FIFTH ANNUAL REPORT

N. C. STATE - INDUSTRY COOPERATIVE

FOREST TREE IMPROVEMENT PROGRAM

School of Forestry
North Carolina State College
Raleigh

June, 1961

FIFTH ANNUAL REPORT

N. C. STATE - INDUSTRY COOPERATIVE

FOREST TREE IMPROVEMENT PROGRAM

Introduction

Activities of the past year have far exceeded those of the previous years of the cooperative program. Previous Annual Reports have emphasized tree selection, seed orchard establishment, basic research contribution of the students, and changes in direction and scope of the Cooperative Program. This, the Fifth Annual Report, will briefly summarize the work underway, with emphasis on results achieved to date.

THE COOPERATIVE PROGRAM

Industrial support continues as it has in the past, with added impetus given by two welcome developments: (1) as of January 1, 1961, Catawba Timber Company (Carolina Bowaters) joined the program and has initiated a group of activities, such as location and preparation of a seed orchard site, selection of trees for their seed orchard, and consultation regarding wood properties. (2) The "cost-of-living" raise, suggested at the June, 1960 Advisory Committee Meeting, was implemented as of January 1, 1961.

Tree Selection and Seed Orchards

Tree selection for use in seed orchards continues for most companies, but for several the task is essentially complete, at least for the time being and for loblolly pine. The percentage of new trees graded has sharply shifted from loblolly to Virginia pine, a species in which four of the

Figure 1. One of the most difficult problems is to find loblolly pine trees that are straight. The tendency toward a spiral-twist is rather high in this species and it is inherited quite strongly. This tree is one of the straight trees found on the industry selection program.

cooperative companies have an increasing interest; its good wood, plus ability to yield heavily with short rotations on the poorer sites, has been a major factor underlying this shift of interest and effort. A considerable number of pond pine selections were also made. As indicated in last year's report, initial work has been done on selecting hardwoods, namely yellow poplar and sweet gum. Approximately fifty trees of these species have now been graded and accepted for use as parent trees in seed orchards.

The seed orchard phases have progressed well, and 31 separate orchards have now been established. As the grafted trees grow older, problems have arisen, two of which seem especially serious. (1) Cronartium fusiforme has appeared on the rootstock, often buried in the mulch, or actually underground. One orchard has about 25 per cent of the rootstock infected; from the position of the infection it would appear that the stock was infected prior to the deep planting of the grafting rootstock. No Cronartium fusiforme has appeared on the grafts themselves. (2) Incompatibilities between graft and rootstock have appeared for certain clones; overall, about 1 clone in 10 appears to have some degree of incompatibility. This usually does not show up until the second or third year following grafting, when overgrowth of the scion above the stock takes place, the roots of the stock plant die, and eventually the whole graft dies.

The losses due to Cronartium fusiforme and incompatibilities could be very serious if the grafts were made at the ultimate spacing (30' x 30'), or if the minimal number of clones (15) had been used. Very fortunately, however, most companies planted 15' x 15', or 15' x 30' as recommended,

Figure 2. Species other than loblolly are being worked on. Here, Bill Keithley of Bowaters (Hiwassee Land Co.) is looking at a fine two-year-old graft of Virginia pine. This species grafts rather easily, but the job is time-consuming and frustrating because of the very fine branches used as scions and the difficulty of getting a stock-scion match.

Figure 3. One of the handsomest of all grafts is shortleaf pine. This three-year graft at Bowaters Seed Orchard is a beauty. Many of the shortleaf clones have this good form. This species grafts in a manner similar to loblolly pine.

Figure 4. The most serious losses in our seed orchards have been from stock-scion incompatabilities. This loblolly graft, though still healthy and vigorous, has the typical overgrowth of stock over scion. From past experience, it will almost surely die. About one out of ten clones has shown such incompatability to some extent.

and most have more than 15 clones in each orchard. Under these circumstances the dead grafts can be removed from the seed orchard without the necessity of replacing them.

Yellow poplar and sweet gum seed orchards were started this year. This new activity finds us starting from "scratch", for we need simultaneously to learn how to handle this material, how to graft or root it, and how to handle it in the field. Hence, establishing these hardwood orchards requires no small expenditure of contemporaneous experimental effort to assure a reasonable degree of success. Considerable grafting of these two species has been done, but it is too early to feel sure of positive results. Approximately 600 field grafts of these hardwoods were made by Weyerhaeuser Co. (N. C. Division) and some greenhouse grafts were made at N. C. State.

Progeny Testing

A substantial acreage of open-pollinated progeny is already planted on company lands, and this is being expanded as seed becomes available. Establishment of these test plantings has gone forward rather slowly because many of the select trees are in dense stands, and without release or other measures tend to produce light and irregular cone crops.

The design to be used for testing and outplanting the seed orchards was developed during the past year, by means of much sweat, thought, and help from the quantitative statisticians. The first draft of the plan was presented at a "workers' meeting" hosted by the International Paper Company and the West Virginia Pulp and Paper Company at Georgetown, South Carolina. The final plan was written mimeographed, and sent out to the companies

Figure 5. Grading sweet gum was a new and interesting experience. Some very fine stands were searched by personnel of N. C. Pulp. This stand, several thousand acres in extent, was nearly pure sweet gum. The selected trees averaged 60 years of age and were over 100 feet tall.

Figure 6. Some emphasis in the selection program is now geared toward sweet gum and yellow poplar. Good phenotypes are hard to find in these species just as they are in pine. The top of the tree in the center of the photograph shows a large yellow poplar with very fine, short branches.

after changes were made based on comments received at this meeting and further consultation with the statisticians.

Since many of the seed orchards are flowering fairly well this year, as they did last year, a number of additional control crosses have been made. With luck, some of the control-pollinated seed will be available for planting one or two years from now. A number of companies have already designated the areas where the control progeny tests will be made. These test areas are to be typical of land owned by the company, and will be handled similarly to commercial plantings. After the trees on these test areas have served their purpose, they will be harvested just as trees in any other plantation. One of the main points to keep in mind is that these areas are not to be regarded as "preserves" but are available for harvest in the regular manner, when the relevant observations and measurement program on them has been completed.

Wood Studies

Much basic research on wood is being done and will be described later in this report. Work continues on the analysis of specific gravity and related wood qualities for the select trees. In line with expectations expressed at last year's advisory meeting, we have nearly completed determining tracheid lengths for each company's select trees. As had been suspected, the individual tree variability turned out to be large. Outward appearance gave no hint of tracheid length. At 30 years short tracheid loblollies (with shortest of 2.6mm) looked outwardly identical to those with long tracheids (longest being over 6mm).

Figure 7. Virginia pine has been looked on as a weed species by many southern foresters. In recent years, however, its good productive capacity on poor sites and short rotations coupled with its good wood has caused an increase of interest in this species. This Virginia pine tree, being held up by Dave Sowers of the West Virginia Pulp & Paper Company, is growing in West Virginia and will be used in their seed orchard. Several companies have seed orchards of Virginia pine. Much to everyone's surprise, some of the very best Virginia pine were found southwest of Birmingham, Alabama by Walter Chapman of Coosa River.

ENLARGED SCOPE OF THE RESEARCH PROGRAM

In the earlier Annual Reports emphasis was placed on the major research program involving wood properties done primarily in the laboratories at N. C. State. In addition to these basic studies, a considerable number of empirical tests and studies are underway by various members of the cooperative program. Some of these studies are directly connected with the N. C. State-Industry Cooperative Tree Improvement Program, while others may, though they represent essentially separate industry effort, have a great deal of interest and bearing for every member of the program. It is our firm conviction that the greatest good from all this effort will accrue when all the cooperating companies are well informed about research activities which by their very nature cannot involve trade secrets. These industry-activated and financed projects contribute a great deal to both the basic and the applied research programs. It has been our observation that, although much good work has been and is accomplished through study of this sort, it is not known by others in the profession, and, as a result, related and supporting effort at other locations is rendered less effective and rewarding.

A number of activities of the nature suggested in the preceding paragraph will now be described.

1. Establishment of Arboretum and Tests of Exotic Species:

A number of companies are interested in testing exotics; Halifax Paper Company has set aside land and is now establishing a pine breeding arboretum which will contain all pine species available that will grow in

the Piedmont and Coastal Plain of North Carolina. This most valuable job is well underway; although the number of pine species in hand changes daily as seed is received, Halifax and N. C. State together have obtained over 70 species or varieties of pines, many of which have been planted in the Riegel nursery. First planting was done two years ago, and some of the exotic material is growing well. This project is of a great deal of interest and potential value for later selection of possible useful exotics and for cross breeding with our southern pines. At International's Southlands Experiment Forest a number of exotics have been planted, including some of the Mexican pines.

Several of the other companies are either interested in testing exotics, or have agreed to grow some for us. For example, Weyerhaeuser Co. (North Carolina Division) planted a number of Mexican pines for us in 1958, some of which are growing well. Champion is very interested in, and has underway, tests of various Eucalypt species. They are also interested in testing various coniferous exotics in the mountains. Hiwassee Land Company (Bowaters) has similar interest in conifers and may try certain exotics, especially some of the Mexican pines, in the Cumberland Plateau.

Although they cannot technically be considered as exotics, several companies have grown and planted species not normally handled in forestry in the South or are trying species outside their natural range. For example, West Virginia has grown Atlantic white cedar, cypress, and several other conifers on some of their swamp lands. Weyerhaeuser and Coosa River have planted considerable numbers of yellow poplar, and Coosa River also grew

Figure 8. Although hybridization has not been emphasized in the industry program, some early attempts at hybridization have been made. These conelets are on Japanese Black pine (p. thunbergii) that has been pollinated with slash pollen. This is a very unlikely and wide cross, but conelet set has been good.

and outplanted successfully a number of sweet gum and black gum seedlings. Continental Can, Weyerhaeuser, Riegel, International and others are trying various species on the deep sands in the Carolinas. For example, Continental Can has an intensive study underway with the objective to determine the pine species most suitable for use in the Sand Hills.

2. Tests of Insecticides and Fungicides:

The use of systemics for the control of both insects and disease has generated a lot of interest. Continental Can has underway extensive tests of phytoactin (a Pabst product) to attempt control of Cronartium fusiforme. Champion recently has tried this material on infected stock in their seed orchards, and Halifax will also try this.

The possibilities of controlling insects in the seed orchards by the use of an organo-phosphate, i.e. Di-Syston (a systemic manufactured by Chem-Agro) are getting extensive trials from several companies. In early field and nursery plantings and tests, Weyerhaeuser and International both had good results for control of tip moth during the first season following planting, and similarly, last year Union Bag-Camp found satisfactory reduction in tip moth incidence through use of Di-Syston. Continental Can has initiated Di-Syston studies on loblolly in the Sand Hills of North Carolina. Testing on a larger scale is being planned or started; our special interest is obviously in the possibility that a systemic may reduce spraying requirements for seed orchard trees.

Halifax, Union Bag-Camp, Georgia Kraft, and perhaps other cooperating companies are testing the value of this systemic in controlling aphids, red spider, tip moth and cone insects in their plantations and seed orchards.

3. Geographic and Site Variation Studies:

Any company with extensive land holdings must be concerned about local races of trees that have been developed, either in response to moisture, soil differences, or latitudinal differences. An arbitrary division has been made between the Coastal Plain, Piedmont and Sand Hills. But we need to know how far seed can be moved without loss of growth, survival or both, i.e., whether local racial diversity exists to an important degree.

In 1956, we started a local geographic seed source test of loblolly pine in North Carolina, with collections from the coast westward to the limit of the species range. These have been outplanted for us, in the Coastal Plain by Weyerhaeuser and in the Piedmont, by Halifax. This material is in its second growing season and will provide good knowledge of the differences from coast to foothills.

Several companies have initiated similar geographic studies. One of the largest and most intensive is that carried on in the Savannah District by Continental Can, who will establish another study of this type in the Hopewell, Va. District and at Hodge, Louisiana.

4. "Pilot Plant" Tests on Wood:

Several companies have spent considerable time and money helping to find out variation patterns and relationships of wood to final product. Union Bag-Camp early made some good studies on wood-weight and cellulose-yield relationships, the results of which have been reported in TAPPI and at the Fifth SFTIC Conference. Riegel has had the wood of a number of their trees analyzed and, in cooperation with the Institute of Paper Chemistry,

have more studies underway. Riegel has made available some data on tracheid characteristics from the same trees on which we had made certain wood studies earlier. The data have been combined and analyzed, and will be reported by us at the 6th SFTIC Conference in June, at Gainesville, Florida. Similar studies on wood by West Virginia and Union Bag are being undertaken with cooperation of the IPC. An article on relationship of wood properties for some trees on the Westvaco Experimental Forest, prepared jointly by IPC and N. C. State, was published recently in TAPPI.

One of the select trees of Chesapeake had to be cut so they have had it analyzed both by our micro method, and by pilot plant tests where actual pulping and paper tests were made. All results are not available at this time, but our portion is shown in the following section entitled "The Anatomy of a Tree." Several of the companies have cut select trees after scions from them have been established in the seed orchards, and a number of good studies on wood characteristics are underway.

Figure 9. We always have troubles. Ice is one of them, even in the more southerly orchards. This photograph was taken by Paul Otterbach of International at their 8-Oaks seed orchard near Georgetown. Luckily, damage was minor.

THE ANATOMY OF A TREE

Last year, Chesapeake Corporation of Virginia found it necessary to cut one of their select trees, the Haynes Tree 4-19. Disks were obtained every 5 feet up the tree to a 4-inch top, and sent to us for analysis of specific gravity and tracheid length.

The following series of photographs illustrate what was obtained. Note from Figure 10 that width of 5-year segments are plotted to scale. The right side of the tree shows actual specific gravity values obtained for the 5-year segments; the left side shows whole, uncut tracheid lengths for summerwood at each 5-year ring. As you might expect, we hasten here to remind you, that these data represent one tree only; other trees might well exhibit a different pattern of variation. But this instance gives at least an idea and provides a bench mark on the variation that was encountered within one select tree.

The patterns that emerge from examination of the data are not wholly alike for specific gravity and tracheid length.

Specific Gravity:

Two outstanding patterns are evident for specific gravity: (1) the very great similarity of the specific gravity of the 5-year segment of wood near the pith, at any height in the tree, (2) the rapid change and increase in specific gravity from the pith outward, at any height in the tree. This pattern follows the usual increase with number of rings, i.e., age from the pith, and is in good concordance with earlier determinations on a large number of other trees.

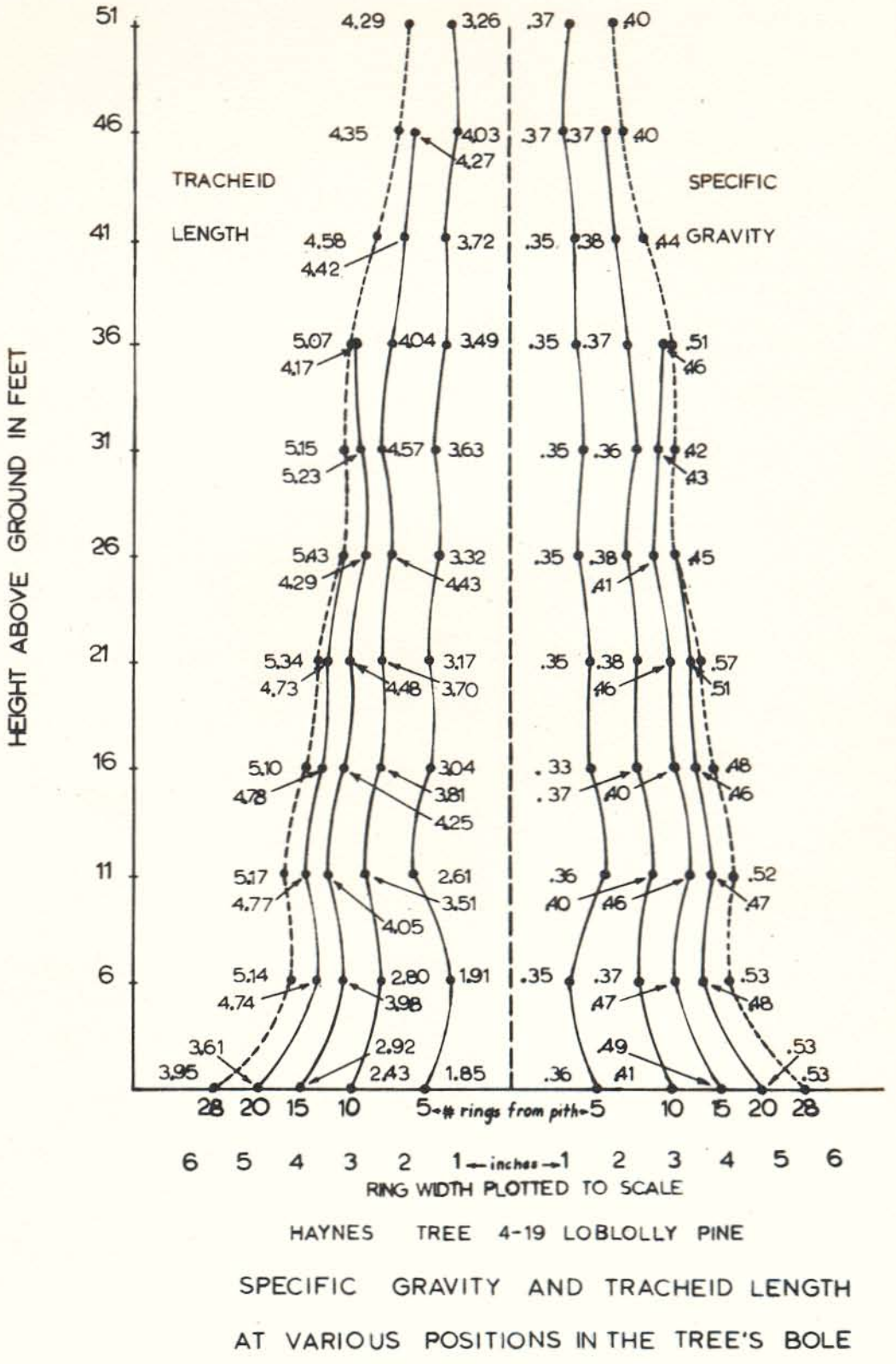


Figure 10. This photograph shows the variation of wood properties within a tree. (It is discussed under the section "Anatomy of a Tree"). This is plotted to scale, and shows specific gravity on the right of the diagram and tracheid length on the left of the diagram.

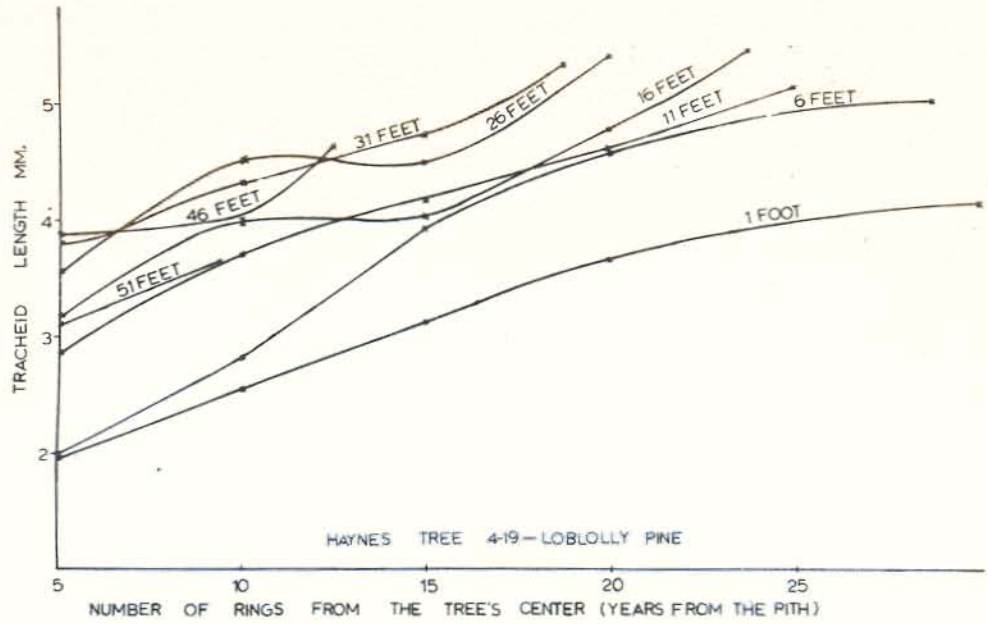
Tracheid Length:

Two distinct patterns also emerge for tracheid length: (1) in contrast to changes observed in specific gravity values, tracheid lengths grow longer with increasing height from base of the tree; (2) like specific gravity trends, tracheid length increases from the pith outward. Looking at this one tree it is evident that the top log consists of low specific gravity wood with relatively long tracheids, while the butt log has much higher specific gravity, but somewhat shorter tracheids.

Figure 11 shows the changes in tracheid length with distance from the pith at different heights in the tree. Note that tracheid length is always shortest near the pith, that it increases considerably with distance from the pith, no matter at what height, up to 4-inch top, the sample is taken.

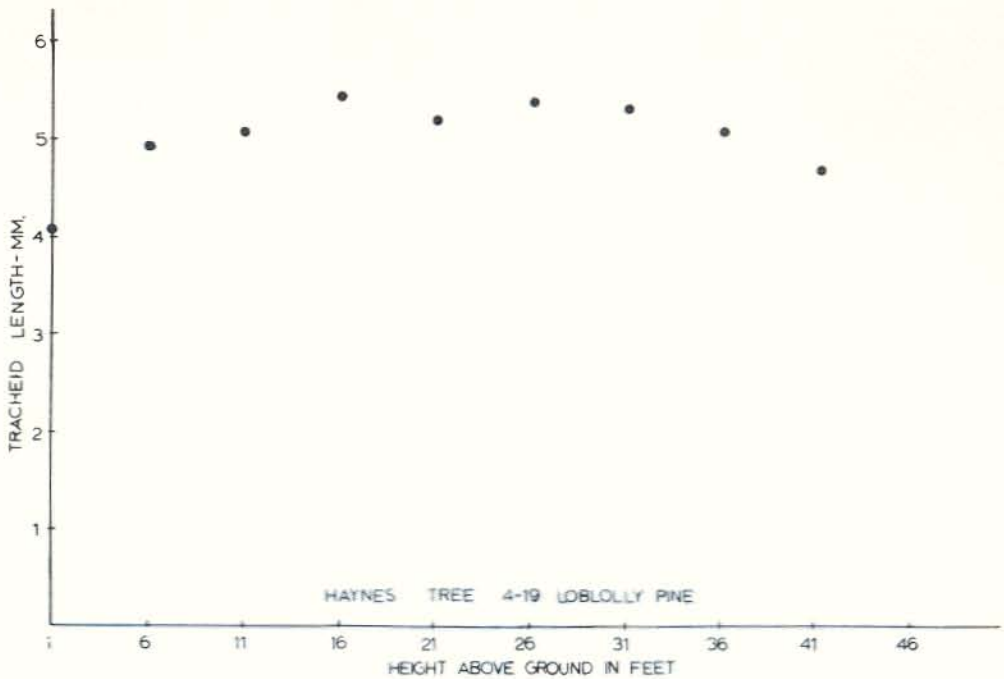
The tracheid lengths that are present just under the bark, regardless of distance from the pith are shown in Figure 12. This wood is the type obtained from slabs from a sawmill.

The fourth graph (Figure 13) illustrates the change in tracheid length with change in specific gravity. The values for the first 10 rings are for the so-called core, or juvenile wood,and are illustrated by black dots. Values for outer wood are shown by crosses. It is quite evident here, that if sampling is confined to either core or outer wood subdivisions, there is essentially no relationship between specific gravity and tracheid length. If this separation in sampling is not made, a considerable trend is bound to emerge; thus, near the pith specific gravity would be low just as tracheid length is low. However, this trend should not be construed that there is



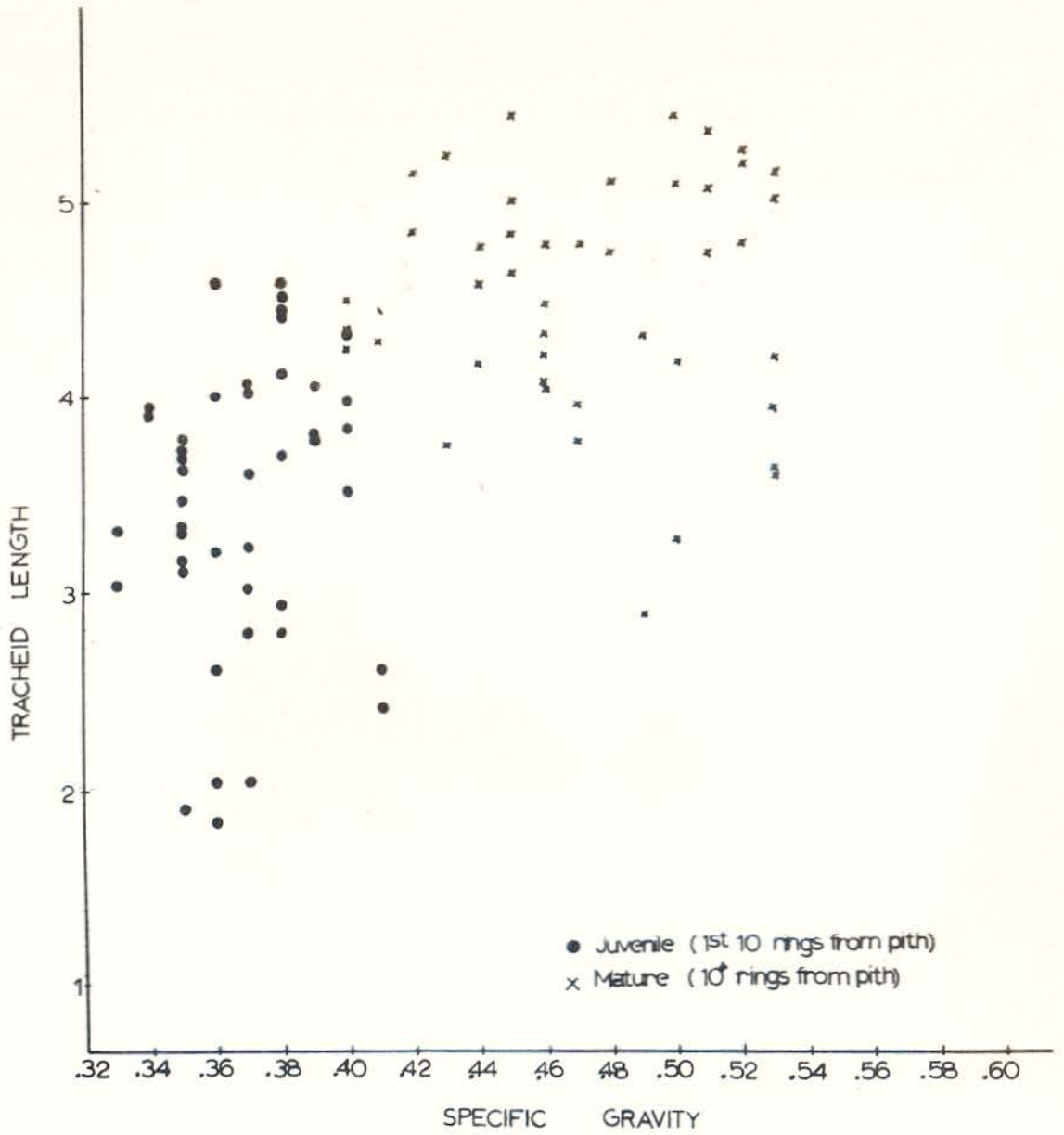
AVERAGE TRACHEID LENGTH OF SUMMERWOOD
FOR DIFFERENT HEIGHTS ABOVE GROUND

Figure 11. Tracheid length is shortest at the center of the tree and increases as you get farther from the pith. However, for this tree, tracheid length near the tree was greater as you went up the tree.



LENGTH OF TRACHEIDS OF LAST RING FOR VARIOUS HEIGHTS

Figure 12. From the above graph it appears that there is not too much difference in tracheid length at the outside of the tree, no matter at what height. These results for this one tree are somewhat different than those reported in the literature.



HAYNES TREE 4-19

RELATIONSHIP OF SPECIFIC GRAVITY
TO
TRACHEID LENGTH

Figure 13. See the test for the discussion of ring width to specific gravity within a tree. The black dots are for core wood, the crosses for outer wood.

a relationship of tracheid length to specific gravity between trees. We have abundant evidence that there are high specific gravity trees with either long tracheids or with short tracheids. Several of our studies have clearly shown that these two characteristics are not highly correlated, when comparisons involve wood from different trees.

THE HERITABILITY STUDY

Thanks to the fine cooperation of International Paper Company, and the National Science Foundation Grant, the heritability study has made exceptionally fine progress. International's Southlands Experiment Forest personnel have continued to make available facilities, labor and supplies that have kept this study going. The most critical years -- the past year and the one immediately ahead -- have been handled very well by Dr. Frank Cech, who is directly in charge of field phases of this study, and his assistants. Mr. Roy Stonecypher and our laboratory assistants have made equally satisfactory progress in the laboratory phases of the study.

Progress to date in the heritability study is as follows:

(1) Open-pollinated seed has been collected, grown in the nursery, and outplanted on two sites at the Southlands Experiment Forest. The first outplanting was made the past winter, and required approximately 40 acres for the tests of the 28,000 seedling progeny involved.

(2) Control pollinations were again successfully made this spring. Last fall some seed was collected and more will be collected this fall. Depending on success of this year's crossing we may, or may not, be required to do some "mop up" crossing next spring before we can report the crossing phase "closed". First control progeny tests will be planted in the nursery next spring.

(3) Analysis of parent trees is nearly completed. This has been a huge job to classify each of over 300 parent trees by a number of morphological

characteristics, including wood, as well as by soil characteristics, competition and other factors that might have affected its growth and development.

(4) Greenhouse tests to get some early heritability estimates for juvenile characteristics are being set up.

(5) A side study of open-pollinated seedlings to provide material for analysis of wood properties, while the trees are still young, is being set up. This test can be done only by destroying the trees, so installation of a side study was necessary to obtain this information.

Along with the basic research on wood properties, this cooperative heritability study will be one of the most significant contributions of the Tree Improvement Program. Vital information will continue to be obtained from it for years to come.

Figure 14. Nature produces many odd things. The group of pollen catkins shown here all have grown into the form of a club. These were found on several trees in one small area.

Figure 15. In the seed orchards some very odd things happen, often that cannot be explained. Last spring, one clone in the Riegel Seed Orchard developed some very odd needle characteristics. The needles were short and stunted on one side of the limb, normal on the other. Howard Mills indicated that this oddity appeared for every graft of this clone, but on no other clone in their seed orchard.

THE GRADUATE PROGRAM

The number of graduate students directly involved in tree improvement, or working in a basic field tied closely to tree improvement, is the same as last year (i.e., a total of 18 M. S. and Ph. D. candidates, mostly for the latter). Several students have completed their work or some definitive phase of it, and several new students will be reporting for study soon. Those completing theses are listed in the PUBLICATIONS section of this report, where the title and a brief summary of the thesis is given. Some of those listed as having already completed M. S. programs are continuing their studies towards the Ph. D. degree.

In addition to the regular graduate students, two special students have spent a semester with us. Mr. Ivo Herpka, from Yugoslavia, is doing special studies on the genus Populus and has done some work with cytology of this species. Dr. Klaus Stern, from Germany, has special interest in Quantitative Genetics, and is undertaking research in this field. He is working jointly with the School of Forestry and the Department of Genetics.

We have a grant from the National Science Foundation called the Undergraduate Research Participation Program. Mr. Carlysle Franklin has been working with us on this program for over a year. His special problem is on drought resistance of loblolly pine - to determine if trees from different soil types have inherently different drought resistance capabilities. Another student, Mr. Charles Selden, worked on root development of trees from different soil types when grown on different soils.

He reported root form and development was largely controlled by the soil on which the tree was grown.

Students that have completed their studies, received their degrees and have jobs elsewhere are as follows:

1. Dr. Eyvind Thorbjornsen completed his Ph. D. degree, his topic being on variation of loblolly pine. Thor is now in charge of forest genetics and silvical research for the Tennessee Agricultural Experiment Station, University of Tennessee, Knoxville, Tennessee.

2. Mr. Donald Smith completed his studies for the M. S. degree, having worked on the relationship of limb specific gravity to bole specific gravity in young trees and seedlings of loblolly pine. Don has accepted a position in the genetics program of Auburn University, Auburn, Alabama, and reported for work at Auburn, Alabama, in February.

3. Mr. Ray Steinhoff completed his studies for the M. S. degree, with his research involving nutrient content of pine foliage, in a study supported by $3,000 grant from the Allied Chemical Corporation. Ray has been awarded a research assistantship at Michigan State University to continue his studies in forest genetics.

Arrangements have been made to have summaries of all theses published, either in a recognized periodical, or as a Technical Report put out by the N. C. State College School of Forestry.

Students coming for the first time this year will be:

1. Mr. Jorgen Sjolte Jorgensen, a student of Dr. Syrach-Larsen and Dr. Søegaard, from Denmark. He will study towards the Ph. D. degree.

2. Mr. Robert Kellison, a staff member from the University of West Virginia. Mr. Kellison has been in charge of the School Forest in West Virginia and will be working initially for the M. S. degree, but intends to continue for the Ph. D. degree.

3. Mr. Walter F. Beineke from Duke University, who just received his M. S. degree under Dr. Frank Woods, will come to study for the Ph. D. degree in the area of physiological genetics.

4. Mr. Paul W. Perry, who has just received his B. S. degree at Pennsylvania State, will come to study for his M. S. and intends to continue for Ph. D. degree.

STAFF MEMBERS

A number of persons are directly or indirectly involved in the Co-operative Program. Staff members devoting all their efforts to the program are:

1. Bruce Zobel, Professor of Forest Genetics, head of the Program.
2. Bob McElwee, Liaison Geneticist.
3. Miss Cicely Browne, Research Assistant (full time).
4. Mrs. Dorothy Booker, Research Assistant (full time).
5. Miss Ann Law, Secretary (full time).
6. Mrs. Elga Filton, Research Assistant (half time).
7. Ross Moore, Field Assistant (part time).

Staff members aiding the Program through research or technical aid are:

1. T. E. Maki, Head of Management Department, administratively involved, who advises on soils, fertilizer and related problems.

2. Thomas O. Perry, Associate Professor, aids in problems involving plant physiology and chemistry, has supporting research projects related to physiology and genetics.

3. Arthur Kelman, Professor of Plant Pathology, aids in problems involving tree diseases. He specializes in disease resistance studies.

4. Mr. Leroy Saylor will initiate a program on cytogenetics and taxonomy of the pines. Mr. Saylor works jointly with the School of Forestry and Department of Genetics. He is financed by a National Science Foundation Grant recently awarded.

5. Several specialists in Quantitative Genetics in the Department of Genetics spend much time guiding us in our problems and aiding the graduate students in their problems.

PUBLICATIONS

A considerable number of publications were prepared during the past year. The studies on wood properties have progressed very satisfactorily; however, the great mass of data requires much time and many facilities to boil it down into a usable form. Despite completion of several publications during the year, we still have a backlog of interesting data that should be published and placed in circulation, but heavy involvement in field work and liaison in the initial phases of this program has not left sufficient time to analyze the data and prepare them in published form.

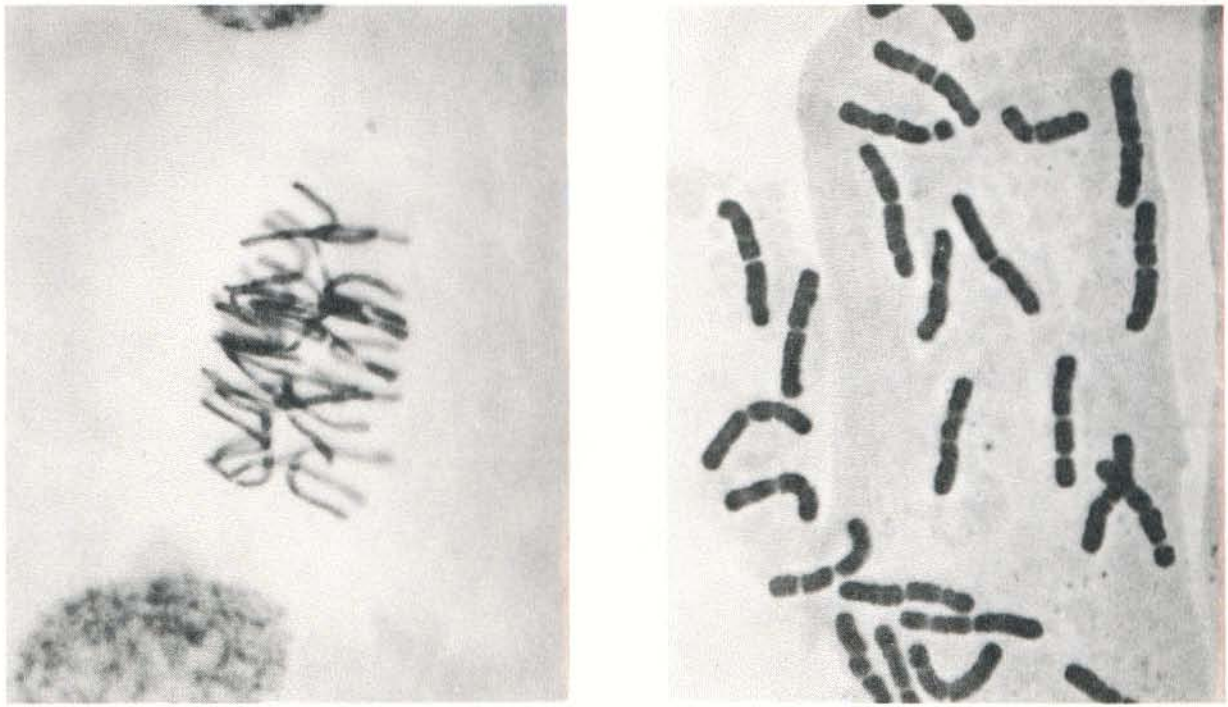


Figure 16. This year, a National Science Grant was received for studies of pine cytogenetics and taxonomy. These studies are to be a joint responsibility between Forestry and Genetics; actual studies will be under the direction of Leroy Saylor. Techniques have been a problem. The photo to the left shows pine chromosomes (Virginia pine) with no pretreatment. The photo to the right shows how pine chromosomes (Bristlecone pine) look after treatment. Note how plain the centromere and secondary constriction regions are.

For convenience, the publications will be broken down simply into staff and graduate student contributions. It is impossible to make a complete separation of those studies supported solely from industry funds and those supported from other sources. Publications listed below were printed since June 1960, or are currently in press.

Staff Publications: These papers are a direct contribution from the N. C. State -- Industry Cooperative Tree Improvement Program.

1. Zobel, B., Henson, F. & Webb, C. 1960. Estimation of certain wood properties of loblolly pine and slash pine trees from breast height sampling. Forest Science 6 (2):155-162.

How well can the wood characteristics of the merchantable portion of the tree be estimated from a breast height sample of the tree? This article reports results for a number of loblolly and slash pines showing that for specific gravity, it is very feasible to estimate whole tree values with samples obtained at breast height. This study was an extremely tedious, expensive job that took nearly a full year for completion of the laboratory phases alone.

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

This paper was presented to the TAPPI Biology Committee meeting in Seattle in August, 1960. The effects of three levels of fertilizer, including the native one, on wood properties are discussed and analyzed. A significant decrease in specific gravity was caused by heavy fertilization; also, although non-significant, a trend toward shorter tracheid lengths and lower cellulose yields appeared to be evident as a result of fertilization.

3. Zobel, B. J., Thorbjornsen, E., & Henson, F., 1960. Geographic, site, and individual tree variation in wood properties of loblolly pine. Silvae Genetica 9 (6):149-158.

The results of several years study are reported in this paper. Its objective was to assess the variability of wood properties (specific gravity, tracheid length, and cellulose yields) within the tree, between sites, and between geographic origin for natural stands of loblolly pine in the southeast. Definite regional trends were found. Specific gravity and tracheid length averaged less as the source of sampling proceeded from south to north. Individual tree variability was large, with only minor differences between sites within a geographic area.

4. Zobel, B. J. 1960. Selection and breeding of coniferous trees with superior wood characteristics. Proceedings, Fifth World Forestry Congress, Seattle.

This paper was presented by request in Seattle and will appear in the Proceedings of the Fifth World Forestry Congress when printed. Preprints were distributed to those who attended the Forestry Congress. The paper summarizes what is known about inheritance patterns in wood properties.

5. Zobel, B. J. 1960. Narrowing the genetic base. A contribution to the Symposium "Possible consequences of southern pine monoculture." Fourth Conference on Southern Industrial Forest Management, Duke University.

A discussion of the probability of danger from narrowing the genetic base through seed orchards was presented. The point was made that the base for physiological and adaptive characteristics is actually increased when a seed orchard is established though there is an attempt by the geneticist to narrow the morphological base, which involves useful form and wood characters of the tree.

6. Zobel, B. J. 1960. Tree improvement and the southern forest industries. Seventh Northeastern Forest tree Improvement Conference: 9-13.

We were requested to explain to a group of people interested in genetics what industry's role has been in tree improvement in the South. Although this paper was presented in August, 1959, it was not published until 1960.

7. Cech, F. C., & Zobel, B. J. 1960. What is inherited -- how can we tell? Forest Farmer, July.

A short discussion in lay language was given of the objectives of the cooperative International Paper Company -- N. C. State pine heritability studies.

8. van Buijtenen, J. P., Zobel, B. J., & Joranson, P. 1961. Variation in some wood and pulp properties in an even-aged loblolly pine stand. TAPPI 44(2):141-144.

In 1956 we selected a number of trees at Westvaco Experimental Forest for certain wood studies. These same trees were sampled for other characteristics by the Institute of Paper Chemistry. Both organizations felt the maximum value could be obtained by combining results in a single publication. One of the major conclusions from the study is the large amount of variation from tree to tree for most characteristics studied.

9. Zobel, B. J. 1960. Improving our trees -- how much? Southern Lumberman, Christmas Issue: 153-158.

This was a request article to put into lay language what we currently know about possible gains in forestry through genetics.

10. Zobel, B. J. 1961. Development of better poles by forest tree breeding. South Atlantic Wood Pole Conference, N. C. State College, April.

Members of the conference wanted to know what can be done to obtain more trees with characteristics desirable for use as poles, and what the pulp and paper companies are doing in their genetic programs that would affect the pole industry.

11. McElwee, R. L. & Zobel, B. J. 1961. Silvical and wood characteristics of loblolly pine in the southeast. In Press (to be published as a Technical Report, School of Forestry, N. C. State College).

For more than a year, we have been analyzing the mass of data collected from some 800 select and 4000 check trees sampled in the industrial seed orchard program. Some results by individual counties, companies, and species have already been sent to the cooperating companies. The gross compilation is in press.

12. Zobel, B. J. & McElwee, R. L. 1961. Interrelationship of wood properties in loblolly pine. Sixth Southern Forest Tree Improvement Conference, Gainesville, Florida.

For several years the Riegel Paper Corporation has had data regarding tracheid length, tracheid width and cell wall thickness for 14 loblolly pine trees. We had cellulose yield and specific gravity for these same trees. These combined data are reported in our paper; in addition we have amassed data from several hundred of our select trees in which we can relate tracheid length, growth rate, and specific gravity data together. The paper relates results from both groups of data. For the most part, it appears that tracheid length and tracheid width are not closely tied to specific gravity. As would be expected, cell wall thickness and specific gravity are quite closely correlated.

13. Zobel, B. J. 1961. Inheritance of wood properties in conifers. Silvae Genetica (In press).

The editor of Silvae Genetica requested that an article be prepared containing new information combined with that given at the World Forestry Congress in order to bring up to date information on the genetics of wood to a larger group of readers than attended the World Forestry Congress. Although this was submitted several months ago, it is already becoming out of date as new information has become available in this rapidly changing field.

14. Zobel, B. J. 1961. The consultant's concern with wood quality. The Consultant 6(2):4-10.

A number of talks have been given to foresters and pulp mill personnel regarding variation in wood within a tree, between trees, between sites, and between geographic areas, with a discussion of the importance of this information. This article attempts to illustrate, in lay language, certain variations and their importance to the wood industry.

Several papers have been published by staff members who are working on problems of direct interest to the members of the N. C. State - Industry Cooperative Forest Tree Improvement Program, although their research is not directly supported by industry funds.

15. Perry, Thomas O. 1960. Pruning of slash and loblolly pine grafts. Jour. of For. 58(4).

16. Perry, Thomas O. and Wang, Chi Wu 1960. Genetic variation in the winter chilling requirement for date of dormancy break for Acer rubrum. Ecology 41:785-790.

17. Perry, Thomas O. 1960. The inheritance of crooked stem form in loblolly pine (Pinus taeda L.). Jour. of For. 58(12):943-947.

18. Wang, Chi Wu, Perry, T. O., and Johnson, A. G. 1960. Pollen dispersion of slash pine (Pinus elliottii Engelm.) with special reference to seed orchard management. Silvae Genetica 9(3):65-92.

Figure 17. Some of the grafts have grown very rapidly. The one pictured here is clone 80 (N. C. Pulp Div. of Weyerhaeuser) being admired by Dr. Risto Sarvas from Finland and Mr. Tom Swofford, U. S. F. S. from Atlanta. This graft is three years old and has produced both male and female "flowers" for the past two years.

Graduate Student Publications: A number of research projects have been completed for theses by graduate students working with the program, some of whom are on assistantships made available by industry funds. These theses will either be published in condensed form in recognized periodicals, or will be put out as Technical Reports by the School of Forestry.

1. Webb, C. D. 1960. Some problems related to field grafting loblolly pine (Pinue taeda). M. S. Thesis. N. C. State, School of Forestry Technical Report No. 10.

This paper was a summary of Webb's thesis work. It discusses the best covering to use for field grafting, the best schedule for release and care of grafts and the costs involved with the several methods used.

2. McElwee, R. L. 1960. An analysis of factors contributing to the flight patterns of loblolly pine pollen. M. S. Thesis.

This paper will soon appear as a N. C. State Technical Report. In this thesis McElwee covers pollen flight distances and the effect of wind and humidity on pollen dispersal. He theorizes on isolation strip width and other problems of seed orchards. A good review of the literature was presented.

3. Saylor, L. C. 1960. A karyoptic analysis of selected species of Pinus. M. S. Thesis.

Saylor has submitted a summary of this thesis to Silvae Genetica, where it will be published. He found that karyoptic variation is not large in this genus; results similar to these reported by earlier workers. He did find certain species of the group Lariciones (red pine is one example) that had different chromosome morphology, a fact not previously reported.

Development of a suitable technique for such karyoptic studies was a primary contribution of this research.

4. Thorbjornsen, E. 1960. Variation in loblolly pine (Pinus taeda L.) Ph. D. Thesis.

Thor assessed the variation patterns for a large number of characteristics of loblolly pine throughout the species range. One of his major conclusions was that, for almost all characteristics studied, the tree-to-tree differences accounted for the bulk of the variation, while site-to-site and geographic area differences were less important. A summary of this work will be published as a Technical Report from N. C. State.

5. Smith, D. 1961. Correlation of limb wood properties to bole wood properties in loblolly pine. M. S. Thesis.

Smith found that, even though highly significant relationships were obtained between bole and limb, the correlation coefficients were often too small to enable making useful estimates of specific gravity of an individual tree from its limbs, although this would be satisfactory for groups of trees. His results were variable from stand to stand. He found that one important source of variation was tip moth which increases incidence of compression wood and thus lessens the reliability of any specific gravity estimates.

6. Steinhoff, R. J. 1961. A study of the nutrient and dry matter content in the foilage of loblolly pine (Pinus taeda L.) as related to the nutrition and growth of the trees studied. M. S. Thesis.

An attempt was made to relate growth to nutrient content of the needles. Of special interest to the geneticist was the very large tree-to-tree variation in nutrient content of the needles as well as the dry matter content. Steinhoff

also found that trees from certain seed sources had significantly different nutrient contents than others from different sources, even though they were growing under similar conditions. This material will be published as a Technical Report from N. C. State.

7. Lane, Carl L. 1960. The early performance of loblolly pine (Pinus taeda L.) and shortleaf pine (Pinus echinata, Mill) in plantations from a local seed source and several non-local seed sources. M. S. Thesis.

As might be expected, early height of loblolly was superior to that of shortleaf, but on both "good" and "poor" sites, individual shortleaf attained heights as great as the best of the loblollies, suggesting the possibility of improvement of early shortleaf growth through selection. For both species, the seedlings that were taller after one year's growth continued to be significantly taller at the end of 5 to 7 years after planting.

COOPERATING COMPANIES

Company	Working Units and States
Catawba Timber Co. (Bowaters Southern Paper Corp.)	One - S. C., N. C.
Champion Paper & Fibre Co.	One - S. C., N. C.
Chesapeake Corp. of Virginia	One - Va., Md., Del.
Continental Can Co.	One - (Savannah Div.) S. C., Ga. One - (Hopewell Div.) N. C., Va.
Coosa River Newsprint Co.	One - Ala.
Georgia Kraft Co.	One - Ga., Ala.
Halifax Paper Co.	One - N. C., Va.
Hiwassee Land Co. (Bowaters Southern Paper Corp.)	One - Tenn., Ga., Ala., Miss.
International Paper Co.	One - S. C., N. C., (Coastal Plain) One - S. C., N. C., (Piedmont)
Riegel Paper Corp.	One - N. C., S. C.
Union Bag - Camp Mfg. Co.	One - (Savannah Div.) Ga., S. C. One - (Franklin Div.) N. C., Va.
West Virginia Pulp & Paper Co.	One - (South) N. C., S. C. One - (North) Va., W. Va., Ohio, Md.
Weyerhaeuser Co. (N. C. Division)	One - N. C., Va.