EIGHTH ANNUAL REPORT

N. C. STATE-INDUSTRY

COOPERATIVE TREE IMPROVEMENT PROGRAM

School of Forestry

North Carolina State

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INTRODUCTION

The past year has been our busiest yet and marked as usual by both triumphs and difficulties. One of the main efforts, production of seed from orchards, is beginning to pay off several years earlier than expected; a few orchards are already coming into commercial production. The nature and extent of gains that can be achieved through the tree improvement approach has come into clearer focus through progeny tests, wood studies, and research results. This year's experience painfully emphasized how little is really known about the forest trees with which we work. Careful observations made on the seed orchards have disclosed various pests, especially "physiological diseases." Many of these are spotted by the large number of alert cooperators in the Program, who work closely with the orchards and have become quite experienced in seed orchard management. This very effective "spy system" makes it difficult for any disease or insect to go undetected for very long.

The past year marks the end of the first full year of participation by Bob Kellison, who took Bob McElwee's place as liaison geneticist when McElwee took over direction of the Hardwood Research Program. And what a year Kellison has had!! I'm sure he wonders what he has gotten into and how long this pace can be maintained. During this year he has graded 241 new trees in six pine species and helped in the establishment of several new seed orchards and seed production areas. During the year, the first large plantings of control-pollinated seedlings, several large-scale wood studies, and the effort to "outguess" diseases, insects and weather, have kept both Kellison and Zobel on the road more than in any previous year. We do not for a moment regret this activity - rather, we welcome it, for such activity reflects progress, and progress there has been of a significant and satisfying nature.

We welcome to the Cooperative Program the newest member, the Tennessee River Pulp and Paper Company. This company became actively associated on January 1, 1964; and judging by subsequent happenings, the word "active" is an apt description of their participation. Their joining brings the total in the Program to 18 active companies or major company divisions and two state forestry organizations with land in ten southeastern states. Such widespread participation requires much travel, but as illustrated by the accompanying map (Fig. 1) the various organizations blanket the Southeast so completely that progressive travel usually involving several companies can be arranged for each trip.

THE APPLIED PROGRAM - SEED PRODUCTION

As in past years, major effort has been expended toward producing improved seed on a scale suitable for the planting and direct-seeding programs of the cooperating organizations. The main avenues to reach this goal have been seed orchards and seed production areas, aided by geographic source studies and a small hybridization program. The applied phase of the Cooperative Program was emphasized in the Seventh Annual Report (June, 1963) and will be brought up to date in the current report.

Seed Orchards and Tree Selection:

Selection of trees for use in seed orchards has produced more activity than in any previous year of the Cooperative Program. This year over 250 new trees have been graded, making a total of 1335 trees from 10 species (see the map in Fig. 1, current to March, 1964). Emphasis still continues on loblolly pine, but during the past year a considerable number of longleaf pine were graded for the first time for the Weyerhaeuser Company and North Carolina Forest Service. At least two other organizations in the Cooperative Program have shown an active interest in longleaf pine. Interest in Virginia pine remains high and a number of trees have been graded; currently, seven organizations are working with this species. Marathon Southern Corporation has now

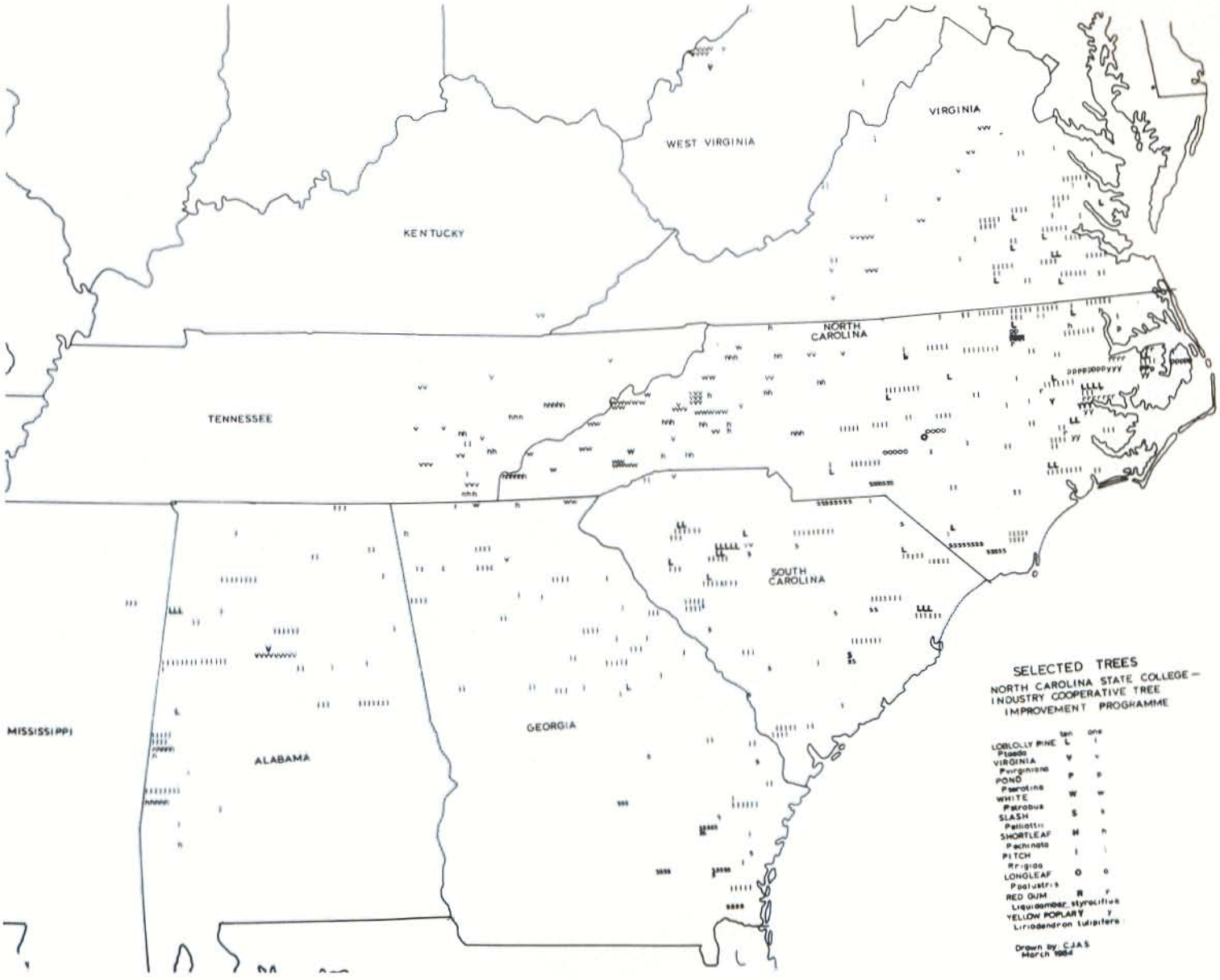

Fig. 1. Trees graded in the N. C. State-Industry Tree Improvement Program up to Mar. 1, 1964. Each capital letter denotes 10 trees, and each lower case letter represents a single tree. Symbols indicate locations exact to county.

an active program involving shortleaf pine, and over 20 excellent trees of this species were graded for them last year, in addition to those graded for the North Carolina Forest Service. In the past, only limited work was done with slash pine, but 50 trees of this species were graded for the South Carolina Forestry Commission during the past year.

The question has been asked whether our current standards of grading have remained constant over the years. There has been no change in the grading system, but as the men searching out the trees have gained more experience and skill, and as we have found it possible to be more selective, we must honestly say that we believe our currently-graded trees are better phenotypes than those initially selected. Each new species causes a shift in emphasis in the grading procedure which is tailored for it. For example, the standards for characteristics such as bole straightness for longleaf pine are higher than for loblolly pine simply because longleaf has more acceptable phenotypes with this characteristic than has loblolly.

Five new seed orchards have been started during the year, bringing the total (when broken down into organizations, geographic area, and species) to 61. Total area of orchard land already established, or in the process of being established, is approximately 750 acres. In addition to the new orchards, existing orchards are being expanded by a number of companies, thus adding considerably to the total acreage.

A number of the orchards are coming into commercial production, with several hundred cones on some of the individual grafts (Fig. 2). Over-all, in 1963 both the male and female flower crop were good; in 1964 they were excellent, with the exception of one of the more northern orchards which had only a moderate flower crop. Because of the good crop the control crosses for progeny testing of the seed orchards are progressing considerably ahead of schedule, with enough crosses achieved in several instances to suffice very nearly for the necessary tests (Fig. 3). Last year over 60 crosses were planted in the nursery, and in April, 1964 over 150 were sown. If all goes well, we expect nearly 1000 progeny-test crosses to be available for the 1965 season.

Fig. 2. Seed orchards such as this one at Manteo, N. C. (West Virginia Pulp & Paper Company) are coming into commercial seed production at five and six years of age. Trees of this size often have dozens to hundreds of female flowers, and male flower production is likewise becoming heavier.

Fig. 3. Flowering was unusually heavy in 1964. The Piedmont loblolly pine pictured here is in the Riegel Seed Orchard at Lumberton, North Carolina, and bore an abundant crop of both female and male flowers.

The design used for control crosses is a 4-tester system. The progeny outplantings are made on areas representative of the average condition of the company lands. In addition to the tests under these standard conditions, Weyerhaeuser Company has established tests on both organic and mineral soils, with and without the use of fertilizers. Direct seeding was also a part of the progeny test to obtain information supplemental to that obtained from planted seedlings. International Paper Company used two different site classes for their progeny tests, while Champion Papers, Inc. will plant under "ideal" conditions as well as under average conditions.

The earliest open-pollinated progeny tests of trees used in the seed orchards are now over five years old and are producing some most interesting and useful information, especially for those companies desiring to expand their present seed orchards. Certain clones have been rogued or will be closely watched because one or more serious defects have shown up. For example, in the Hiwassee Land Company open-pollinated tests two mother trees produced an unusual amount of forking and ramicorn branching, although not enough to cause roguing. Certain progenies in other orchards were found to have considerable Cronartium fusiforme infection. Most significant, however, is that in every instance the open-pollinated seed from the select trees have produced seedlings greatly superior in height growth to commercial seed checks. Even more striking is the relative uniformity of growth and form of progeny from the selected trees as compared with the commercial checks.

There seems to be a lack of understanding among laymen just what the seed orchard concept entails. To try and clarify the objectives of the Cooperative Tree Improvement Program, a paper entitled "Seed Orchards for the Production of Genetically Improved Seed" was published in the April issue of Silvae Genetica. This paper made an attempt to clarify the difference between production seed orchards and research seed orchards and to explain why vegetative rather than seedling orchards are being used in the Cooperative Tree Improvement Program.

Methods to increase flowering, cone and seed set are under way by several companies. All are using fertilization, but four companies (Catawba Timber Company, Albemarle Paper Mfg. Company, Union Bag-Camp Paper Corporation, and Kimberly-Clark Corporation), with the help of Dr. C. B. Davey and Dr. T. E. Maki, established irrigation schedules in combination with various fertilizer regimens. Topping trees, root pruning, banding and other methods to help flowering are being tried by various organizations; the oldest of such trials (by Hiwassee Land Company) has as yet produced no positive results.

All is not completely "rosy" with the seed orchards. As reported last year, graft incompatibility is still a major problem, forcing abandonment of several excellent clones. Loss from incompatibility seems to have been greatly accentuated during the drought periods; several clones that for five or six years appeared trouble-free suddenly sustained heavy losses late in 1963. In an attempt to save some of the most valuable clones, graduate student Tony Shelbourne at N. C. State, Joe Landino at West Virginia Pulp & Paper Company, Manteo, North Carolina, and Bill Keithley at Hiwassee Land Company, Rose Island, Tennessee, undertook rooting tests (Fig. 4). Previous experience and research had pretty well demonstrated the difficulty of rooting older pines, but a recent paper reported good results on 25-year-old pines. Results of our recent tests mainly confirmed the earlier reports: young trees rooted well, middle-aged trees poorly, and trees over 25 years of age responded rather miserably. However, the 10% success by Joe Landino gives some basis for hope that certain incompatible clones, otherwise clearly doomed, may now be saved.

Freeze damage, so severe that in some older grafts the stems actually split, was evident in several orchards, causing a great deal of concern and a limited number of losses. More severe, however, was the delayed dying of Virginia and shortleaf pines in the Hiwassee Land Company seed orchard where extensive kill of large grafts occurred. Several severe ice and snow storms hit certain orchards (Fig. 5), but damage was remarkably light. Damage appeared to be associated with certain clones;

Fig. 4. Rooting tests of incompatible clones were made by West Virginia Pulp & Paper Company at Manteo, North Carolina, at Hiwassee Land Company in Tennessee, and at N. C. State. Pictured is the rooting bed at N. C. State with the intermittent sprays on. Best results were at Manteo where nearly 10% rooting was obtained on old pond pine grafts. Some Virginia pine has rooted, but it is too early to assess results. Although the percentage rooting is low, it is most encouraging, enabling the maintenance of incompatible clones that would otherwise be lost.

at Chesapeake Corporation, records over the past four years indicate that certain clones sustained far more severe damage than others. The hardest hit orchard in 1964 was that of Champion Papers, Inc. but most loss was confined to branch breakage. Since not a single orchard was hit by hurricanes, tornadoes, hail or floods, we can only feel that we did escape many hazards that might have come our way. No more Fomes was detected in the orchards during the past year, though careful watch is being kept for any incipient signs.

A very discouraging loss at this stage was the killing of female flowers by late March freezing temperatures that dipped as low as 21° F. In those orchards where the female flowers had emerged from the bud scales or had developed to maximum receptivity the losses were especially heavy. Slash flowers were killed even after they had closed, in one of the more northern orchards. Near Georgetown, South Carolina, freezing killed up to 90% of the flowers, both inside and outside the pollination bags; in other cases the damage was much more severe to bagged than to unbagged flowers. This mortality was especially disconcerting since the flower crop in this area was the heaviest that had yet been obtained.

Cronartium fusiforme is still a major problem on the rootstock, but only rarely on the graft itself. Excising of small or young cankers has been quite effective, and in many hundreds of grafts the disease that would otherwise have killed the tree appears to have been arrested by such "surgery."

A "new" puzzling problem has been noted on the rootstock of grafts in several orchards. The cambium growth becomes very irregular (see Fig. 6), giving the tree a fluted or buttressed appearance. Site conditions, rust infection, and a "new" kind of incompatibility have all been suspect as the prime cause. Despite several tests by Dr. Maki, Dr. Kelman, and Dr. Davey, we are still not sure of the cause but the following associations have been noted: (1) the phenomenon usually occurs in orchards on heavier soils; (2) fungal mycelia have been isolated in some affected trees but by no means in all of them; (3) there is an unusual, dramatically

Fig. 5. Damage from ice and snow was remarkably light considering the amount of initial distortion. The orchard pictured is Kimberly-Clark's in Alabama, courtesy of Walt Chapman. Note the upright terminals of certain clones that did not bend from the snow.

excessive taper of the trunk; (4) it sometimes appears in a clonal pattern about five years after grafting, although it lacks the typical swollen, saddle-type overgrowth of an incompatible graft; (5) affected trees "break down" in growth, the leader dies back, the foliage has a "poodle tail" look, and sometimes the trees die (Fig. 7); and (6) flowering is usually heavy on the affected trees. This trouble has shown up in about seven loblolly pine orchards but has been widespread in only one. We are continuing tests and observations in an attempt to determine the cause.

Seed Production Areas:

Seed production areas have not been a major objective in the Cooperative Program, although a number have been established and are producing large amounts of seed. Several have been registered in states where seed certification is practiced. Georgia Kraft Company has been most active the past year and has established several new seed production areas (Fig. 8). This company, like others who have worked with seed production areas, finds it difficult to locate suitable stands. Experience of companies such as Continental Can Company, Inc., International Paper Company, and West Virginia Pulp & Paper Company has shown that the seed cost from seed production areas is not prohibitive - in fact, seed are larger, pounds of seed per bushel of cones are greater, and percentage of germinable seed is higher than for standard commercial seed.

Reported results of genetic gains from seed production areas are sketchy but have been greater than hoped. For young stands of 5 to 8 years, gains of 15% in volume production have been reported; it must be remembered, however, that perhaps the greatest value of seed production areas is to provide a reliable source of seed from the proper geographic area.

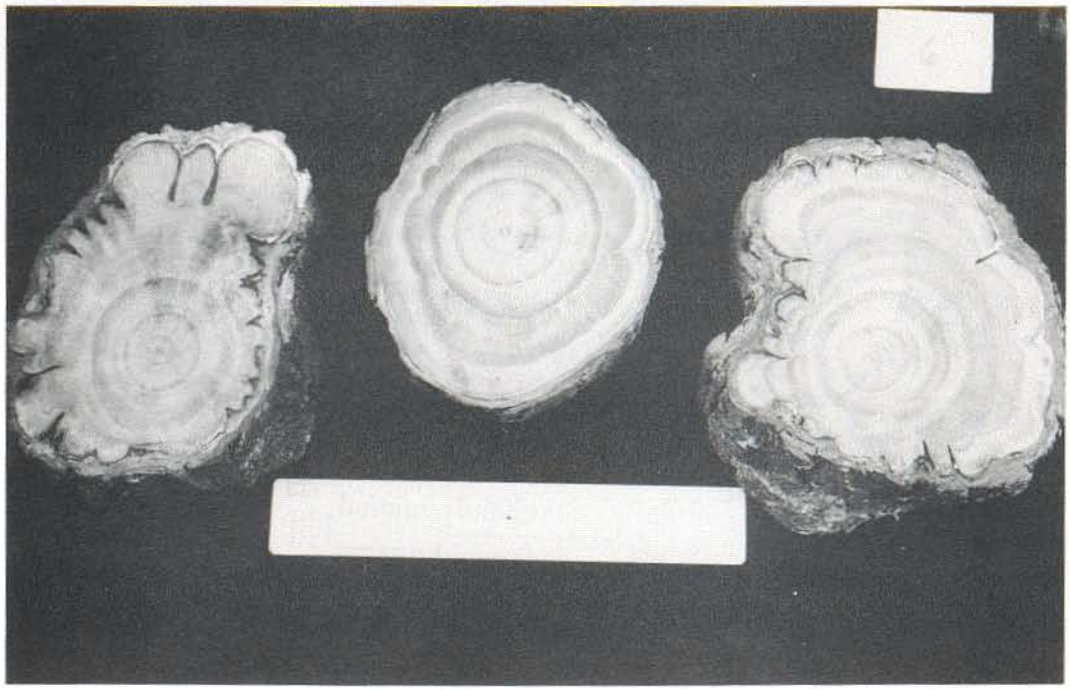

Fig. 6. Cross sections of the stock of grafts with unusual dying and fluting of the trunk are illustrated. The middle section is of the graft of the affected plant, which occurs just above the graft union. The sections to either side were obtained from the stock, just below the graft union. Such deformities have been found in all areas of the Southeast - the ones pictured came from the Kimberly-Clark Corporation orchard in Alabama. Note the fluting present in the stock and essentially absent in the graft.

Fig. 7. Typical breakdown of the fluted trunk, excessively tapered trees. Note the absence of a leader and the tufted appearance of the foliage. Cross section of the trunk of this tree growing in the Kimberly-Clark orchard has the appearance as shown in Fig. 6.

Long-Term Research Orchards:

As a logical follow-up to the establishment of the current production seed orchards, first steps are already being taken to obtain the necessary plant material for development of future orchards with different and better qualities. Mr. Ron Woessner, graduate student from West Virginia, has made a number of crosses in several seed orchards, combining loblolly pine from Texas, Louisiana, Tennessee, Georgia, South Carolina, North Carolina and Virginia. His crossing pattern is designed to give combinations among greatly differing "geographic strains" of loblolly pine and thus to produce crosses with diverse genetic combinations. From these crosses, new and (hopefully) good combinations will be selected to comprise new seed orchards or to improve the quality of current orchards. Such wide crossing within a species is difficult, long-term, and very time consuming, but most geneticists feel that this is one of the best methods of obtaining additional genetic improvements.

The crossing phase of seed orchard development and research aimed at producing new and better combinations will grow increasingly important in the Cooperative Program. It is easily in the realm of possibility that certain combinations will have outstanding growth rates, high quality of wood, or both, and will exceed by a considerable margin the gains obtainable from the first, simple, selection system applied to the current production orchards. If this anticipated outcome proves to be so, the use of genetics in forestry may have much greater utility than we had reason to hope, particularly since the gains through simple selection already have so greatly exceeded first estimates.

Hybridization Program:

The hybridization program initiated by Union Bag-Camp Paper Corporation is developing on schedule and has now been enlarged through work undertaken by West Virginia Pulp & Paper Company. This program is under close surveillance of Dr. Saylor, who is helping to coordinate the breeding work at N. C. State. He

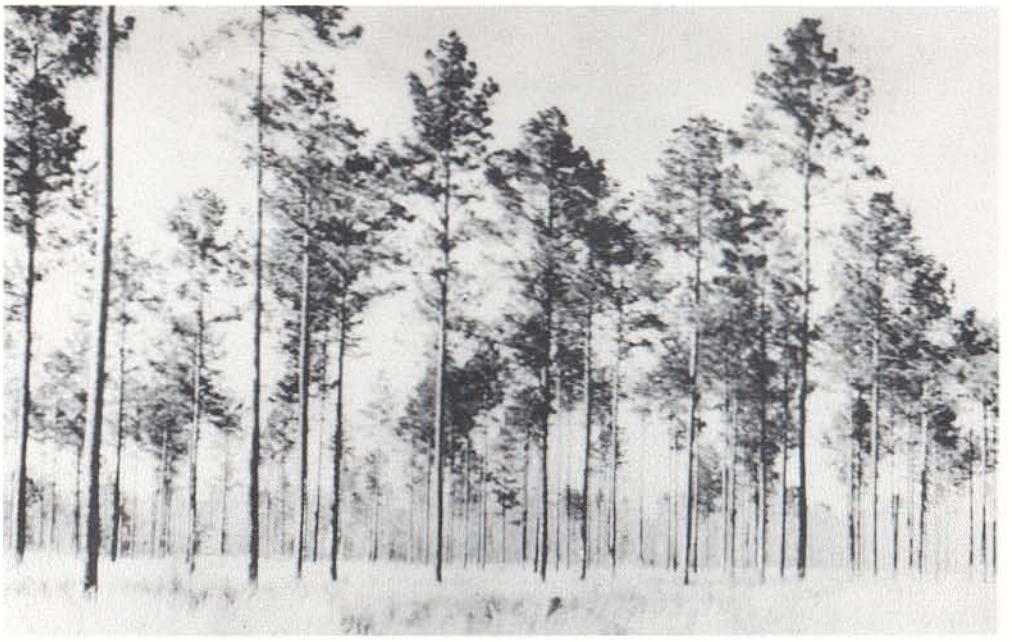

Fig. 8. A certified seed production area established by Georgia Kraft Company in central Georgia. Suitable stands for seed production are very difficult to find.

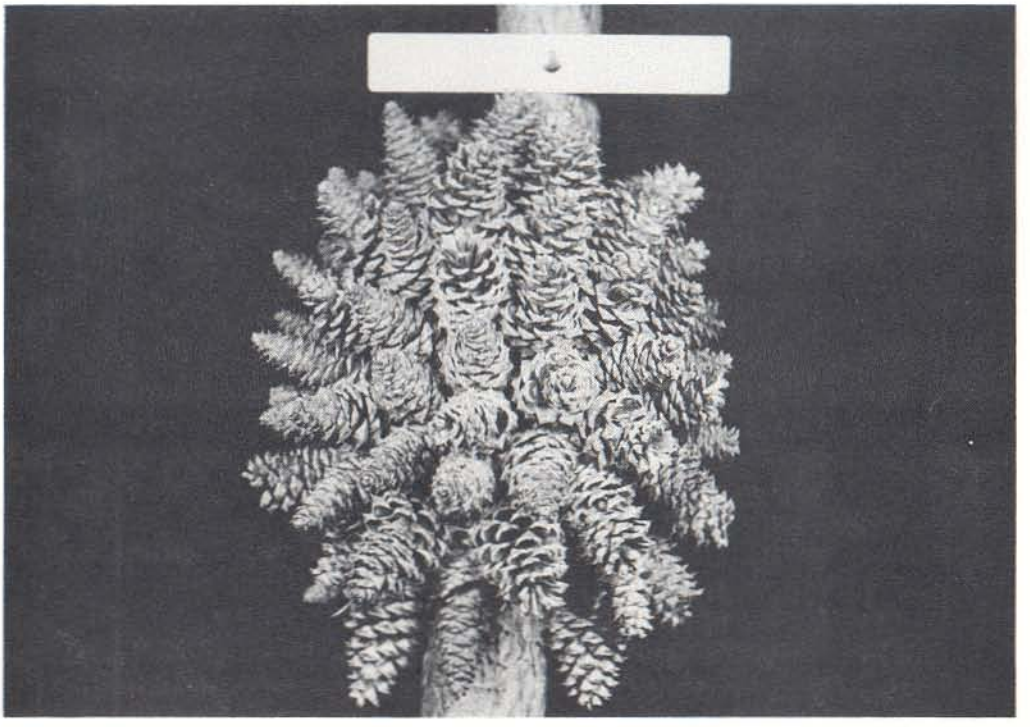

Fig. 9. In working intensively with any species, freakish-appearing events are often observed. The cone formation on loblolly pine shown above is illustrative of the odd, and the bizarre, phenomena that the many members of the Cooperative Program occasionally encounter. The cone cluster was found by L. T. Easley, West Virginia Pulp & Paper Company. Other oddities of nature frequently show up: for example, West Virginia Pulp & Paper Company reports one clone in which cones mature in one year instead of two, but unfortunately only seed wings and no sound seed are produced.

reports that several test crosses have been completed and that several major crosses have been made this year. Success of the test crosses cannot yet be ascertained, since the seed from them have only now become available for planting. The crosses anticipated as a result of completed hybridization work in several of the company seed orchards, as well as at N. C. State, are listed in Table 1.

Table 1. Crosses in the Hybridization Study

Cross	Status
Slash x pond*	Crosses completed
Slash x sand*	Crosses completed
Slash x drought resistant loblolly1/	Major crosses made this year (min. of 120 bags)
Slash x drought resistant longleaf	Major crosses made this year (min. of 120 bags
Loblolly x Virginia*	Crosses completed
Loblolly x pitch	Major crosses scheduled for 1965 (selected pitch pollen collected this year)
Slash x swamp loblolly*	Major crosses made this year (min. of 120 bags)

*Includes also the reciprocal cross.
1/Pollen obtained from Dr. van Buijtenen, Texas Forest Service, College Station, Texas.

WOOD STUDIES

During the past year investigations on wood quality have increased in tempo and depth, surpassing the activity in any preceding year. A major development has been the initiation of a number of studies by several companies with their own personnel using their own laboratories. This report will not discuss the industrial research - only the studies in which all or part of the wood analyses have been done at N. C. State. It should be mentioned, however, that the over-all results of the industry studies, some of which have not been published, have been excellent and have greatly enhanced our knowledge of wood, of wood variation, and of the

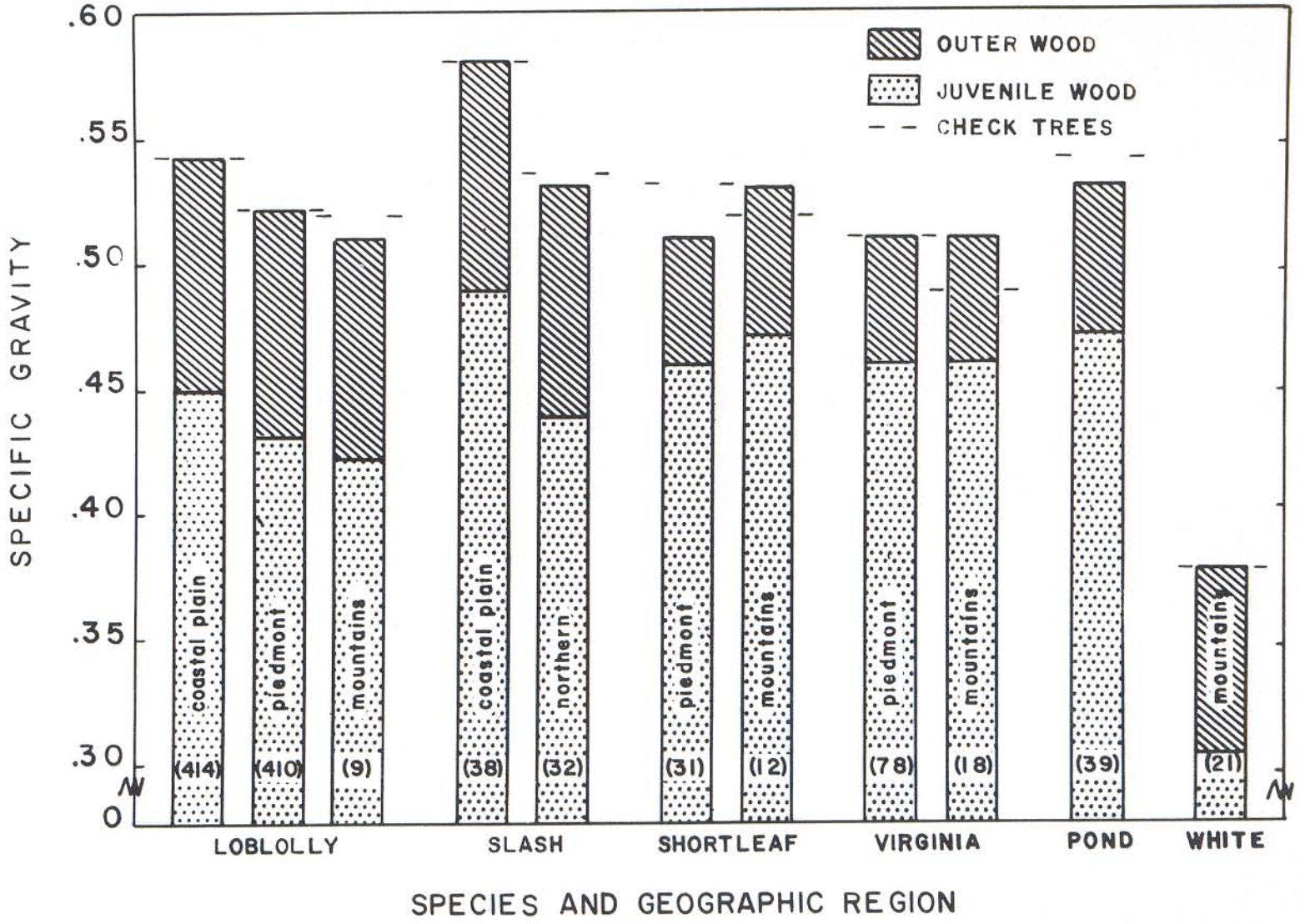

Fig. 10. Bar graphs of specific gravities by species and physiographic region for all trees graded for the seed orchards. Numbers of trees represented are shown in parentheses at the base of the bar. The line at the top of the dotted portion represents the average juvenile wood specific gravity, and the line at the top of the superimposed cross-hatched section represents the mature wood specific gravity. The dashed lines represent the average mature specific gravity for the check trees, of which there were five for every select tree.

effect of wood quality on the final product. As an example, the cooperative study by the International Paper Company and the Wood Science & Technology Department at N. C. State[1/] on a sample of trees from the heritability study gives answers to questions vitally needed for proper application of genetics to improvement of wood as a raw material for industrial uses.

As a feature of the Eighth Annual Report, a summary was made of specific gravity and tracheid lengths for all trees selected for seed orchards in the Cooperative Program. These have been recorded by species and physiographic region both for core- and outerwood (Fig. 10) and for the tracheid length of summerwood at the 15th and 30th annual ring (Fig. 11).

The Corewood Study: (International Paper Company)

Field work and most analysis of data for the first phase of this cooperative study have been completed. This phase dealt with the effect of age, spacing and site on the proportion and qualities of corewood and outerwood. Results have been converted to an acreage basis, yielding information to determine dry wood production for stands harvested at different ages, grown under different conditions. Regression equations were developed to convert breast height values to total tree values; correlations between breast height and total tree values were high for both specific gravity (Fig. 12) and tracheid length. Part of the wood analysis for this study was done by Mr. Ed Wheeler from Oklahoma State University, who studied at N. C. State under a College Teachers' Research Participation summer grant from the National Science Foundation. Ed worked on tracheid width as well as on tracheid length.

1/ Barefoot, A. C., Hitchings, R. G., and Ellwood, E. L. 1964. Wood characteristics and kraft paper properties of four selected loblolly pine trees. Part I. The effect of fiber morphology under identical cooking conditions. TAPPI Forest Biology Committee, Mobile, Ala., November 21, 1963 (In press).

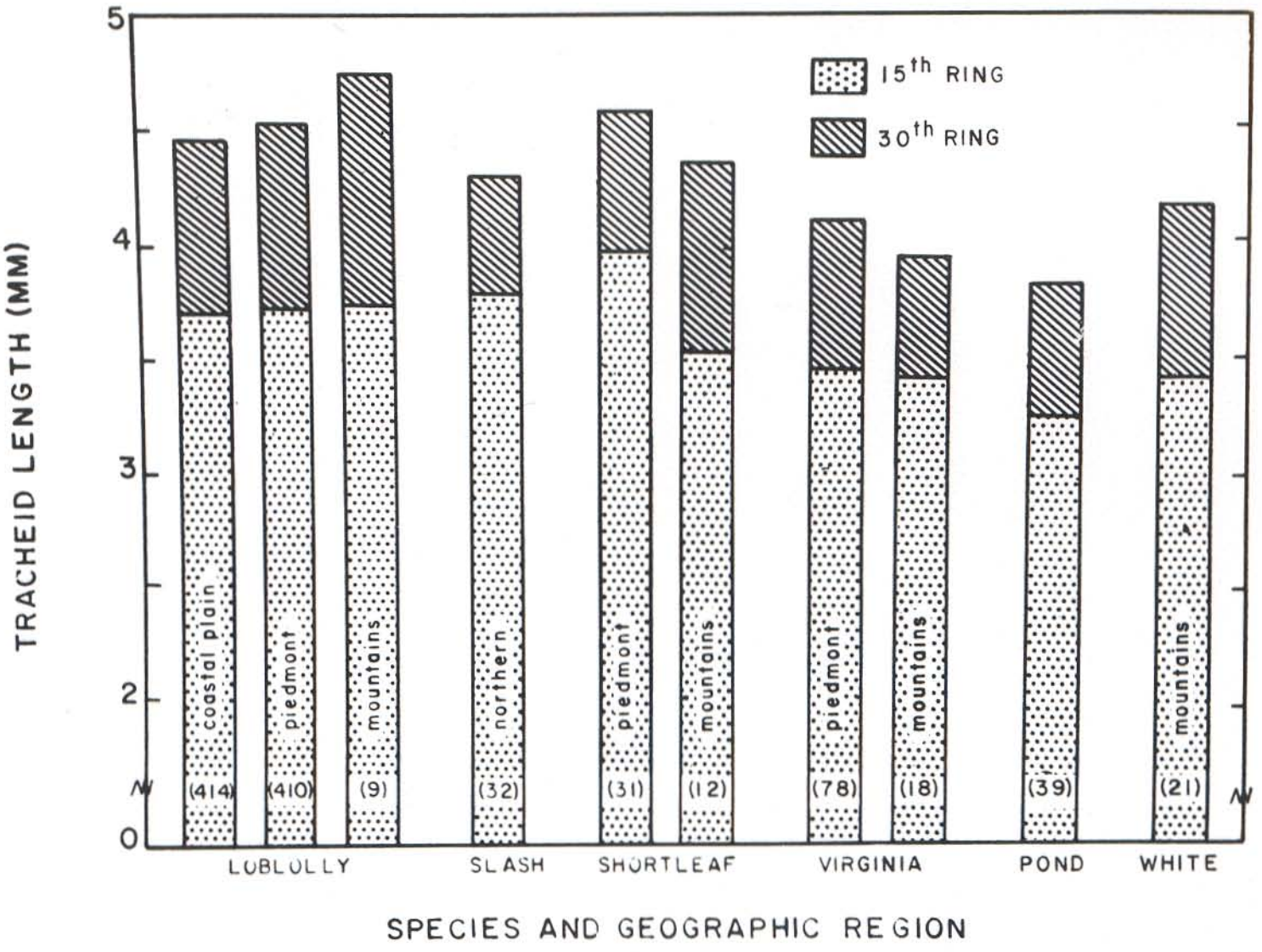

Fig. 11. Bar graphs of tracheid lengths by species and physiographic region for all trees graded for the seed orchards. Numbers of trees represented are shown in parentheses at the base of the bar. The line at the top of the dotted portion indicates the 15-year tracheid length, and that at the top of the superimposed cross-hatched portion indicates the additional length of the 30-year tracheid. Only average values are shown - variation among (and within) trees is considerable.

The second phase of the IP corewood study includes collection of seed from trees with unusual corewood values to see how strongly these traits are inherited. There is considerable emphasis in the industries on shortening rotation ages, but at the risk of a loss in fiber yield per unit volume of wood produced. However, some trees in this study and also in others have shown high yields even near their center; if such trees were regularly cultured, volumes would then reflect more directly actual productive capacity, regardless of stand age.

Species Yield Studies: (Continental Can Company)

The relative yields from the species of southern pines have been a subject of much discussion. Published results often can be misleading because species comparisons included trees of different ages, from different sites, or growing at different stand densities. To eliminate interference from these sources of variation, Don Cole searched and found an area of approximately 15 acres in which four major southern pine species were growing intermixed in an even-aged stand. A determination was made of the unextracted specific gravity, extracted specific gravity, amount of extractives, tracheid lengths, growth rates, cellulose yields and other factors for all four species in an effort to gain better information about them. Data on specific gravity and extractives are summarized in Table 2. Note the difference in resin content, especially in the corewood, among the four species.

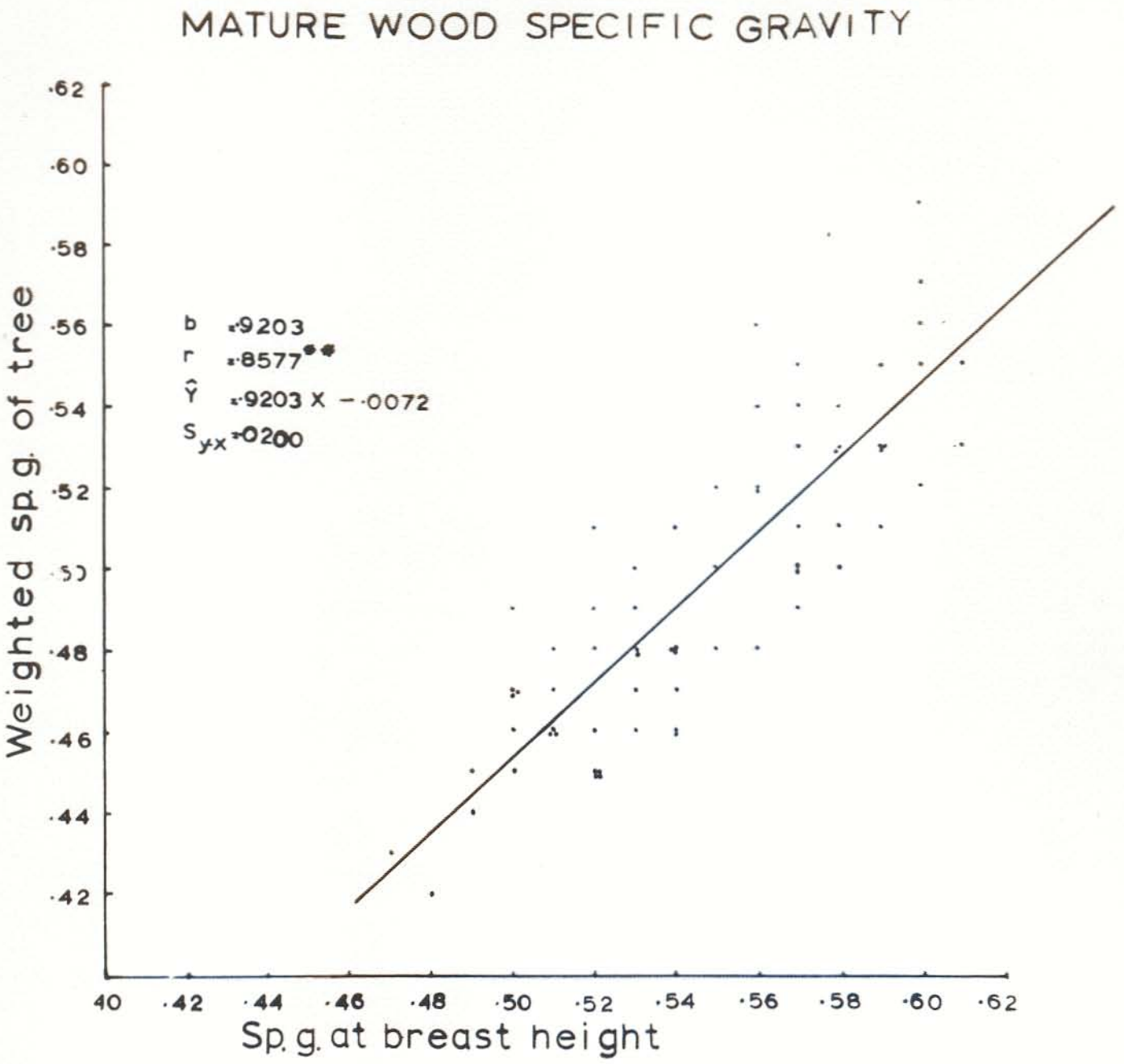

Fig. 12. In order to convert individual tree data to acreage values it is essential to establish the relationship between breast height and total tree values. The regression shown here is based on data from the corewood study with the International Paper Company. It enables conversion of breast height to total tree values with sufficient accuracy for practical purposes.

Table 2. Comparison of specific gravity and resin yield of wood of four pine species growing intermixed in an even-aged stand[1/]

Species	Wood Specific Gravity				Resin Content Based on Extracted Dry Weight	
	Unextracted		Extracted[2/]			
	Core	Outer	Core	Outer	Core Pct.	Outer Pct.
Slash	.46	.54	.44	.53	5.0	1.8
Loblolly	.43	.56	.41	.55	2.9	2.0
Longleaf	.51	.54	.44	.53	13.6	2.4
Pond	.42	.48	.40	.47	6.1	2.6

1/ Fifty trees of each species were analyzed except for pond pine where only ten trees were available.

2/ Extraction by alcohol-benzene.

Special Long-Fibered Loblolly: (Riegel Paper Corporation)

Tracheid length has always been considered an important wood quality for the pines, especially for quality papers. The Riegel Paper Corporation's concern with tracheid length has resulted in the initiation of a cooperative project to breed loblolly pines with extra long tracheids. This effort was suggested by Kirk Semke and Ernie Thornton and has developed into a truly cooperative approach involving the Woodlands Department, the Mill Technical Division, and members of the Cooperative Tree Improvement Program. Trees with long tracheids from Riegel's seed orchard are crossed with the longest tracheid trees from the orchards of neighboring company seed orchards. A number of crosses have already been made for this project, which, if they prove out, will be used as a source of seed for loblolly pine with long tracheids.

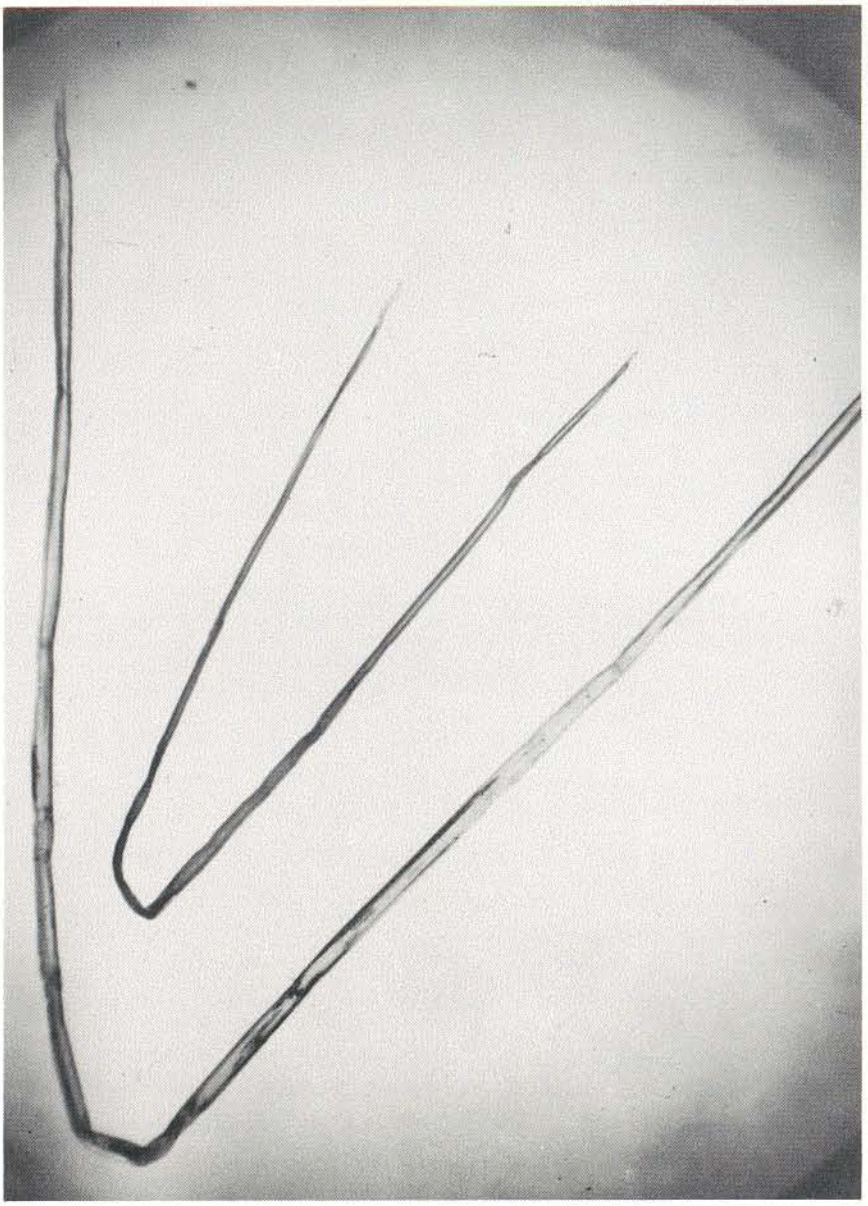

Fig. 13. Some of the Mexican pine samples showed unusually long tracheids. Illustrated is a long tracheid from P. michoacana compared to a normal one in loblolly pine (each x 40).

Wood of the Mexican Pines: (Six Cooperating Companies)

Wood specimens of the Mexican pines were obtained from each tree from which seed were collected. Specific gravities and tracheid lengths for the various species and races have been determined and will be reported in a publication just now going to press. Variations in wood of the Mexican pines were very great, as is indicated in preliminary data in Fig. 13. One species (P. michoacana) did not appear to have typical corewood, and the extracted specific gravity was as high near the center of the tree as it was a number of rings from the pith (Fig. 14).

Inheritance of Cellulose Yield: (International Paper Company)

Initial tests made on three-year-old trees from the International Paper Company-N. C. State Heritability Project indicated a surprisingly high genetic component for cellulose yield. These data will not be published at this time but a full-scale analysis will be made of four-year-old progeny in 1964. Results from the four-year study should indicate whether cellulose yields are inherited in a manner that will enable the development of high cellulose-yielding strains of pines.

Variation in the Wood of Sweetgum and Yellow Poplar:

Two studies have been completed on wood variation of sweetgum and yellow poplar by graduate students Charles Webb and Fred Taylor. Both studies are being prepared as Ph. D. dissertations; most interesting wood property variations, interrelationships of wood properties, and the effect of growth and environmental factors on wood qualities were found. In addition, portions of the Master's theses of Jim Roberds and Bob Kellison deal with inheritance and variation of wood qualities in sweetgum and yellow poplar. These four studies give most useful information about wood of these two important hardwoods (Fig. 15).

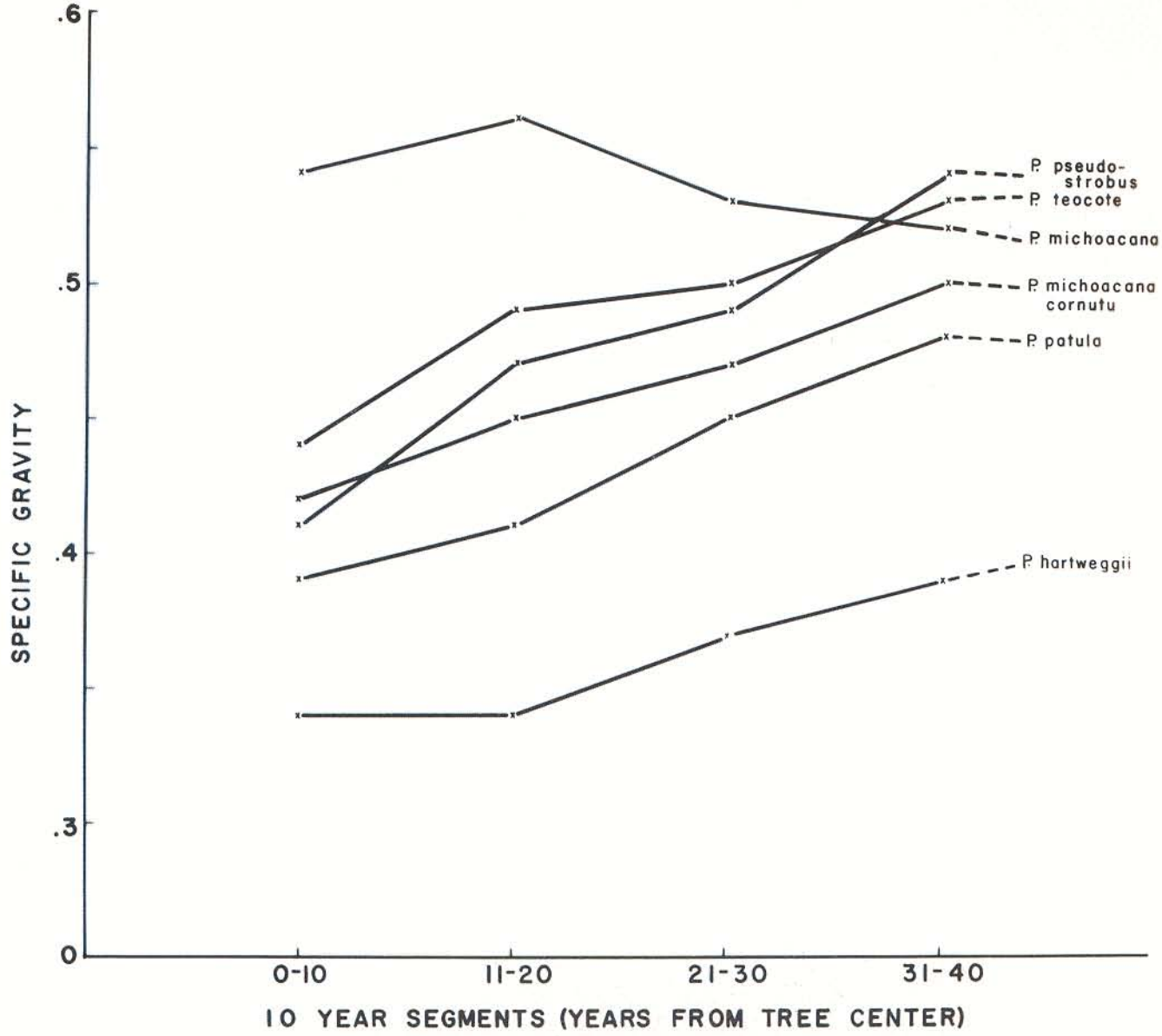

Fig. 14. Change in specific gravity of wood of some Mexican pine species from the center of the tree outward is illustrated. Note that P. michoacana does not show the normal pattern, the wood near the center of the tree being similar to that near the bark. Most trees were over 40 years of age and the dotted line shows the trend toward older ages. Each value represents the average of five trees.

Effect of Fertilizer on Wood of Loblolly Pine:

Over ten years ago a comprehensive study of the effects of fertilizers on the growth of loblolly pine was initiated. The design of this experiment was such that it enabled a good assessment of the effects of fertilizers on wood properties. An earlier preliminary report[1/] showed such relationships to be strong - on the basis of these findings Clayton Posey has completed a detailed analysis of the effects of fertilizers on growth and wood qualities for his Ph. D. dissertation. Results obtained are very interesting: (1) growth increase caused by fertilization of 12- and 16-year-old loblolly on a good site was substantial and related especially to nitrogen applications; (2) specific gravity of wood and tracheid length on the average were lowered following fertilization; (3) cell dimensions and wall thickness were altered, mostly in a direction favoring the production of high quality papers; (4) some trees reacted in a manner different from the average - for example, 24 of the trees studied had longer tracheids rather than shorter ones following fertilization. Such individual tree reactions indicate the possibility of selecting strains of trees particularly responsive (in the desired way) to fertilization.

Inheritance of Wood Properties: (International Paper Company)

First detailed results on inheritance of wood qualities other than cellulose as found in the Cooperative International Paper-N. C. State Heritability Study were published this year[2/]. Inheritance of specific gravity was found to be very high. Genetic control of diameter growth in trees decreased from the second to third year. It was found that the fastest-growing trees within a family tended

1/ Zobel, B. J., Goggans, F., Maki, T. E., and Henson, F. 1961. Some effects of fertilizers on wood properties of loblolly pine. Tappi 44(3):186-192.

2/ Stonecypher, R., Cech, F. and Zobel, B. J. 1964. Inheritance of specific gravity in two- and three-year-old seedlings of loblolly pine. Tappi (In press).

Fig. 15. Progeny testing requires a lot of time and effort. The yellow poplar shown are part of Bob Kellison's thesis research. Seedlings are grown in the Clayton Nursery of the North Carolina Forest Service. In addition to growth and form, tests are made on wood properties of the progenies of 108 mother trees with which he is working.

to have the lowest specific gravities but certain fast-growing families were found that had high over-all specific gravities, indicating the possibility of combining both growth and specific gravity. Roy Stonecypher will report the results in more detail in his forthcoming Ph. D. thesis.

OTHER STUDIES

A number of studies are under way dealing with subjects other than the production of improved seed on a commercial scale or on wood. Special effort is expended in the field of quantitative genetics and much of the fundamental research effort falls in this category.

Heritability Study:

By far the largest and most intensive basic study in the Tree Improvement Program is the Cooperative International Paper Company-N. C. State-National Science Foundation sponsored heritability study. This research, devoted to quantitative genetic analyses of forest trees, has been described elsewhere[1/], and first results on wood properties were mentioned in the previous section of this report. The research has been done at the Southlands Experiment Forest of the International Paper Company under the direction of Dr. Charles Driver and Dr. Franklin Cech. In February Dr. Cech accepted an appointment as professor at West Virginia University, and he was replaced by Roy Stonecypher, who will soon be awarded his Ph. D. in quantitative forest genetics.

The heritability study has been partly financed by a National Science Foundation Grant which will expire in January, 1965. At that time funds to help continue this basic research will be made available as a part of the National

1/ Cech, F., Stonecypher, R. & Zobel, B. J. 1962. Early results from the cooperative loblolly pine heritability study. Proc. For. Gen. Workshop, Macon, Ga. Pub. #22, South. For. Tree Improvement Committee. pp. 64-68.

Institute of Health Grant given to N. C. State for quantitative genetic studies. Thus, this basic research on quantitative genetics of forest trees should continue uninterrupted. First major findings will soon be published as Roy Stonecypher's Ph. D. dissertation.

Details of the heritability study were described in earlier Annual Reports. It is sufficient to say now that the approximately 40 acres of open-pollinated tests, have, for the most part, grown well. Control crossing has been completed, and the last of the 53 male groups (1 male crossed to 4 females) has been planted. Approximately 25 acres of this material has been planted in the field and is surviving and growing well. A start on the vegetative phase has been made this year and will be intensified next year.

A number of other studies using control-pollinated seedlings have been made in excess of those needed in the N. C. State Design I. Several of these studies deal with wood and have been previously mentioned, namely, heritability of specific gravity, tracheid length, cellulose yields and growth. Also, special studies on disease resistance, root development and relation of wood properties to paper properties have been made. An assessment of inheritance of tree form and bole straightness will use the heritability plantings as a source of data. Basic research is planned on the degree, importance and effects of inbreeding and related matings on development of inheritance values and selection indices.

Reproductive Patterns, Genetics and Inbreeding in Sweetgum and Yellow Poplar:

A comprehensive analysis of the method of reproduction, how to control-pollinate, and the effect of selfing that takes place in sweetgum was the subject of the Ph. D. thesis of Dr. Dan Schmitt. His studies, partially financed by the National Science Foundation, provide the necessary foundation for continued and more intensive quantitative research on sweetgum. A study of genetic relationships within yellow poplar, using a diallel crossing pattern, has nearly been

completed by Kingsley Taft for his Ph. D. dissertation. Because of its somewhat restricted habitat preference, and dependence on insect-pollination, this species shows some indication of having a different breeding system than most forest trees and appears to have a considerable amount of self-pollination under natural conditions. Taft's studies are designed to give the first indication of yellow poplar's genetic system, enabling the forest geneticists to undertake a tree improvement program in a more efficient manner.

The Mexican Collections:

Collection and testing of Mexican pines was not designed as a basic study but as a trial to determine which, if any, species might grow reasonably well under various conditions in the South. The study was well described[1/] in Technical Report #18. Seedlings were grown in the Riegel, Hiwassee, and Kimberly-Clark nurseries. Growth, for the most part, was reasonably good until the winter cold, although the two high elevation species (P. rudis and P. hartweggii) had very little height growth and stayed in a semi-grass stage (Fig. 16), as illustrated by P. montezumae.

Although it was known that some species would not survive the cold weather, the seedlings were left through the winter in two of the nurseries. In the third they were lifted and stored before the severe freeze. It soon became obvious that freezing weather would take its toll. Several species such as P. douglasiana and P. oocarpa succumbed completely, while others such as P. michoacana browned up badly. More disturbing, some species such as P. montezumae survived the winter but were killed by the late spring freeze. Some of the more northern plantings now have only a few species still surviving. Unusual problems in storage

1/ (Members, 1962 collecting team). 1963. Collecting pine material in Mexico for provenance trials and wood studies. Tech. Rept. #18, School of Forestry, N. C. State. pp. 1-23.

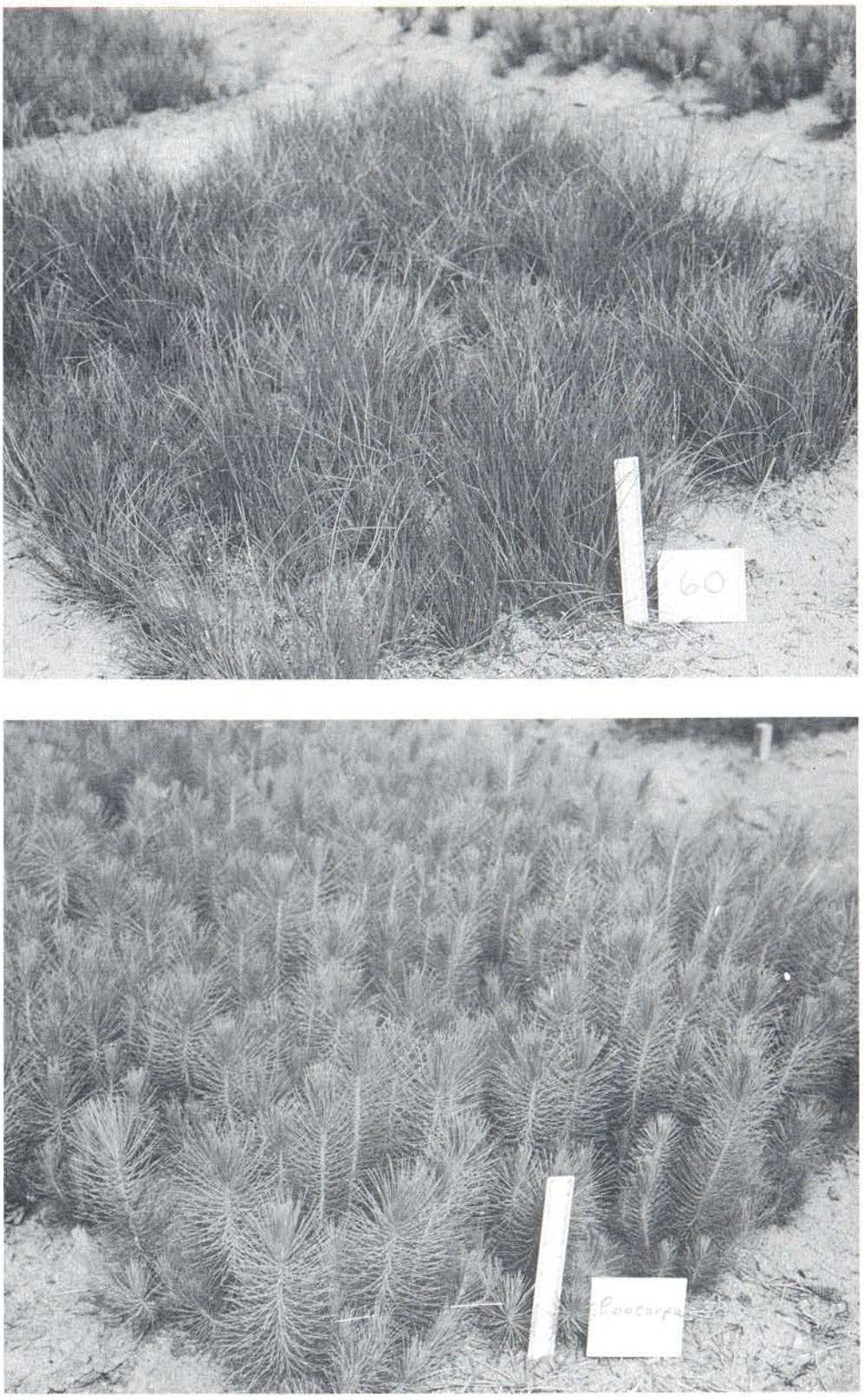

Fig. 16. Growth of the Mexican species was in most instances quite good in the nursery before injury and kill from freezing weather. No. 60 is P. montezumae, showing its typical grass stage. Note the lush growth and lack of secondary needles on the P. oocarpa. This species suffered very heavy freeze damage. Seedlings pictured are from the Riegel nursery.

developed, resulting in considerable loss of some species. Despite the losses to freezing weather and storage-induced deterioration, plantings were made in over 10 areas, with a total of 250 acres, from the tip of Florida to Virginia and West Virginia. Several plantings are also planned in Brazil and in Hawaii. All plantings are of the same design as developed by Saylor and thus can be compared directly.

The collection teams worked from northern Mexico to the central, nearly subtropical, regions. Unfortunately, there was a cone crop failure in the North so the bulk of collections were made from the warmer regions, undoubtedly a major factor in subsequent losses from cold when outplanted. One point emerges more clearly even than found from earlier collections from Mexico[1/], i. e., it is not the absolute temperatures that cause the damage as much as the temperature fluctuations and the stage of development of the seedling when the freezing temperature occurs.

It has already become abundantly clear that of the 17 species collected from various environments, only very few are adapted to conditions in the cooler portions of the Southeast. Of these species, even less appear to have reasonable growth rates; the high elevation species, especially, are very slow starters. In the milder climates in the South several species appear to have reasonable growth rates. Only time will tell how they react to insects, diseases and droughts, and what kind of wood they will produce.

Other Studies:

Space does not permit a complete listing of the many other studies under way, most of which are done by students. For example, Sam Land's research on salt tolerance has indicated (much to our surprise) that certain sources of loblolly pine appear to be more salt tolerant than pond pine near the Coast.

1/ Zobel, B. J. & Cech, F. C. 1957. Pines of Nuevo Leon, Mexico. Madroño, 14(4):133-144.

Carlyle Franklin's preliminary assessment of drought resistance of newly-germinated seedlings substantiates reports from Texas on older seedlings that a great amount of tree-to-tree variation in drought hardiness occurs as well as differences among seed sources. A small-scale test, made by Bro Kinloch, indicates that wood in and around fusiform rust galls has low specific gravity, with short, often multiple-forked, thin-walled tracheids.

Graduate Student Programs

As has been the policy in the N. C. State-Industry Cooperative Program, some funds are expended for, and a considerable quantity of the basic research is done by, graduate students, working either directly with the Tree Improvement Program or working on projects related to or of interest to it.

	Student	From	Present Location	Research Project
1.	Walter Beineke	Duke	N. C. State	Genetics of transplantability
2.	Miguel Caballero	Mexico	N. C. State	Mexican pines
3.	Jaime Castillo	Colombia	N. C. State	Genetics of coffee
4.	Jon Dietrichson	Norway	N. C. State	Special non-degree student (wood quality)
5.	Ke Won Kang	South Korea	N. C. State	Relationship of loblolly and pond pines
6.	Robert C. Kellison	West Virginia U.	N. C. State	Yellow poplar variation
7.	Bro Kinloch	N. C. State	N. C. State	Resistance to Cronartium fusiforme
8.	Fred Ledig	Rutgers	N. C. State	Photosynthetic efficiency
9.	R. L. McElwee	N. C. State	N. C. State	Pollen flight
10.	Garth Nikles	Australia	N. C. State	Pines of the Caribbean
11.	Brooks Polk	U. of Missouri	U. of Missouri	Control pollination of pine
12.	Clayton Posey	Oklahoma State U.	Auburn University	Fertilizer effect on wood
13.	James H. Roberds	N. C. State	N. C. State	Quantitative genetics (sweetgum)
14.	Dan Schmitt	U. of Florida	Southern Institute of Forest Genetics	Reproduction and selfing in sweetgum
15.	Tony Shelbourne	England and N. Rhodesia	N. C. State	Inheritance of straightness and form
16.	Roy Stonecypher	N. C. State	International Paper Company	Quantitative genetics (pine)
17.	Kingsley Taft	U. of Michigan	T. V. A.	Genetics of yellow poplar
18.	Fred Taylor	N. C. State	U. of Missouri	Wood of yellow poplar
19.	Charles Webb	N. C. State	U. S. For. Service, Macon, Georgia	Wood of sweetgum
20.	Ronald Woessner	West Va. U.	N. C. State	Wide crosses within loblolly pine

The students listed on the previous page are guided by several professors with different specialties in forestry. These include Dr. Perry, Dr. Saylor, Dr. Kelman, Dr. Duffield, Dr. Namkoong, Dr. Maki and Dr. Zobel. Six of the students listed have nearly completed requirements for the Ph. D. Degree and have taken jobs. In addition, three have nearly completed Master's Degrees, two of whom will continue their studies toward the Ph. D. Degree.

Students are financed through a number of sources in addition to the several assistantships supplied by Industry funds. Included are the National Science Foundation and National Institute of Health Grants, as well as special grants made available for students by the Kellogg Foundation, Ford Foundation, and Rockefeller Foundation.

PUBLICATIONS

Previous annual reports have listed publications related to and of interest to the Cooperative Tree Improvement Program. During the past year the following were published or submitted for publication:

1. Cech, F. C., Stonecypher, R. & Zobel, B. J. 1962. Early results from the cooperative loblolly pine heritability study. Proc. Forest Genetics Workshop, Macon, Ga. pp. 64-68. Pub. #22, Southern For. Tree Impr. Committee.

2. Maki, T. E. 1963. Proceedings, Special Field Institute in Forest Biology. School of Forestry, N. C. State. pp. 1-248.

3. McElwee, R. L. & Zobel, B. J. 1962. Some wood and growth characteristics of pond pine. Proc. For. Genetics Workshop, SAF, Macon, Ga. Pub. #22, Southern For. Tree Impr. Committee. pp. 18-25.

4. McElwee, R. L. 1963. Genetics in wood quality improvement. Presented at Gulfport, Miss. Southern Forest Tree Improvement Committee. June, 1963.

5. Namkoong, G. 1963. The statistical analysis of introgression. Ph. D. Thesis. pp. 1-87.

6. Perry, T. O. 1961. Physiological-genetic variation in plant species. Sixth Southern Conference on Forest Tree Improvement. (Proceedings). pp. 60-64.

7. Perry, T. O. 1962. Racial variation in the day and night temperature requirements of red maple and loblolly pine. Forest Science 8:336-344.

8. Perry, T. O. 1963. Differences in protein constituents in dormant and vegetative pine tissue. AIBS Bulletin 13:73-75.

9. Perry, T. O. & Roberts, A. Y. 1964. Volume formulas for loblolly pine seedlings in the vicinity of Raleigh, North Carolina. Jour. of For. 62:185-187.

10. Perry, T. O., Wang, Chi Wu, and Schmitt, D. M. Photoperiod, growing season, and height growth of loblolly pine provenances. Silvae Genetica. (In press)

11. Saylor, L. C. & McElwee, R. L. 1963. Collecting pine material in Mexico for provenance trials and wood studies (Members, 1962 collecting team, mss. prepared by L. C. Saylor & R. L. McElwee). Tech. Rept. No. 18. pp. 1-22.

12. Schmitt, D. M. 1964. Self-sterility in sweetgum (Liquidambar styraciflua L.) Ph. D. thesis, N. C. State. pp. 1-104.

13. Stonecypher, R., Cech, F. & Zobel, B. J. 1964. Inheritance of specific gravity in two- and three-year-old seedlings of loblolly pine. Tappi. (In press)

14. Zobel, B. J. 1963. Breeding for wood properties in forest trees. World Consul. of For. Gen., Stockholm. pp. 1-31 (Chap. 7 of Final Report).

15. Zobel, B. J. 1964. Variation in specific gravity and tracheid length for several species of Mexican pine. (In press)

16. Zobel, B. J., Cole, D. E. & Stonecypher, R. W. 1962. Wood properties of clones of slash pine. 1963 Proc. For. Gen. Workshop, SAF, Macon, Ga. Pub. #22, Southern For. Tree Impr. Committee. pp. 32-39.

17. Zobel, B. J. & McElwee, R. L. 1964. Seed orchards for the production of genetically improved seed. Silvae Genetica. (In press)

COOPERATING ORGANIZATIONS

Organization	Working Units and States
Albemarle Paper Mfg. Co. (Roanoke Rapids Div.)	N. C., Va.
Catawba Timber Company (Bowaters Carolina)	S. C., N. C.
Champion Papers, Inc.	S. C., N. C.
Chesapeake Corp. of Virginia	Va., Md., Del.
Continental Can Co.	Savannah Div. - S. C., Ga. Hopewell Div. - N. C., Va.
Georgia Kraft Company	Ga., Ala.
Hiwassee Land Company (Bowaters Southern)	Tenn., Ga., Ala., Miss.
International Paper Company	Coastal Plain - S. C., N. C. Piedmont - S. C., N. C.
Kimberly-Clark Corporation (Coosa River Div.)	Ala.
Marathon Southern Corp.	Ala.
North Carolina Forest Service	N. C.
Riegel Paper Corp.	N. C., S. C.
South Carolina State Commission of Forestry	S. C.
Tennessee River Pulp & Paper Co.	Tenn., Ala., Miss.
Union Bag-Camp Paper Corp.	Savannah Div. - Ga., S. C. Franklin Div. - N. C., Va.
West Virginia Pulp & Paper Co.	South - N. C., S. C. North - Va., West Va., Ohio
Weyerhaeuser Co. (North Carolina Div.)	N. C., Va.