Determine the relative contribution of provenance and family within provenance effects on nutrition as well as the genotype x nutrient interaction among different sites.

(3) Assess the impact of genetic variation on the critical levels of foliar nutrient concentrations used as diagnostic variables for fertilizer prescriptions in forest plantations.

Material for the study will be from four of the 1982 and 1983 Florida Loblolly Pine Provenance/Progeny Trials established by members of the Florida and N. C. State Tree Improvement Cooperatives. Families within provenance will be evaluated for the following sources: Marion County, Gulf Hammock, Southern Atlantic Coastal Plain, and Lower Gulf Coastal Plain. Foliar samples were collected from 52 total families in December and January with sample preparation and nutrient analysis following in the spring of 1992. Statistical analyses and completion of the project is targeted for late 1992.

PIEDMONT LOBLOLLY INBREEDING STUDY - AGE THREE RESULTS

The Piedmont Loblolly Inbreeding Study was established in five field trials in the spring of 1988. The trials were established by Bowater (SDW), Procter & Gamble, Bowater (CWD), Federal and S. C. Commission of Forestry. The Procter and Gamble trial was abandoned due to poor survival. The four remaining piedmont trials were measured in 1991 at age 3.

The objectives of the inbreeding study are:

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

(2) To characterize family differences in sensitivity to inbreeding.

Parents used in the study are all second generation selections. Four levels of inbreeding were created from matings among selfs (F=.50), full-sibs (F=.25), half-sibs (F=.125) and unrelated selections (F=0). For all matings, except selfs, parents were mated to two individuals to lessen the bias caused by the other parent in the cross.

In general, inbreeding in outcrossed species results in reduced growth and survival. This trend has also been reported in loblolly pine (Sniezko and Zobel, 1988). Age three results of the Piedmont Loblolly Inbreeding Study shows a significant reduction in growth from inbreeding, but shows minimal effects of inbreeding on survival. As can be seen from Table 1, selfs had only slightly lower survival than the other three inbreeding levels. Half-sib and full-sib matings showed no reduction in percent survival. Growth responses to inbreeding were, however, quite dramatic. Age 3 results indicate that for every .1 increase in the inbreeding coefficient (F value) there is, on average, a 5.5% reduction in height growth. Figure 1 graphically displays the actual growth response and the predicted growth response. An analysis of variance confirmed a significant difference in inbreeding levels at the .01 level. Perhaps of even

TABLE 1. Piedmont Loblolly Inbreeding Study Percent Survival - Age 3

Trial	Unrelated Matings (F=0)	Half-sib Matings (F=.125)	Full-sib Matings (F=.250)	Selfs (F=.50)
Hiwassee (SDW)	98.2	98.1	99.0	95.8
Catawba (CWD)	98.7	99.1	99.0	97.8
S. C. Comm. For.	96.8	96.8	97.4	91.3
Federal	97.7	95.7	96.4	94.1

Dramatic loss in vigor is displayed for a selfed family in South Carolina Commission of Forestry's planting of Inbreeding Study.

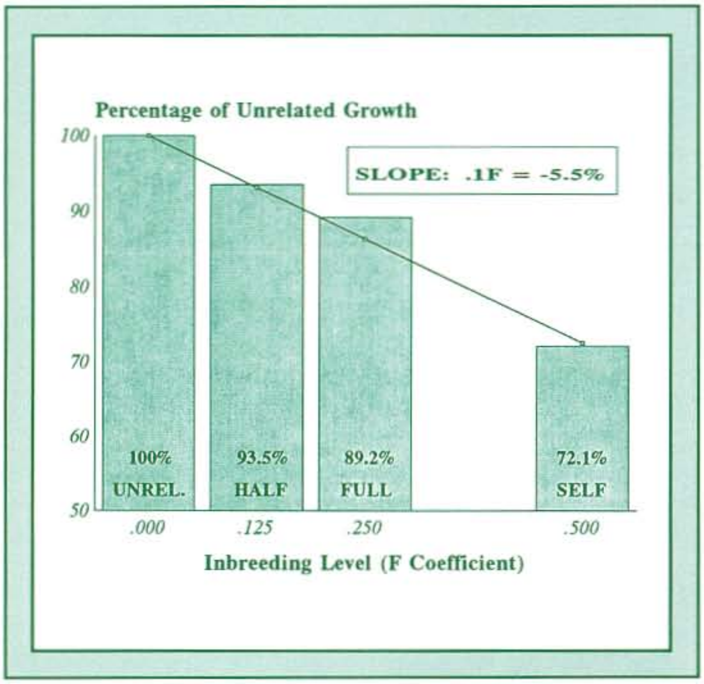


Figure 1. Relationship of growth performance to inbreeding level.

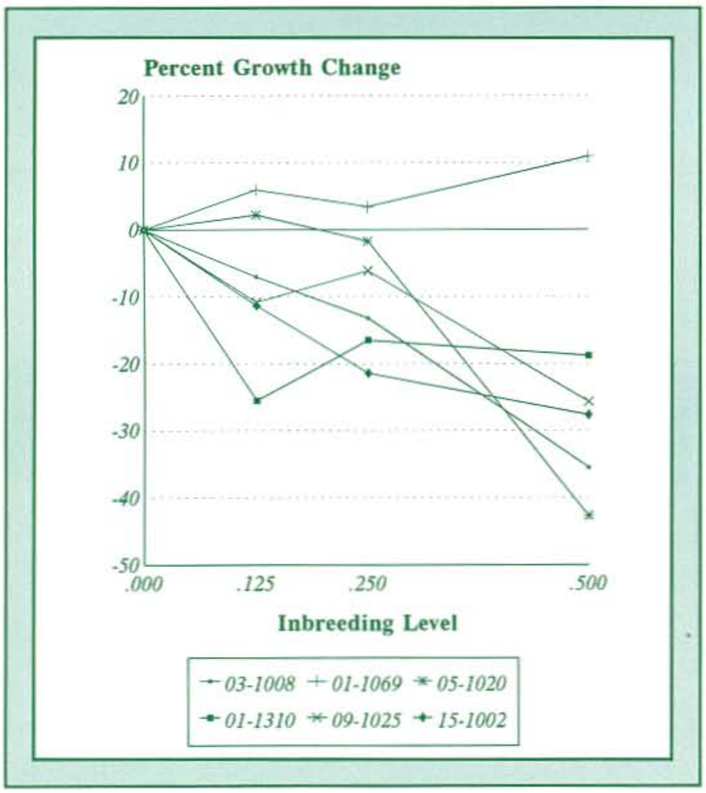


Figure 2. Growth response of six clones at three inbreeding levels.

greater concern was the significant interaction between clones and inbreeding levels. Figure 2 displays the response of six clones at each inbreeding level. It is obvious from this graphical display that specific clones respond quite differently to the three levels of inbreeding tested. Clone 3-1008 performed very close to the average predicted growth response. Clone 1-1069 showed a positive response to inbreeding at all three inbreeding levels. Clone 1-1310 performed very poorly at the least severe level of inbreeding (F=.125), but showed increased and relatively constant growth performance at higher inbreeding levels. Such significant interactions suggests that no general prescription could be made for use of related individuals in production seed orchards.

While the results are interesting and the trends perhaps indicative of later responses, it is much too early to assume the final answer. The inbreeding study will be remeasured at age six in 1994. The remeasurement should provide not only a more reliable estimate of growth responses to related matings and family differences in sensitivity to inbreeding, but should also provide an opportunity to examine growth response over time.

EARLY DIALLEL MEASUREMENT STUDY

The Early Diallel Measurement Study was initiated in 1986 with the following objectives:

(1) To determine changes in heritabilities and genetic parameters in young tests of loblolly pine.

(2) To determine the optimal age for single-stage and two-stage selection in advanced generation tests.

Three to five diallel test series in each of seven of the Cooperative's eight testing areas are to be included in the study. The inclusion of several test series in each area will provide information on any geographic pattern of variance component changes. Each test series included in the study will be measured annually through age eight and at specified intervals thereafter to rotation. Height, rust and survival will be assessed at all ages. Beginning with the age four assessment, diameter and straightness will be added to the traits assessed. At the completion of test establishment in 1991, 22 test series had been identified for inclusion in the study. The distribution of test series by area and the establishment dates are shown in Table 2.

TABLE 2 Distribution of Diallel Test Series in the Early Diallel Measurement Study

Test Area Cooperators	Test Series Establishment Dates	Test Area Cooperators	Test Series Establishment Dates
Area 1 (Virginia)		Area 5 (Lower Gulf)	
Chesapeake	1984-1985	James River	(1992-1993)
Union Camp	1989-1990	Container	(1993-1994)
Va. Dept. of Forestry	1990-1991	MacMillan Bloedel	1988-1989
Westvaco	1988-1989	Scott	1986-1988
Area 2 (NC Coastal)		Area 6 (Upper Gulf)	
Champion	(1992-1993)	Ala. For. Comm.	1991-1992
Federal	1989-1990	Champion	1984-1985
N. C. Forest Ser.	(1992-1993)	International Paper	1991-1992
Weyerhaeuser	1984-1985	Kimberly-Clark	1986-1988
		Packaging Corp. of Am.	1988-1989
Area 3 (SC Coastal)			
International Paper	1987-1988	Area 7 (GA-SC Piedmont)	
S.C. Comm. Forestry	1988-1989	Procter & Gamble	1991-1992
Westvaco	1989-1990	Hiwassee	1989
Georgia Pacific	1992 (Special)	Catawba	1989-1990
		Ga. For. Comm.	1988-1990
Area 4 (Ga.-FL Coastal)		Evergreen	(1992-1993)
Mead	(1992-1993)		
ITT Rayonier	1986-1988		
Union Camp	1987-1988		

NOTE: ( ) predicted date of test series establishment

The average individual tree heritabilities based on currently available measurements are given in Table 3. Heritability estimates at ages one through three are based on 30-55 percent of the total diallels to be included in the study. Estimates at ages four through six are based on approximately 7% of the total diallels. While the estimates through age three may be much more indicative of the final results than those at later ages, all of the estimates are subject to change as data on the remainder of the diallels in the study become available. A majority of the diallels show a decrease in heritability at age two followed by an increase at age three. This is not surprising since similar trends have been reported in other studies. It is also important to note the considerable spread in minimum and maximum heritability estimates. This reflects the lack of precision in estimating heritability from a single diallel (6 parents) or a very small number of diallels. A single diallel provides a very weak genetic sample and thus imprecise estimates.

TABLE 3. Individual Tree Heritability Estimates from the Early Diallel Measurement Study

Age	Number of Diallels	h^2	Minimum h^2 Estimate	Maximum h^2 Estimate
1	28	.1483	.000	.493
2	26	.0882	.000	.391
3	18	.1809	.000	.394
4	4	.2255	.112	.303
5	4	.2140	.117	.297
6	6	.2030	.106	.302

The average ratio of specific combining ability to general combining ability is given in Table 4. Current estimates indicate that the SCA/GCA ratio is declining with age. Similar trends have been reported in other studies, including those from the NCSU-IPCo

TABLE 4. Ratio of Specific Combining Ability to General Combining Ability

Age	Number of Diallels	Ratio SCA/GCA	Minimum Value	Maximum Value
1	22	.874	.01	4.44
2	21	.835	.04	3.19
3	14	.689	.00	3.14

Heritability Study (Balocchi *et. al.* 1992). The estimates, as reflected by the minimum and maximum values, are extremely variable ranging all the way from 0 to 4.4.

The estimates presented represent a very preliminary analysis of the available data. A more detailed analysis is underway and should be completed this summer.

TABLE 5. An example of expected genetic gain at age 25 with selection at age six for several loblolly pine tree improvement strategies. (Derived from Balocchi *et. al.* 1992).

Strategy	Gain Height	Gain Volume
(1) 1st Generation Unrogued Seed Orchard	4.0%	7.1%
(2) 2nd Generation Unrogued Seed Orchard	6.2%	11.2%
(3) "Bulking Up" with Rooted Cuttings the Best 5/200 Full-sib Families from 1st Generation Progeny Tests	7.0%	12.8%
(4) Propagating with Rooted Cuttings the Best Tree in 5/200 Full-Sib Families from 1st Generation Progeny Tests	11.0%	20.7%

Assumes initial site index of 60, base age 25.

LOBLOLLY AND SLASH PINE ROOTED CUTTING PROJECT

Through the joint efforts of the forest products industry and N. C. State University, a loblolly and slash pine rooted cutting project was initiated in January, 1992. A university research team comprised of physiology, genetics, and horticulture specialists has been assembled to conduct this research. The project duration is four years with any decision to continue contingent on progress and additional research needs. The project will be conducted in close alliance with the Tree Improvement Cooperative.

Rooted cutting technology offers enormous potential for increasing forest productivity and value. In many parts of the world, intensively managed forest plantations established with rooted cuttings are producing high value/low cost wood for an increasingly competitive offshore forest products industry. The advantages of a successful rooted cutting system, compared to a seedling based reforestation program, are well documented. Advantages include:

(1) The opportunity to exploit the total genetic variation thereby increasing the "captured" genetic gain.

(2) A shorter time interval for exploiting genetic gains.

(3) Utilization of greater selection intensity thus increasing genetic gains.

(4) Production of more uniform trees within forest stands.

(5) Elimination of wild pollen dilution of the genetic gain in seed orchards.

(6) The potential for matching genotypes to specific sites or products.

The potential increase in genetic improvement through exploitation of the total genetic variation and an increase in the selection intensity (#1 and #3 above) is displayed in Table 5. These estimates are derived from the NCSU-International Paper Heritability Study and as such represent one conservative appraisal of the possible benefits from vegetative propagation by stem cuttings.

In addition to realizing more gain per cycle of breeding and testing, it is possible for rooted cuttings to shorten the time interval from selection to improved plantations by a minimum of six years (Balocchi *et. al.* 1992). The economic value of the benefits enumerated in items 4 thru 6 are difficult to realistically estimate with any general set of assumptions. They nevertheless represent important opportunities for exploitation once rooted cutting technology is developed.

No rooted cutting program can be successful without a sound genetic resource development foundation (breeding, testing and selection). This dependence of a viable rooted cutting program on selection, breeding, and testing prompted development of this rooted cutting research project in close alliance with the N. C. State University-Industry Cooperative Tree Improvement Program.

Research will be focused in five primary areas of investigation:

(1) Genetic selection for rooting will be evaluated for its potential to enhance rootability and its effect on genetic gain for yield.

(2) Molecular biology studies will concentrate on understanding the role of gene expression in the developmental process of adventitious root initiation. The work will include research on the process of maturtion and the accompanying loss of rooting.

(3) Stock plant physiology and culture, with initial emphasis on managing the carbohydrate/nitrogen ratio in stem cuttings, will be evaluated.

(4) Rooting environment research will be accomplished with a working group of project sponsors and will build on past research. In addition to continued work on nursery systems, a containerized "plug-nursery" system will also be evaluated. A second area of emphasis in rooting environment will be to determine which media produce rooted cuttings of a quality that will ensure survival and performance following out-planting.

(5) Root system quality will be evaluated under varying auxin treatments.

All five areas contribute to an increased understanding of adventitious root initiation and development, and/or work toward refinement of a useful rooted cutting technology that will allow the full potential of clonal forestry to be realized.

Seedlings and rooted cuttings from nine control pollinated families ready for planting at three locations to determine how effectively families for rooted cutting programs can be selected in seedling progeny tests.

BREEDING, TESTING, AND SELECTION

BREEDING AND TESTING PROGRESS

Progress continued in 1991 toward breeding and testing of the nearly 4000 plantation and second generation selections. As of December, 1991, crossing for the plantation selections was estimated at 90% complete (up from 82% last year) and 86% complete for the second generation diallels (up from 80%). The breeding and testing progress is displayed by region in Figures 3 and 4. It is interesting to note that region 1 is leading the cooperative in second generation crossing (95%) and is second to region 3 in second generation test establishment (40%). This is quite an accomplishment since region one is on the northern edge of the loblolly range where late spring freezes and resulting poor seed yields are not uncommon. The cooperators in this region are to be commended for their accomplishment.

During the 1991 planting season, approximately 147 tests were established, 126 plantation and 21 second generation. Through 1991, 510 tests have been established representing 40% of the total for this testing cycle. Last year, 1992 was estimated to be the peak establishment year, but due to some poor seed yields in 1991, it now appears that 1993 will be the peak year (Figure 5). If the 1992 crop

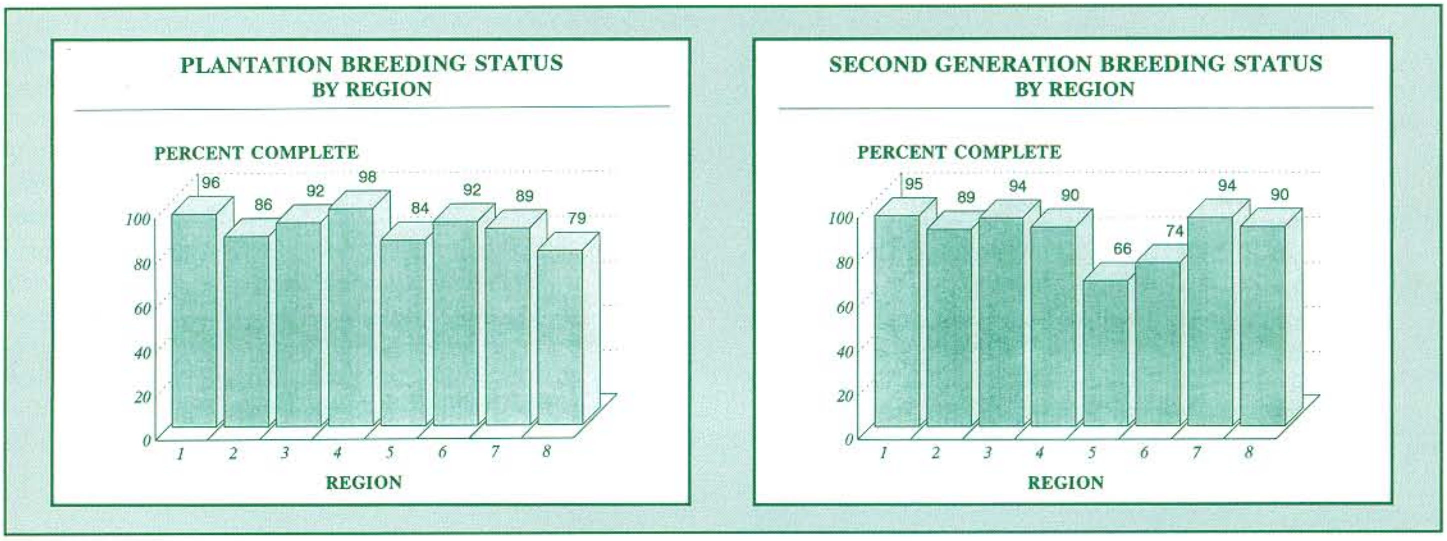


Figure 3. Percent of crossing completed for plantation and second generation diallels as of December 31, 1991.

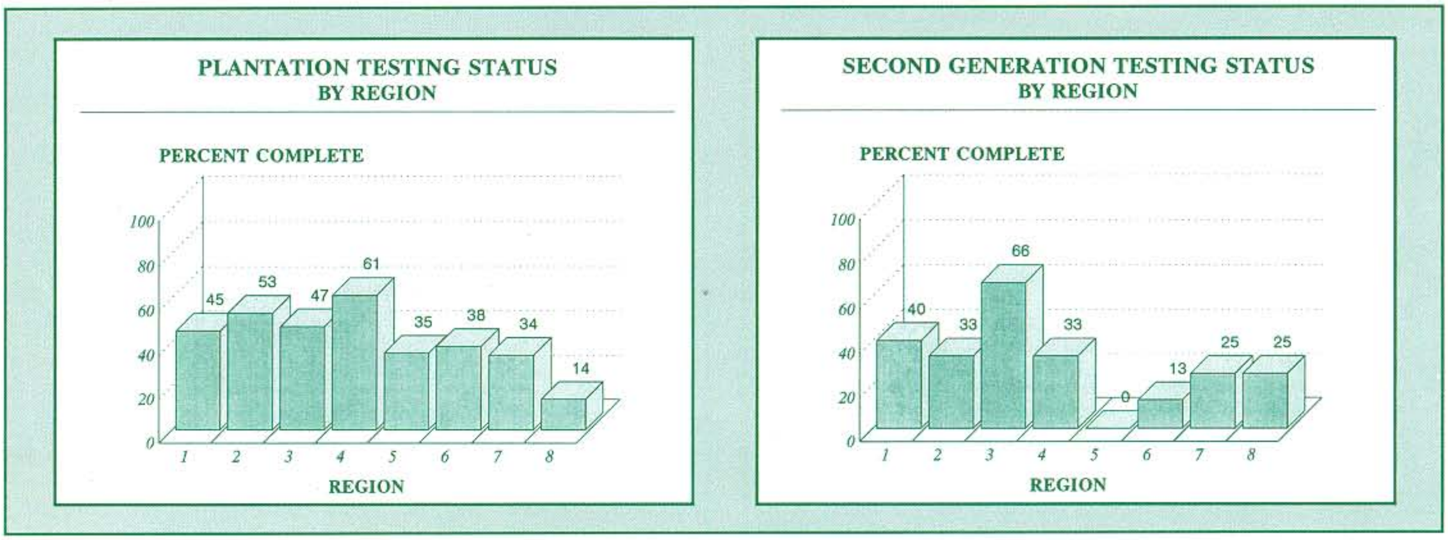


Figure 4. Percent of test establishment completed for plantation and second generation diallels as of December 31, 1991.

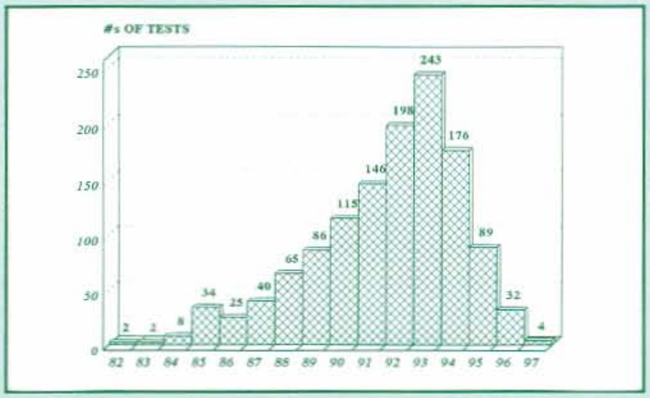


Figure 5. Distribution of progeny test establishment by year.

produces average yields, another 45 second generation tests should go out in 1993. It is anticipated that an additional 200 tests will be established in 1992 followed by the establishment of 243 tests in 1993.

Fourteen programs have finished breeding their plantation diallels and are engulfed in test establishment (Table 6). With crossing almost complete for many cooperators, final plans are underway to complete test establishment. Many are faced with very heavy test establishment loads. While it is important that tests be planted as soon as possible, it is even more important that they be established properly. The cooperative staff has been working with many cooperators to set realistic and achievable goals for establishing tests in a timely, yet quality, fashion.

TABLE 6. Leaders of the pack: Programs who have completed crossing and are well on the way in testing.

Crossing Complete		% Planting Completed
Weyerhaeuser, NC	(16)	100
Union Camp, GA	(15)	80
Union Camp, VA	(12)	75
Bowater CWD	(17)	74
Westvaco, SC	(18)	72
Packaging Corp.	(14)	71
International Paper, SC	(11)	60
Scott	(8)	56
Bowater SDW	(19)	53
Kimberly Clark	(15)	50
Virginia Dept. For.	(16)	50
MacMillan Bloedel	(14)	44
Westvaco, VA	(4)	44
Ga. Pacific, SC	(17)	18

Note: parenthesis ( ) represent number of diallels bred.

WRAP-UP OF DIALLEL CROSSING

As in the first generation, crossing will not be pursued to the bitter end, but will be brought to a logical conclusion in the near future. All cooperators have been urged to make a concentrated effort to complete their breeding in 1992. Each cooperator will be asked for a breeding status report in the summer of 1992. Based on the status report, wrap-up plans for each breeding program will be developed. Options may involve one or more of the following:

(1) Continue breeding for another year

(2) Plant 5-tree diallels

(3) Collect open-pollinated seed from clones which have not been bred for inclusion in regional open pollinated tests

In planning the wrap-up, it has been emphasized that cooperators not free-lance. Wrap-up plans can only be developed after a thorough assessment of the breeding status within and among breeding programs for a given breeding region. Upon completion of this assessment, regional planning workshops with Cooperators will be held in late summer or early fall of 1992 to finalize the wrap-up plans.

This pollen isolation bag was one of thousands put up in breeding clone banks this spring as Cooperative members made an all out push to complete diallel breeding.

SEED ORCHARD PRODUCTION

CONE AND SEED YIELDS

The Cooperative's loblolly pine seed orchards recorded a moderate seed crop in the fall of 1991. Approximately 39 tons of loblolly pine seed were collected, a 27% increase over the 1990 crop of 30.4 tons (Table 7). In reporting yields it is important to emphasize "collection" rather than "production". Organizations continue to utilize various collection strategies to optimize gain, in many cases collecting from only the better parents. Cones from many of the older first generation orchards are not collected at all. Most organizations have seed inventories that are more than adequate and thus are collecting only for current year needs. Of the 84 loblolly orchards in production, 23 reported "no collections" in 1991. It is estimated that 10 tons of seed were left uncollected. What a luxury to be able to practice this further "selection" for increased genetic gain.

Also on the positive side, yields were back up (1.40 lbs./bushel) after being disappointingly low in 1990 (1.19 lbs. /bushel). It is noteworthy that total seed production (38.8 tons) increased 27% over the 1990 crop while bushels collected increased only 9.0%. This dramatically reflects the higher lbs./bushel yields. Yields for the three year period 1989-91 averaged .32 lbs./bushel less (1.30 lbs./ bushel) than the previous three years (1986-1988 averaged 1.62 lbs./ bushel). Efficiency is definitely down, probably due to a combination of weather patterns and insect problems. With an abundance of seed in storage, some cooperators have backed off insect control due to costs and environmental pressures.

TABLE 7. Ten Year Seed Yields from Loblolly Pine Orchards

Harvest Year	Bushels of Cones	Tons of Seed	Lbs./ Bushel
1982	44,761	30.5	1.36
1983	68,447	49.0	1.43
1984	105,239	80.1	1.52
1985	52,155	37.8	1.45
1986	84,953	70.1	1.65
1987	112,822	93.3	1.65
1988	56,822	42.7	1.50
1989	23,247	16.1	1.38
1990	50,944	30.4	1.19
1991	55,555	38.8	1.40
Totals/Avg.	654,945	488.60	1.49

A pleasant surprise was the record collection of 12 tons of seed from second generation orchards. This represents a 160% increase over the 1990 collection of 4.6 tons and is the largest second generation collection ever. More significant is the percentage of the total crop represented by second generation seed. The 1991 collection of second generation seed represents almost one-third of the total crop, more than double that of any previous year (Figure 6).

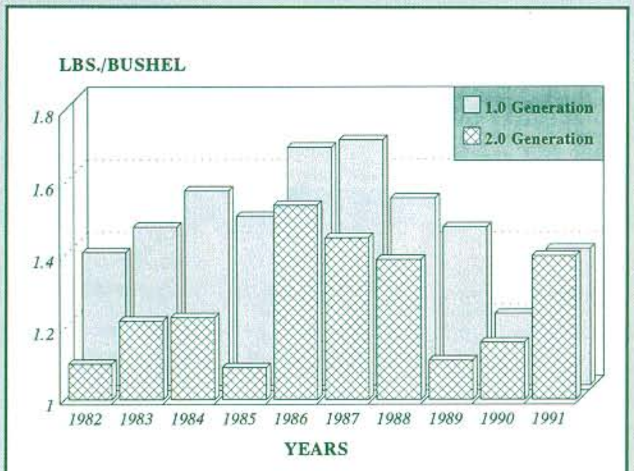


Figure 6. Second generation seed orchard production as percent of total production for past 10 years.

Another significant trend is that lbs./bushel yield for second generation orchards has steadily increased over time and for the first time has equaled the overall (combined piedmont and coastal) yield figure for the first generation orchards. Figure 7 shows second generation and first generation yields for the past 10 years. The second generation has always been lower than the first but the gap has finally closed. When broken down by piedmont and coastal, the Coastal second generation orchards were significantly better than the Coastal first generation (1.54 vs 1.30) but the Piedmont seconds were much lower than the Piedmont firsts (1.12 vs 1.57). The difference between the Coastal and Piedmont second generation yields (1.54 vs 1.12) is probably a reflection of the Piedmont orchards generally being younger. Young second generation orchards have produced lower yields partly because of pollen shortages. As these orchards gradually mature, pollen availability increases thus increasing the yields. Another factor contributing to lower yields in young second generation orchards is management philosophy. At very young ages, many managers feel that insect control is not justified for such small cone crops, and therefore,

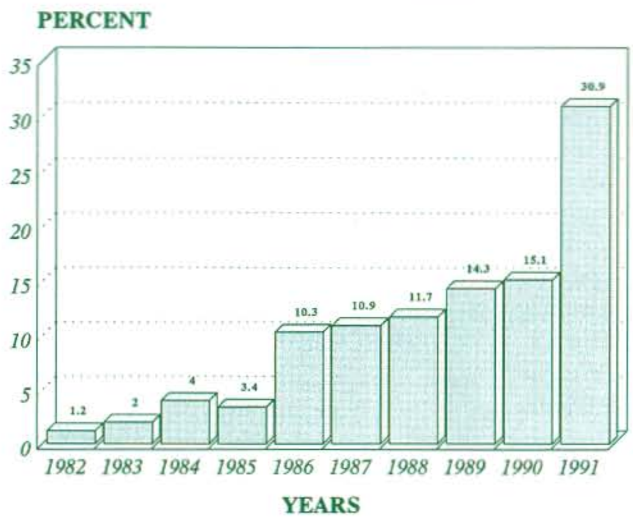


Figure 7. A comparison of the pounds per bushel seed yields for first generation and second generation loblolly orchards for the past 10 years.

withhold insecticide applications. In the future, we expect first generation yields to decline as the intensity with which they are managed declines.

Table 8 compares yields in bushels and pounds of seed for the 1990 and 1991 harvests for 5 species in addition to loblolly pine. Slash pine seed collection was up this year by 23% (7.9 tons). Yields per bushel in slash pine remained essentially unchanged from 1990. Three organizations collected longleaf this year for a total of 3.8 tons and a 1.10 lbs./bushel yield. No longleaf collections were reported in 1990. Small amounts of Virginia, white pine, and Fraser fir were also collected.

TABLE 8. Comparison of 1990 and 1991 seed orchard yields for all species.

Species	Bushels of Cones		Pounds of Seed		Pounds of Seed Per Bushel of Cones	
	1991	1990	1991	1990	1991	1990
Loblolly:						
Coastal 1.0	25,792	32,016	33,491	37,895	1.30	1.18
Piedmont 1.0	12,752	11,069	20,036	13,692	1.57	1.24
Coastal 2.0	11,901	4,786	18,275	5,947	1.54	1.24
Piedmont 2.0	5,110	3,073	5,698	3,216	1.12	1.05
Totals	55,555	50,944	77,500	60,750	1.40	1.19
Slash Pine	14,123	11,203	15,730	12,816	1.11	1.14
LongLeaf	6,973	--	7,663		1.10	--
Virginia	139	54	160	47	1.15	0.87
White Pine	1,617	3,882	1,275	2,847	0.79	0.73
Fraser Fir	314	--	861	--	2.74	--
Totals	78,721	66,083	103,189	76,460		

PRODUCTION LEADERS

While average yields in 1991 surpassed the 1990 yields, not a single orchard achieved a 2.0 lbs./bushel yield. This is the first year this has occurred since the inception of the Two Pound Honor Roll. The Champion (SC) 1.5 piedmont orchard came very close with a yield of 1.97 lbs./bushel. Twelve orchards produced above the 1.70 lbs./bushel mark, with yields ranging from 1.71 to 1.97. Bowater's (CWD) 1.5 Piedmont orchard was second highest in yield at 1.88 followed by: Champion's (SC) Disease Resistant orchard (1.86); Westvaco's 2.0 Coastal orchard (1.85); Container Corporation's 2.0 Coastal orchard (1.82); International Paper's 1.0 north Coastal orchard (1.79); Weyerhaeuser's 2.0 Coastal NC orchard at Lyons, Ga. (1.78); Champion's (SC) 1.5 Alabama orchard and Westvaco's 1.0 Virginia Piedmont orchard (tied at 1.74); International Paper's 2.0 Atlantic Coastal orchard located at Marianna, Fla. (1.73); Westvaco's 1.0 Central Woodlands loblolly orchard (1.72); and Union Camp's 1.5 Georgia Coastal orchard (1.71) (Table 9). It is encouraging that 4 second generation orchards appeared among the production leaders this year, the most occurrences to date. Congratulations to the following orchard managers for maintaining excellence in production: George Oxner (Champion, SC); Jake Clark (Bowater, CWD); Dave Gerwig (Westvaco); Doug Sharp (Container Corp.); Marietta McConnell (International Paper); Franklin Brantley (Weyerhaeuser); Tim Slichter (International Paper); and Marvin Zoerb (Union Camp).

Though no orchard averaged above the 2.0 lbs./bushel mark this past year, there are some clones that consistently produce above this level. In James River's 2.0 Coastal orchard, the orchard average was 1.54 lbs./bushel but clones ranged from a low of 1.14 to a high of 2.34 (Table 10). Champion SC also reported five clones that yielded above 2.0 lbs./bushel. Three of the five also produced above 2.0 last year.

Table 10. Clonal seed yields from James River's Second Generation Loblolly Seed Orchard

Clone	Bushels	Pounds	Lbs/bushel
12-1066	33	77	2.34
10-1030	46	102	2.22
10-1027	12	23	1.94
05-1036	34	65	1.91
11-1062	18	34	1.89
08-1520	36	63	1.74
07-1008	28	48	1.71
07-1004	68	114	1.68
12-1065	65	96	1.48
12-1072	54	79	1.47
08-1508	37	53	1.42
08-1519	25	30	1.19
12-1092	59	67	1.14
Average			1.54

TABLE 9. Production Leaders in 1991.

Cooperator	Orchard Type	Acres	Avg. Age	Lbs./ Bushel	Manager
Champion (SC)	1.5 Piedmont	20	25	1.97	George Oxner
Bowater (CWD)	1.5 Piedmont	30	17	1.88	Jake Clark
Champion (SC)	Disease Resistant	10	22	1.86	George Oxner
Westvaco	2.0 Coastal	8	17	1.85	Dave Gerwig
Container	2.0 Coastal	36	9	1.82	Doug Sharpe
International Paper	1.0 N. Coastal	11	16	1.79	Marietta McConnell
Weyerhaeuser (GA)	2.0 Coastal (NC)	52	15	1.78	Franklin Brantley
Champion (SC)	1.5 Alabama	10	16	1.74	George Oxner
Westvaco (SC)	1.0 Va. Piedmont	10	22	1.74	Dave Gerwig
International Paper (FL)	2.0 Atl. Coastal	60	14	1.73	Tim Slitcher
Westvaco (SC)	1.0 Central Lob.	12	20	1.72	Dave Gerwig
Union Camp (GA)	1.5 Coastal	66	17	1.71	Marvin Zoerb

The James River orchard represents the benefit of proper insect control. Prior to 1989, James River had utilized ground application equipment for spraying insecticides but were not pleased with yields from the 1987 (.89 lbs./bushel) and 1988 (1.12 lbs./bushel) crops. As the crowns of trees close, ground application becomes less effective in distributing the insecticides. James River has been using aerial applications since the spring of 1989. Yields for 1989, 1990, and 1991 were 1.45, 1.32, and 1.54, respectively. Bill McKee attributes the increase in yields to the better insect control from the aerial applications. The 1976 block of their orchard is left untreated for environmental reasons and it yielded 1.13 lbs./bushel compared to the orchard average of 1.54. Increased yields of .41 lbs./bushel equates to an additional 410 pounds of seed on a 1000 bushel harvest or an additional 5500 acres of plantable seedlings.

SEED ORCHARD PEST MANAGEMENT - UPDATE

During the decade of the 70's, considerable progress was made with the help of the USFS in securing registration for insecticide use in seed orchards -- namely, Furadan, Guthion, Pydrin, and Ambush. No new pesticides have been registered for seed orchard use since the early 1980's. In the interim, concern over environmental issues has resulted in many insecticides being banned or severely restricted in their usage. Starting July 15, 1991, Furadan was restricted for tipmoth control only at time of transplanting. No seed orchard uses now exist. After August 1994, domestic use of Furadan will be limited to 2500 lbs. nationwide. American Cyanamid Co. has requested that the technical label for Malathion be amended, deleting several uses including forestry.

With these trends evident, SFTIC formed a Seed Orchard Pest Management Committee in 1989 with the following objectives:

(1) To keep chemical companies and EPA advised of our interests

(2) To coordinate efforts to relate needs and priorities to research groups

(3) To coordinate efforts to test and register additional insecticides

(4) To coordinate technology transfer efforts to operational programs.

The subcommittee membership represents a broad spectrum of persons and organizations. J. B. Jett is representing the Cooperative on this subcommittee.

Aerial application of insecticides has proven to be very effective in controlling seed and cone insects.

Dioryctria larvae can destroy forty to fifty percent of annual seed crop without effective insect control.

To date, the committee has worked successfully to have the Furadan label revised to maintain the registration of Furadan for limited forestry use. The committee has also succeeded in having seed orchards reclassified from forestry to terrestrial non-food crops. Seed orchard reclassification should significantly lower the cost of pesticide registration for seed orchard use thus making it more attractive to chemical companies to consider registration of their products for use in seed orchards.

The committee has also successfully established a regional cooperative study to evaluate the efficacy of Capture for cone and seedbug control in loblolly and slash pine seed orchards. The study was established in six loblolly and three slash pine seed orchards. Treatments were as follows:

(1) Capture at the rate of 0.2 lbs. AI/acre for the first application in April followed by four additional applications (May, June, July, and August) at a rate of 0.1 lbs. AI/acre.

(2) Guthion at a rate of 3.0 lbs. AI/acre/application for a total of 5 applications (April, May, June, July and August).

(3) Control

Data collection and analyses have been completed. The results indicate that Capture effectively controls cone and seed insects. Hopefully, these data will result in the registration of Capture for seed orchard use by FMC Corp.

The Subcommittee has also developed the work plan for a Guthion rate study. Standard spray has been 3 lbs. AI/acre/spray with six sprays per year applied. The objective of this study is to test varying rates (from 1 to 3 lbs. AI/acre/spray). This study is to be implemented in 1992.

Future activities being considered by the Seed Orchard Pest Management Subcommittee include:

(1) Field validation of degree-day models

(2) Mating disruption studies

(3) Development of ground equipment to simulate aerial application

(4) Review of site classification and new insecticides for potential use in seed orchards

(5) Operational evaluation of Foray (BT)

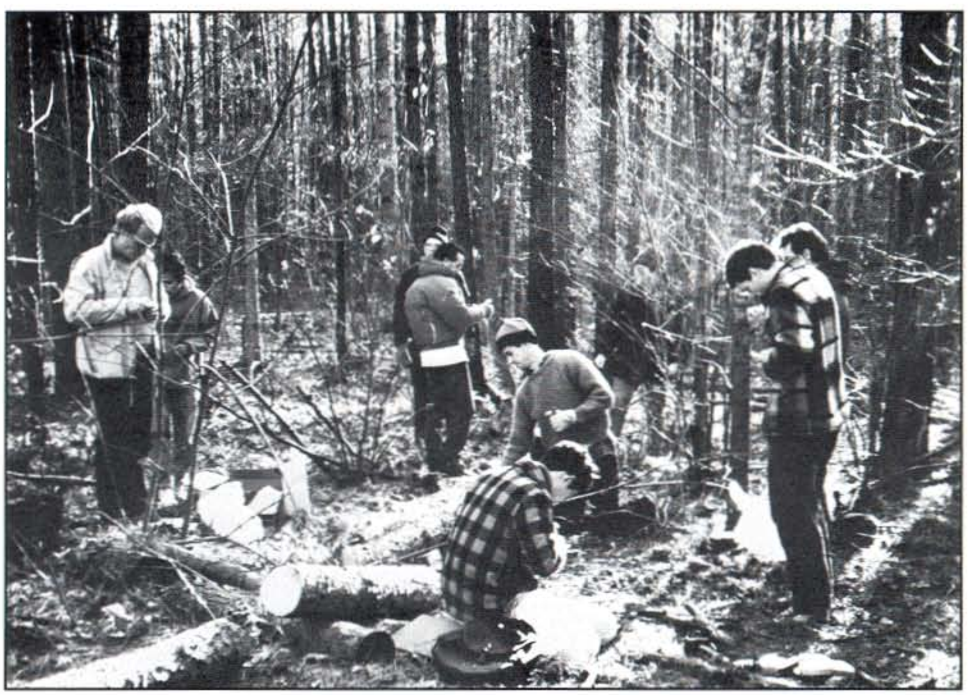
ASSOCIATED ACTIVITIES

GRADUATE STUDENT RESEARCH AND EDUCATION

The education of graduate students and the research they conduct as part of their degree programs continues as a high priority activity of the Cooperative. During the previous year six students completed their degree programs, which caused a substantial decrease in the student population. The graduate students working in association with the Cooperative are listed in the right column.

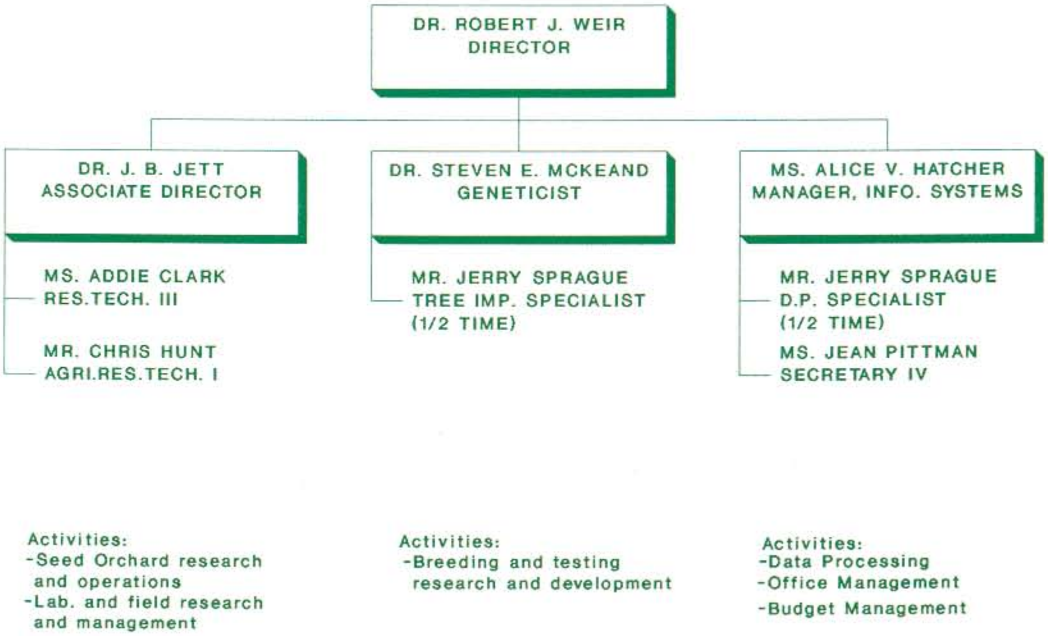
A recent survey of U.S. colleges and universities by the National Plant Genetics Resources Board revealed that in the past decade, 38% or 52 of 136 graduate degrees awarded in forest tree breeding were from N.C. State University. This is an accomplishment for which we are very proud, and one for which the Cooperative membership also deserves a great deal of credit. Cooperative members have generously contributed to graduate student research projects by contributing land, equipment, and manpower resources. We wish to recognize this outstanding contribution, for without it our graduate research and education program would be substantially reduced in scope and accomplishment.

STUDENT, DEGREE, COUNTRY	RESEARCH PROJECT
Roger Arnold, Ph.D. Australia	*Quantitative genetics of Fraser fir, with emphasis on a multi-trait selection index*
Kevin Harding, Ph.D. Australia	*Age trends of genetic parameters for wood properties for loblolly pine*
Jan Svensson, Ph.D. Sweden	*Ecophysiological bases for genetic differences in growth of loblolly pine stands*
Ying-Hsuan Sun, M.S. Taiwan	*Vegetative propagation and DNA transfer in Fraser fir*
Jerry Windham, M.S. U.S.A.	*Variation in the number of archegonia per ovule in loblolly pine*
Jorge Vasquez, M.S. Peru	*Nutritional variation among provenances and families of loblolly pine*
Youhau Zhang, M.S. China	*Genetic differences in seasonal growth patterns associated with fusiform rust resistance in loblolly pine*



Graduate students in Forestry 511 (Tree Improvement Methods) received practical experience in wood sampling procedures.

COOPERATIVE TREE IMPROVEMENT PROGRAM ORGANIZATIONAL CHART - MAY, 1992



MEMBERSHIP OF THE TREE IMPROVEMENT COOPERATIVE

On January 1, 1992, International Forest Seed Company terminated its Cooperative membership due to an ownership change. The new owner's emphasis will be on agronomic crops. Although International Forest Seed Company continues to operate as a seed and seedling company, the forest genetics work has been discontinued.

Otherwise, the Cooperative membership remains unchanged with 24 organizations managing 44 tree improvement centers.

Alabama Forestry Commission
Bowater, Inc.
Champion International Corp.
Chesapeake Forest Products
Container Corp. of America
Evergreen Corp.
Federal Paper Board
Georgia Forestry Commission
Georgia-Pacific Corp.
International Paper Company
James River Corp.
Kimberly-Clark Corp.
MacMillan Bloedel, Inc.
Mead Coated Board
N. C. Div. of Forest Resources
Packaging Corp. of America
Procter and Gamble Cellulose
ITT Rayonier, Inc.
Scott Paper Company
S. C. State Comm. of Forestry
Union Camp Corp.
Virginia Department of Forestry
Westvaco Corp.
Weyerhaeuser Company

PUBLICATIONS OF SPECIAL INTEREST TO MEMBERS OF THE COOPERATIVE

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Arnold, R., J.B. Jett, and H.L. Allen. 1992. DRIS diagnosis for identifying nutritional influences on cone production in Fraser fir. Soil Sci. Soc. Amer. Jour. (in press).

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Balocchi, C. E., F. E. Bridgwater, B. J. Zobel, and S.Jahromi. 1992. Age trends in genetic parameters for tree height in a non-selected population of loblolly pine. For. Sci. (in Review)

Bridgwater, F.E. 1990. Shoot elongation patterns of loblolly pine families selected for contrasting growth potential. For. Sci. 36:641-656.

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McKeand, S.E., F.E. Bridgwater, M.N. Todhunter and G.P. Cannon. 1990. Early selection of loblolly pine based on first-year stem elongation. Abstract 11th N. Amer. For. Biol. Workshop, Athens, GA. p.13.

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Moody, W. R. and J. B. Jett. 1990. Effects of pollen viability and vigor on seed production of loblolly pine. South. J. Appl. For. 14:33-38.

Shimizu, J.Y. and B.J. Zobel. 1990. The importance of inter-family competition in loblolly pine. Silvae Genetica. (In press).

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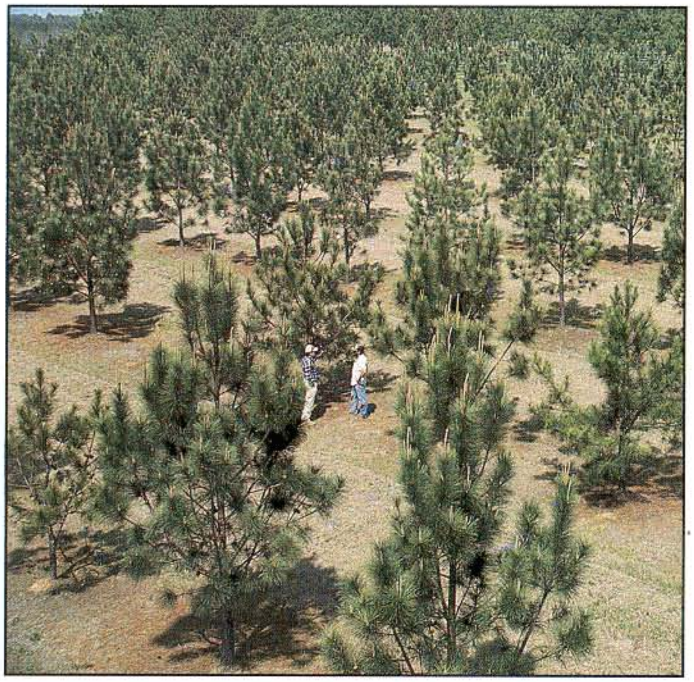
Zobel, B.J. and J.R. Sprague. 1992. A revolution in forestry: a history of tree improvement in the South. (In press).

Wood sampling in the Loblolly Pine Heritability Study is part of the Study of Age Trends of Genetic Parameters.

Research activity of the Cooperative provides a foundation of information and improved technology that leads to greater genetic gains, improved efficiency, and/or lower cost tree improvement in the future.



A location of the Dwarfing Rootstock Study four years after grafting.

Start up work (grafting) for the Grafted Inbreeding Study.