TENTH ANNUAL REPORT

N. C. STATE-INDUSTRY

COOPERATIVE TREE IMPROVEMENT PROGRAM

School of Forestry
North Carolina State University
Raleigh

June, 1966

PROGENY TESTS SHOW WHICH IS BEST

THIS ISSUE DEDICATED TO PROGENY TESTING

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INTRODUCTION

It would be proper that the Tenth Annual Report be something special, something different, in recognition of ten years of achievement, hard work, and occasionally frustration and failure. Two major goals of the past ten years have been to get the seed orchards into commercial production and to test the select trees in the orchards for their genetic worth. Last year's annual report stated: "Commercial seed production is starting." This year it is well under way. Progeny testing of select trees established in the seed orchards has been expanding until we are now fully functional in this phase of the work, having field planted nearly 1,000 different interclonal crosses from the seed orchards. It seems appropriate, therefore, that this Tenth Annual Report should feature commercial seed production and progeny testing.

COMMERCIAL SEED PRODUCTION FROM SEED ORCHARDS

When the program was initiated we estimated that considerable quantities of seed would become available in about the seventh year after orchard establishment and that "commercial production" would commence about the tenth year after the orchards were established. We are ahead of this schedule by three years in most orchards. As a general rule, seed in quantities large enough to be considered commercial are produced the sixth year in most loblolly orchards, the fifth year in pond and shortleaf pine orchards, and the fourth year in Virginia pine orchards. Although our experience with slash pine is more limited, seed production from the most northerly orchards is just starting after six years, while the more southerly ones are producing large numbers of cones in the eighth year. Over-all, the northern slash has been considerably slower in cone production than the slash orchards in the Florida Cooperative Tree Improvement Program. Because of more recent establishment it is too early to make any predictions about seed production from longleaf and white pine orchards although abundant female flowers have been produced on two- and three-year-old white pine grafts.

Cone production as such is not a good measure of seed production because orchards differ greatly in the earliness of effective pollen production. As the result of a lag in pollen production many of the cones produced in a young orchard yield few sound seed. However, it has been our experience that orchards established at the closer 15' x 15' spacings produce fewer hollow seed or "pops" during the first years, because of the more uniform pollen production over each acre of seed orchard. We have found that loblolly pine usually comes into heavy pollen production one to two years after female flower production has started, while Virginia, pond and shortleaf pines produce heavy crops of pollen early in the life of the seed orchard. White pine grafts are slow in producing pollen.

It is difficult to report accurately quantities of commercial seed from the orchards because we have used the bulk of early available flowers in progeny test crosses. Several companies have used as many as 4000 to 6000 control-pollination bags in an orchard in a single year to make progeny crosses. This considerably reduces the "commercially available" crop.

Field plantings on a commercial scale were started in 1965, when enough seed became available to produce approximately two million trees. For example, 570,000 plantable seedlings were grown from seed collected from the Weyerhaeuser Coastal Plain and Piedmont loblolly seed orchards. Nurseryman Bill Bland of the Goldsboro, North Carolina Forest Service Nursery, told us the seedlings were more

If one judges by the caliber of "labor" our Tree Improvement Program is really improving. To illustrate this, the photographs from Kimberly-Clark showing pollination and from Chesapeake Corporation showing "how pollination should be done" have been included. We are all in favor of a continued upgrading of personnel associated with the Cooperative Program.

Weyerhaeuser Company at Plymouth, North Carolina recently dedicated its seed orchard to Mr. John Philip Weyerhaeuser. Shown above is a part of the seed orchard which was dedicated; below is a part of the facilities and the attendees at the dedication.

uniform and appeared to be more vigorous than nursery-run seedlings produced nearby. Harold Nelson of Weyerhaeuser reported that the seed orchard seedlings were even more uniform and several inches taller than the seedlings from seed production area seed. Reports from other companies have been in a similar optimistic vein.

Nursery sowing of seed orchard seed for operational plantations will be considerable in the spring of 1966. The several orchards now in production will yield about 450 pounds of seed, which will produce enough seedlings to field plant more than 6,000 acres at the wide spacings generally in use. Therefore, we are now "off to the races" on seed production.

This year one small orchard has produced nearly two-thirds of the yields per acre predicted for orchards in full production. Encouraging results such as this might make it appear we have overestimated the acreage of seed orchard needed. Actually, however, the projected yields for an orchard are the predicted average over a number of years and include times of flower shortage, ice damage, freeze damage, etc.

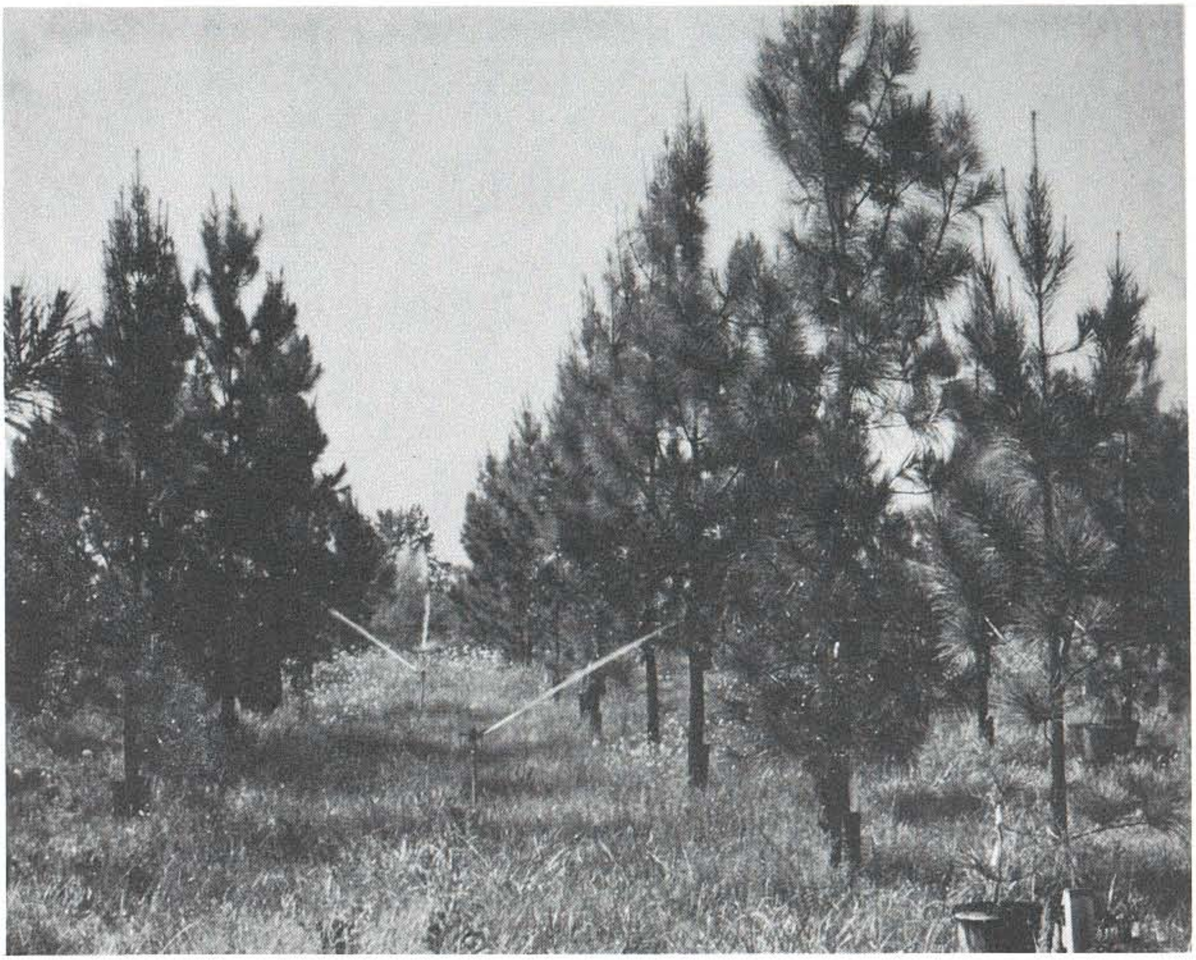
All orchards have shown a trend of large yearly increase in cone production up to eight years, the age of our oldest orchards. The late spring freeze of 1964 interrupted this trend in several orchards, where losses of 90 to 95% of the flowers were sustained; the few flowers that survived the late cold and did mature yielded only a couple of seeds per cone. Since several of the largest, oldest orchards were in this freeze area, the projected operational plantings in 1966 mentioned on the previous page are perhaps only one-half what they would have been without the freeze. In unaffected orchards, seed yields in 1966 were excellent from loblolly pine, with all companies reporting yields between one and two pounds of seed per bushel of cones.

Although the progeny from the seed orchard are so young that conclusions would be premature, many of the crosses from the seed orchards have grown well. Shown is a loblolly cross from Kimberly-Clark after one year's growth in the field.

In every instance seed yields per bushel from seed orchards have been greater than from comparable commercial collections from wild stands. In addition, larger cones with larger seeds (less seed per pound) are obtained from seed orchard trees. For example, in their 1964 collection Weyerhaeuser obtained 14,000 seed per pound vs. the normal 16,000 - 17,000 for commercial collection. Nearly 97% of the seed orchard seed was in the large and medium size classes, whereas commercial collections usually have over 75% in the medium and small seeded class. From farther north, seeds were smaller, and Chesapeake Corporation reported 16,300 seed per pound.

A series of special studies on seed yields, flower set, germination, etc. have been initiated by Dr. Charles Davey with Albemarle, Union Bag-Camp, Catawba, West Virginia Pulp & Paper, and Weyerhaeuser companies. Various levels of fertilizer, irrigation, and fertilizer-irrigation combinations are being tried. Although these studies are relatively recent, some interesting results have already been obtained. For example, in the Albemarle Seed Orchard (1964 seed crop), irrigation resulted in an increase of cone length of approximately 6% over the cones from nonirrigated trees. Water plus fertilization increased cone length by about 3%, and cone width was increased somewhat by both fertilization and irrigation. The larger cones obtained from irrigated and fertilized plots produced larger seed, with approximately 12,000 seed per pound.

Although data comparisons have not been made, it is evident since the first application in the spring of 1964 that the irrigated trees flower as much as two weeks later than nonirrigated trees, and this retardation seems to be carried over to time of cone ripening. It was found that the water-plus-fertilizer treatment resulted in slower germination (perhaps because cone ripeness was affected), but 28 days after the beginning of germination the results of the water-plus-fertilizer treatment were better than from any of the other treatments. Similar results appear likely to be corroborated by the 1965 crop.



Special studies are under way on seed orchard management by a number of companies. Shown is the orchard of Albemarle Paper Company in an area that is both irrigated and fertilized. Differences in seed size and seed yield have been obtained.

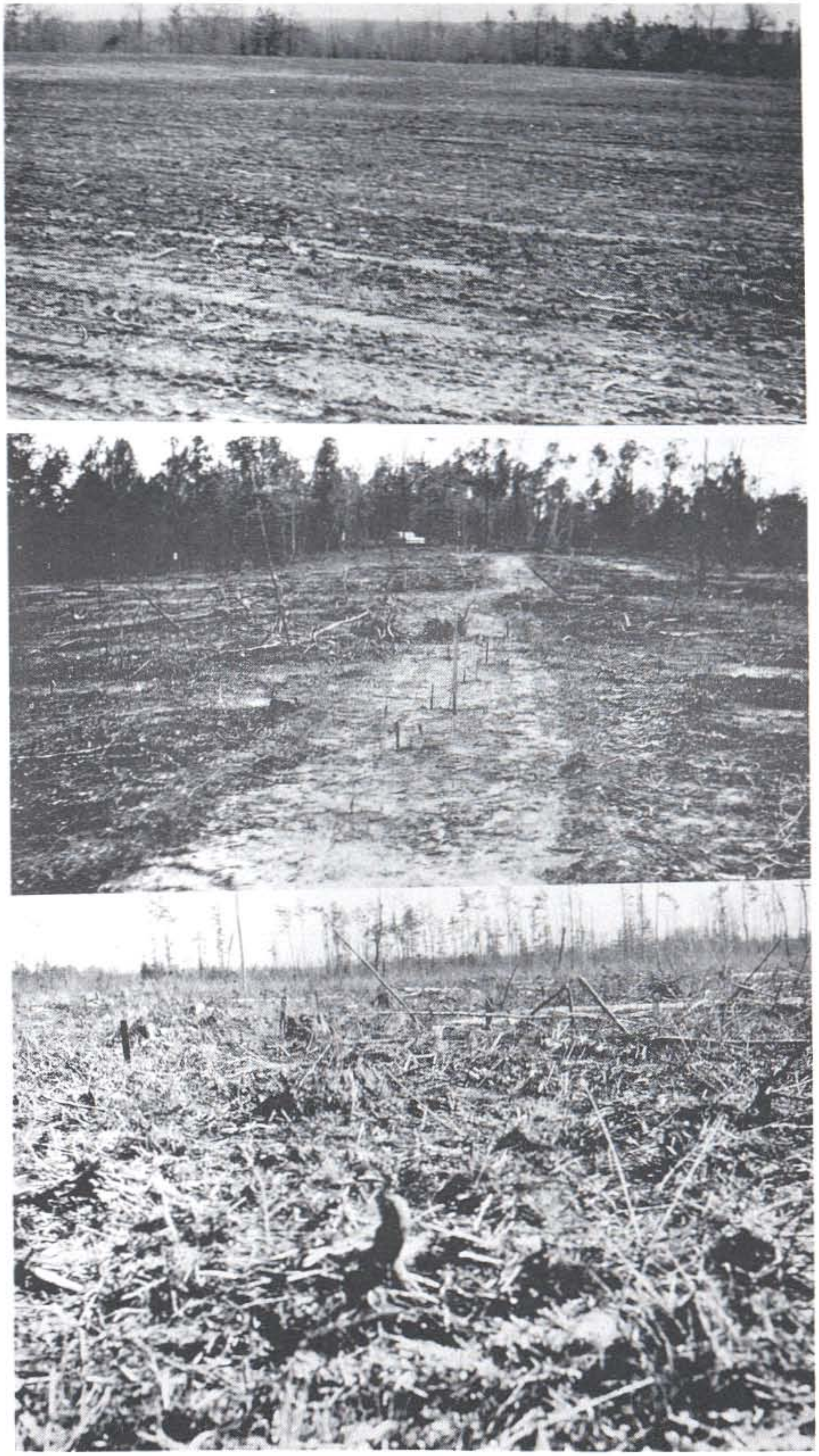
Certain species, such as Virginia pine, flower early and heavily. Here Walt Chapman of Kimberly-Clark shows the large number of control crosses for progeny tests on four-year-old Virginia pine grafts. Four rows of the seed orchard provided all the flowers necessary for one year's crosses.

In a seed orchard program it is wrong to establish orchards north of the species range on good sites. We have one loblolly pine and two slash pine orchards that are lagging in cone production when compared with other orchards of the same species and age, although cone production is now starting on a large scale. We find that the best cone yields come from moderately good sites in the heart of the species range, or a little south of the area in which the trees were selected. Such orchards flower early and are susceptible to manipulation with fertilization.

When production of seed in commercial quantities commences, one major problem is protection from cone insects. This very important problem is receiving attention from several organizations in the Cooperative Program as well as from the U. S. Forest Service and other research groups. The objective is to locate a systemic insecticide that can be applied cheaply and simply and will give maximum protection from insects. Several such systemics appear to be available, but their use is restricted by their extreme toxicity to the men working with them. Another problem involves mass collection of cones or seed from many trees in a short time. This is an "engineering" problem being worked on by several organizations. Need for efficient large-scale collection methods is just now becoming urgent, and improved methods must be developed soon. Studies of this type are done by each organization to fit its own particular needs.

PROGENY TESTS OF THE PARENT TREES

The primary purpose of the progeny tests in the N. C. State Industry Program is to evaluate the breeding potential of the clones in the seed orchards. To achieve this objective, it is necessary to measure and analyze growth, form, wood characteristics, disease resistance and adaptability of the progenies. Based on the detailed analyses of the open-pollinated progeny test results (Technical



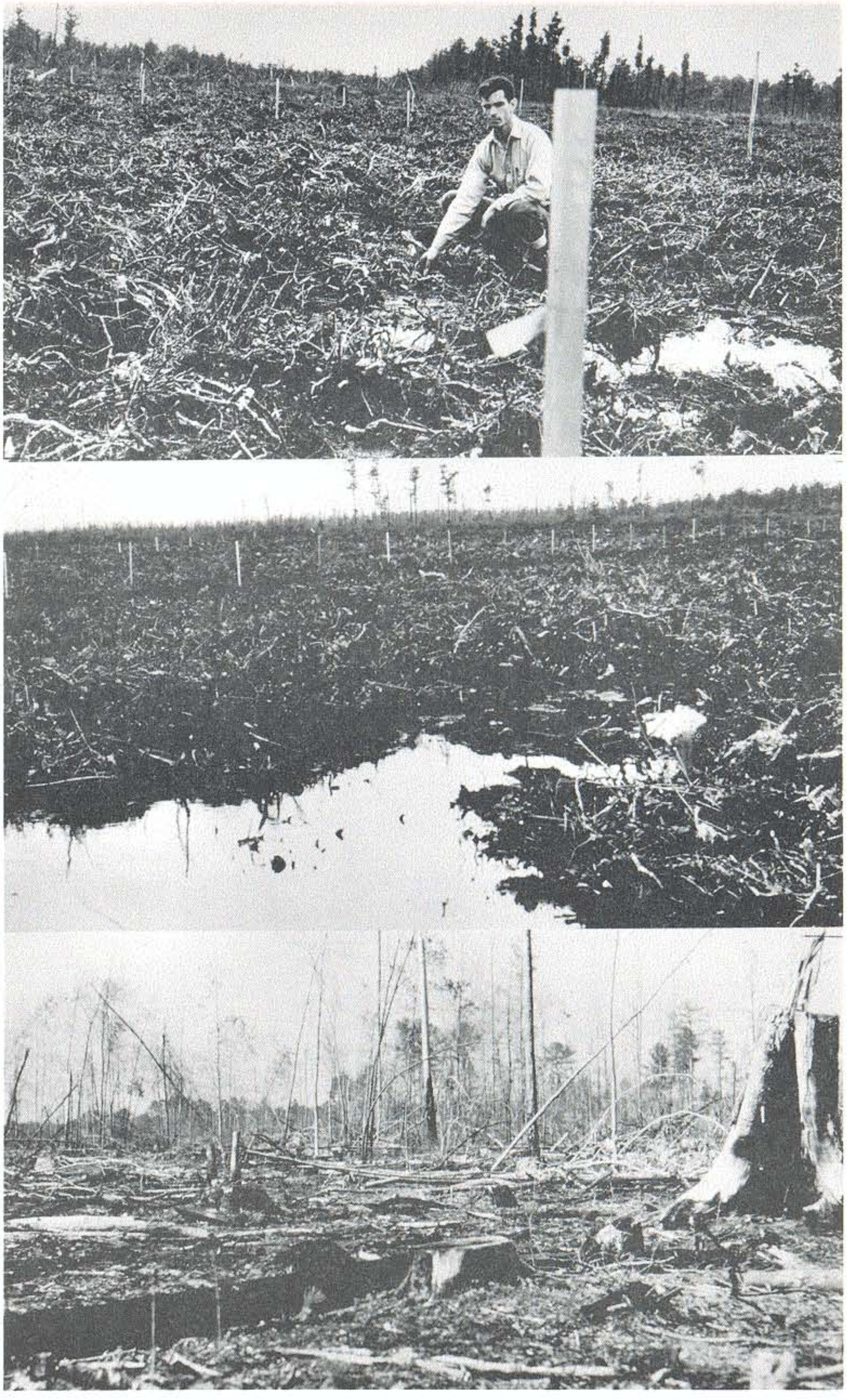
Progeny testing is taking place under many conditions. Shown above (top) is the maximum care test area of Champion, where all possible management techniques (except irrigation) are applied. The center picture shows a typical Piedmont progeny test area of Kimberly-Clark, while the bottom scene is a typical Coastal Plain test area of Albemarle.

Report No. 28 by Ron Woessner) and data collected in the N. C. State-International Paper Company Heritability Study, it has become clear that the following progeny characteristics should be scored. For some characteristics a subjective score will be suitable.

1. Diameter and height.
2. Branch characteristics, including angle, diameter, length.
3. Resistance to Cronartium and other fungal infection as well as insect pests.
4. Bole straightness.
5. Specific gravity and tracheid length of the wood.
6. Adaptability, i. e., ability to grow on different sites and under different environments.

The value of each clone in the orchard as a breeding parent will be determined by comparing progeny among themselves and against the commercial and other check lots. General combining ability will be assessed and, when feasible, specific combining ability will be calculated. All computations and analyses will be done on the IBM-360 computer at N. C. State University.

Design: The control-pollinated progeny testing design is relatively simple, consisting of six replications of 10-tree rows for each of three years or a total of 180 trees per cross. The design was made so that field planting and progeny measurements will be distributed over a number of years. In addition to avoiding environmental extremes for any one year, the planting and data collection work load will be evenly distributed over several years. The design used is made possible by employing a series of genetic checks that enable planting to begin many years before all the seed needed for the total test have been produced. As seedlings are available, supplemental plantings on sites different from the main test are made. Some companies have established "maximum care" test plantings, some have used fertilizers, and one company has direct-seeded as well as planted seedlings in their main and supplementary progeny tests. The design was outlined and described by Zobel and Kellison, 1963.



Some progeny test areas represent extreme environmental conditions. Shown above (top) is the supplementary test area of West Virginia Pulp & Paper Company in Dare County on deep, "raw" peat. The center picture is the main test area for this company on somewhat shallower, more "muck" type soils. The bottom photograph is a special test area on an excessively wet site on which selected sources are being tested by Union Bag-Camp Paper Corporation.

Results: Control-pollinated progeny testing has proceeded rapidly. Already, 997 test lots have been field planted on 127.5 acres of test sites (See Table 1 for detail by species). The field planting in the main and supplemental test plantings totaled 639 lots in 1966 for a total of 78.0 acres. In the same year 536 new crosses were planted in the nursery and, with reasonable luck, the out-plantings should total over 750 lots or nearly 100 acres. It is of considerable importance that 390 crosses have been completed, i. e., enough seed is on hand to complete all three years' planting required in the progeny test design. For some companies this costly and time-consuming control crossing phase of seed orchard establishment is nearing completion.

The oldest control-pollinated plantings established in the field are five years of age, but the bulk of the tests are less than three years old. Even within the more recently established plantings, differences among crosses are being observed. For example, combined first-year results from six companies showed the crosses from seed orchard trees to be 1.3 feet tall compared to 1.1 feet for the commercial check lots (See Table 2). Seedlings that were fertilized were nearly 20% taller than those not fertilized. Differences in bole infection by Cronartium fusiforme were as great as 30% among crosses from one seed orchard. Although all such reports on young material must be tempered with caution, it is most encouraging to find the trend generally favoring the crosses from the seed orchards, even though tipmoth, rabbits, reproduction weevil and other influences tend to equalize them.

In one older test (West Virginia Pulp & Paper Company), pollens from five different select trees were used on a sixth select tree used as female. These crosses have shown considerable differences in growth, form and disease resistance at five years of age. Growth was uniformly better than commercial stock of the same age planted nearby. Such early results, combined with those of our Heritability Study and published results ~~of~~ others, lead to considerable optimism about potential improvements from use of seed orchard seed.

Table 1. Inventory of Control-pollinated Progeny Crosses in the Cooperative Program

Field planted to spring, 1966	Seed Lots	Acres
1. Piedmont loblolly - main tests	169	26.1
2. Piedmont loblolly - supplemental tests	141	16.0
3. Coastal Plain loblolly - main tests	366	49.5
4. Coastal Plain loblolly - supplemental tests	153	18.3
5. Direct seeded Coastal Plain loblolly	95	6.2
Total - loblolly	924	116.1
6. Pond pine - main test	20	3.1
" " - supplemental tests	25	2.3
7. Virginia pine - main and supplemental tests	28	6.0
Total - all species	997	127.5

Nursery planted, spring, 1966	Seed Lots
1. Piedmont and mountain loblolly	196
2. Coastal Plain loblolly	280
3. Swamp loblolly	18
4. Pond pine	33
5. Virginia pine	4
6. Shortleaf pine	5
Total	536

Crosses completed[1/]	Crosses
1. Piedmont loblolly	115
2. Coastal Plain loblolly	217
3. Swamp loblolly	8
4. Pond pine	17
5. Virginia pine	33
Total	390

1/ Enough crosses made to complete all three years' planting.

Progeny testing is advancing rapidly. Shown above are four-year-old open- and control-pollinated loblolly pine on the lands of Westvaco near Georgetown, South Carolina.

Table 2. First-year Height Growth of Control-pollinated Progeny Test Seedlings 1/

Kind of Progeny	Number of Seedlings	Av. Height
Control-pollinated crosses	8792	1.3 feet
Seed production area checks	618	1.2 feet
Commercial checks	561	1.1 feet

1/ Average size at the end of the first growing season in the field. The trees are two years of age.

A comprehensive study of open-pollinated progeny from the seed orchards, Technical Report No. 28, was completed by Mr. Ron Woessner, recipient of an industry assistantship. Despite the limited scale of the progeny tests and deficiencies in design, differences were found in growth, bole straightness, disease resistance and crown and branch form among the progeny of the select trees. This study was also of considerable value in helping determine what characteristics to measure and how they should be measured. Wood studies in conjunction with commercial thinnings are soon to be initiated on some open-pollinated plantations.

When all results from the Cooperative Program and from the literature are combined it now appears that:

1. Bole straightness, wood specific gravity and tracheid length are strongly inherited, and quick gains will be obtained through selection and seed orchard practices.

2. Disease resistance (to _Cronartium fusiforme_) has a real strong genetic component and will best be detected through progeny tests of the seed orchard

Without question, one of the most serious problems in southern forestry is fusiform rust (*Cronartium fusiforme*). Graduate student Ke Won Kang is shown with two trees from the same family that are severely infected. Our studies show great differences in susceptibility to this disease, and it now appears that perhaps the greatest immediate gain from the Cooperative Tree Improvement Program may be in disease resistance.

parents. The mode of inheritance of resistance to this disease has not been clarified and the most efficient breeding procedure is not definitely known, although it is clear for several reasons that selection of apparently resistant parents will be only partially successful as a breeding procedure.

3. Height, diameter and volume growth are more strongly affected by simple selection than anticipated. Improvements are large enough to have economic implications of considerable value. This was seen spectacularly for slash pine in Queensland, Australia, where certain specific crosses were as much as 50% larger than the check lots after nine years in the field.

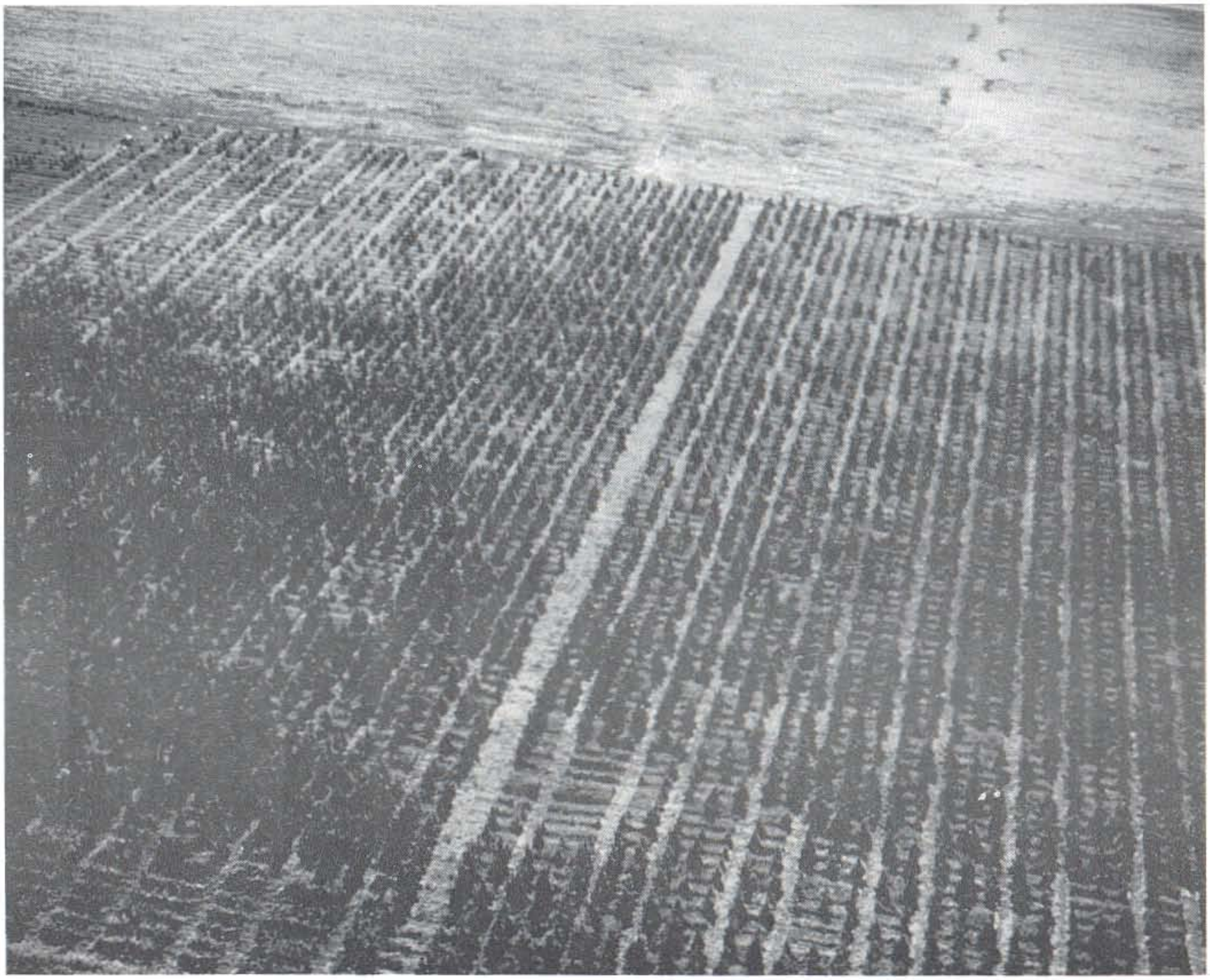
4. Improvements in form and limb characteristics are difficult to assess at this early date, but some improvement is apparent even for young plants.

5. Adaptability to certain specific sites or environments is outstanding. Considerable gains will result from proper selection of parents to produce seedlings for problem areas such as deep sands, deep peat, cold or droughty sites.

THE HERITABILITY STUDY

The long-term quantitative genetics research project (often referred to as the Heritability Study) is now yielding results, some spectacular in nature and nearly all better than we had hoped. This series of studies is truly a cooperative venture, being supported by the International Paper Company, N. C. State Cooperative Tree Improvement Program, National Science Foundation, and the National Institute of Health. Certain studies associated with this research are also financed by special grants. For example, a grant from the Southern Forest Disease and Insect Research Council is partially supporting a study of resistance to fusiform rust (<u>Cronartium fusiforme</u>).

A whole series of publications has resulted from this project (see Publications Section) dealing with growth, disease resistance, wood qualities, root



The largest basic research project is often referred to as the Heritability Study. Seed collection, crosses and planting were on International Paper Company's Southlands Experiment Forest at Bainbridge, Georgia. Shown is a part of the more than 75 acres of progeny, both of open- and control-pollinated sources. This is truly cooperative research on quantitative genetics in which International Paper Company, the National Science Foundation, the National Institute of Health, and the Cooperative Tree Improvement Program joined forces to make the detailed studies.

development and response to fertilizer treatments. Nearly 75 acres of progeny plantations are established, the oldest five years in the field, with many trees over 20 feet tall. Early publications dealt mostly with techniques, while later reports are concerned with inheritance patterns for growth, disease resistance, wood properties, etc. At the present time five students are using the material, wholly or in part, for Ph.D. dissertations.

No matter how the results are viewed, the inheritance patterns and genetic correlations from this young material (up to six years of age) have been stronger than expected, with the major exception of cellulose yields. Cellulose yields on five-year-old trees were found to have such low inheritance values that the possibility of selecting for high yields at this young age is negligible. Wood specific gravity has a consistently high heritability and high genetic correlation with growth rate. Straightness inheritance is high and results with Cronartium fusiforme are nothing short of spectacular, with families being found that are nearly resistant while others consistently have over 95% infection from this disease. Two major publications in this area involving disease resistance will soon be in preparation.

The most important publication from this program is the Ph.D. dissertation of Roy Stonecypher. He has worked out the necessary quantitative genetic and statistical formulations to analyze results from the studies and has programmed all these for analysis on the computer, thus making possible rapid and accurate analysis of measurements taken. He has made many pertinent comments about use of the N. C. State Design I and other progeny test methods, such as parent-progeny correlations. This thesis will serve as a base upon which many of our later papers will be constructed.

TREE SELECTION AND SEED ORCHARDS

Grading trees for the seed orchards has continued at an active rate. To date a total of 1655 trees have been graded for the Cooperative Program. Much of the new grading has included longleaf, Virginia, pond and white pines. In addition, 164 new Fraser firs have been selected for the establishment of a Christmas tree seed orchard. These trees, selected from Christmas tree plantations, will be moved to the seed orchard site on Roan Mountain, North Carolina. Eventually the grading phase of the work will slow down but will certainly not stop, and Bob Kellison and Jim Roberds are kept jumping to fill grading requests.

Seed orchard establishment has increased very rapidly, and we now have approximately 1200 acres of seed orchard established containing over 150,000 grafts. Nearly one-third of this seed orchard area can be considered as now coming into commercial seed production.

Graft incompatibility has been a problem of major concern in the seed orchard program. Although this is basically a physiological problem, one of our graduate students, Clark Lantz, is making a series of detailed empirical studies to determine if the problem can be circumvented. One of his approaches involves a search for a "receptor" family that might be used as rootstock, upon which incompatible scions will be grafted. The test involves control-pollinated families from a number of the industries as well as several species rootstocks such as Sonderegger pine (longleaf x loblolly hybrid) and pond pine. We're all wishing Clark the best of luck because success will enable the inclusion in the orchards of nearly 150 clones that have shown severe incompatibility.

Seed production areas are producing much of the seed used by some cooperators in the Cooperative Tree Improvement Program. The shortleaf seed production area of the Virginia Division of Forestry shows the good quality of trees desired for obtaining improved forest tree seed.

Establishing seed orchards has become quite an art and is done much more efficiently each year. Above is shown Hiwassee Land Company's new seed orchard at Chatsworth, Georgia. Most of the orchard has been established with conventional small grafts, but three large grafts were also moved from the Rose Island, Tennessee seed orchard. Two of the large grafts are shown in the background.

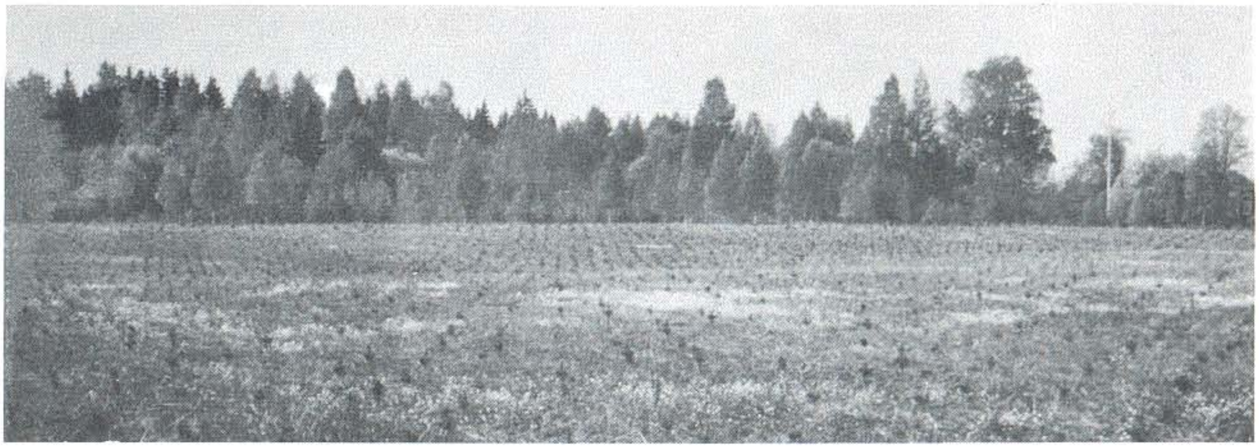
Disasters sometimes strike! The Riegel Paper Company seed orchard was in the center of a rather severe glaze-ice storm. Damage was quite heavy but over-all was much less than first feared. We can do without such events.

WORLD TRAVELLERS

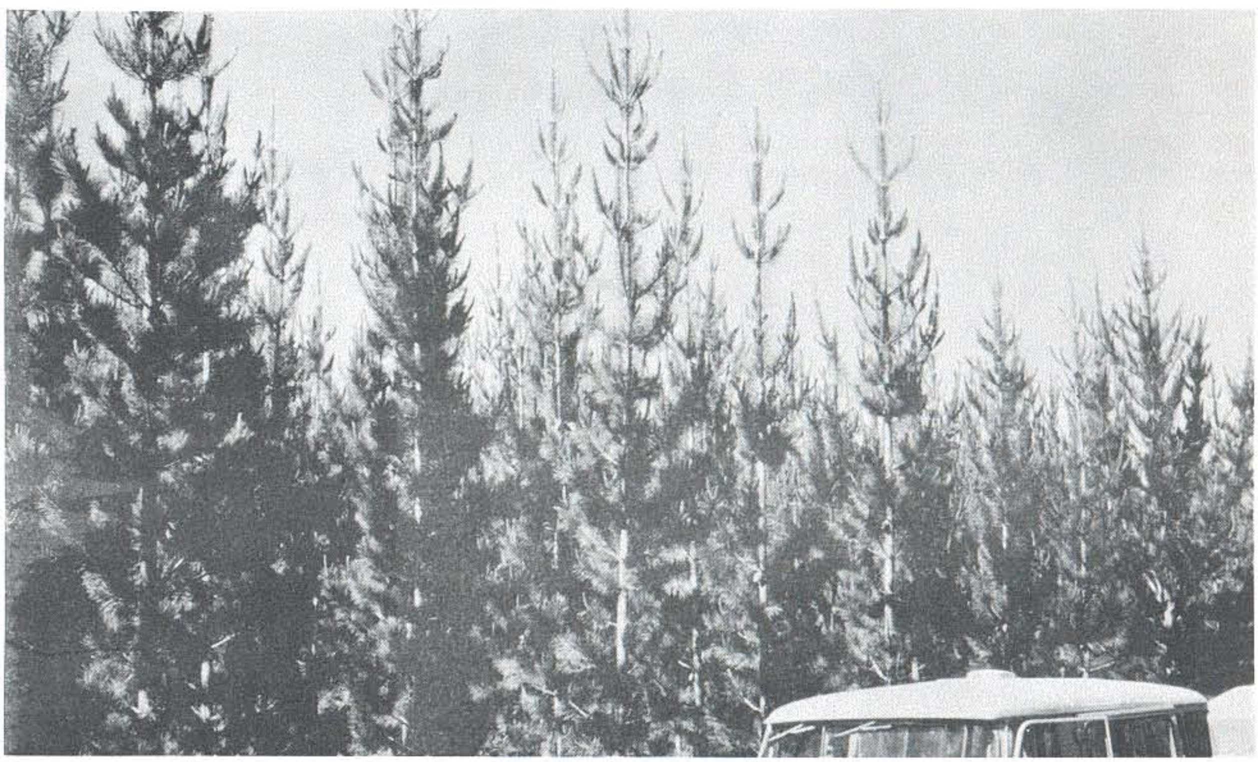
Bob Kellison and Bruce Zobel have really broadened their horizons while making several study tours. From these a number of helpful ideas were obtained that have been used in the Cooperative Program. Also, from such tours contacts are made, often followed by visits from professional people from the countries concerned, that really help to develop the Cooperative Program. Bruce's advisory tour to the State of São Paulo and his and Bud Saylor's brief visit to the forestry operations in the Bahamas are examples of this and have been reported in earlier annual reports.

Bob Kellison returned in August, 1965 from a four-month study-work tour in Sweden and northern Europe. The trip, made possible by the Gunnar E. Nicholson Fellowship for study of forest genetics in Sweden, proved to be really helpful. The primary objective of his trip was to observe the methods and techniques which have been used to make the Swedish Forest Tree Breeding Program so successful. To do this, he spent considerable time at each of the three state experimental stations, where he aided station personnel with grafting, pollinating and progeny testing. The experience was invaluable because by working directly with them he not only got to see their successful work but also the problems that are encountered in Sweden and how these problems were solved. A number of techniques were observed, some of which are being used on an experimental scale this year, which will materially aid our Cooperative Program.

Bob spent time with several Swedish pulp and paper companies and reports that he was very much impressed with their silvicultural and management practices and particularly with their timber harvesting techniques. During the month of July he visited about 20 forest tree breeding and forest product laboratories in eight northern European and Scandinavian countries. Although the pace was torrid he and his new bride were able to get a bird's-eye view of forestry work as it is practiced in these countries.



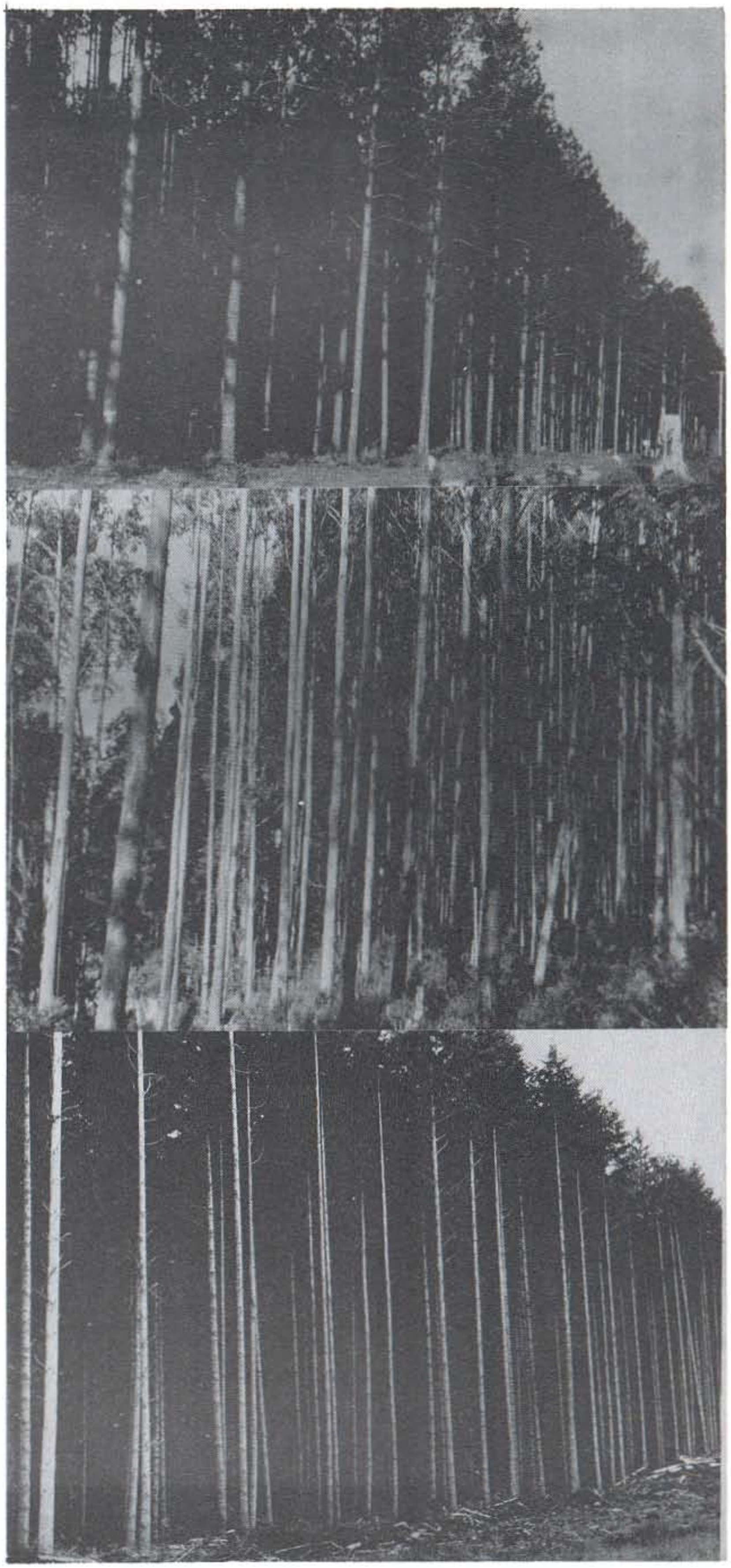
A different point of view in research methods, such as the control-pollinated progeny tests using single-tree plots, was observed by Kellison during his work-study tour of Sweden. This is an example of the many beneficial ideas obtained from other tree improvement programs.



One possibility of tree improvement, not exploited by the N. C. State Cooperative Program, is to use rooted cuttings or other vegetatively reproduced pine material for commercial planting. Encouraging results are being obtained in other areas using this method to produce special products. Workers in Australia and New Zealand have been leaders in such research. The photograph shows a stand of rooted Monterey pine under test in South Australia.

In October and November, 1965, Bruce Zobel made an eight-weeks "consultant" tour of Australia and New Zealand. This trip, sponsored by industries, federal and state organizations of both countries, was extremely valuable. Bruce was shown the problem areas as well as the most productive sites. Several points have already been incorporated into the N. C. State Cooperative Program. Forestry "down under" has tremendous potentials but also has some sticky problems and needs. Bruce came away convinced that closer working relations need to be maintained between the N. C. State Cooperative Tree Improvement Program and the tree improvement organizations in these two countries; both groups will benefit greatly from a close working relationship. In some things our program is more advanced, but in other areas their program is ahead of us. In all things we can help each other. For example, certain of the wood studies overseas have bolstered our interests and ideas, while some of our statistical approaches and designs have been of special benefit to them. Bruce reports it was a hard trip, one in which he probably saw as much forestry as was possible in the time available.

Bruce has been asked to give a paper on the economics of tree improvement at the World Forestry Congress in Madrid on June 8. The paper is truly a compendium of the ideas of many, including nearly every advisory committee member of the Cooperative Program. It is philosophical in nature, pointing out some of the difficulties, pitfalls and considerations necessary in making an economic analysis of tree improvement. Our Cooperative Program is used as an example. In developing the paper Bruce noted that the costs involved seem to be fairly clear-cut, as are some improvements. The main problem in an economic analysis is putting value on quality improvements. A copy of this paper will be sent to each of the industries. Bruce will not travel in Europe but will return home immediately after the Congress closes.



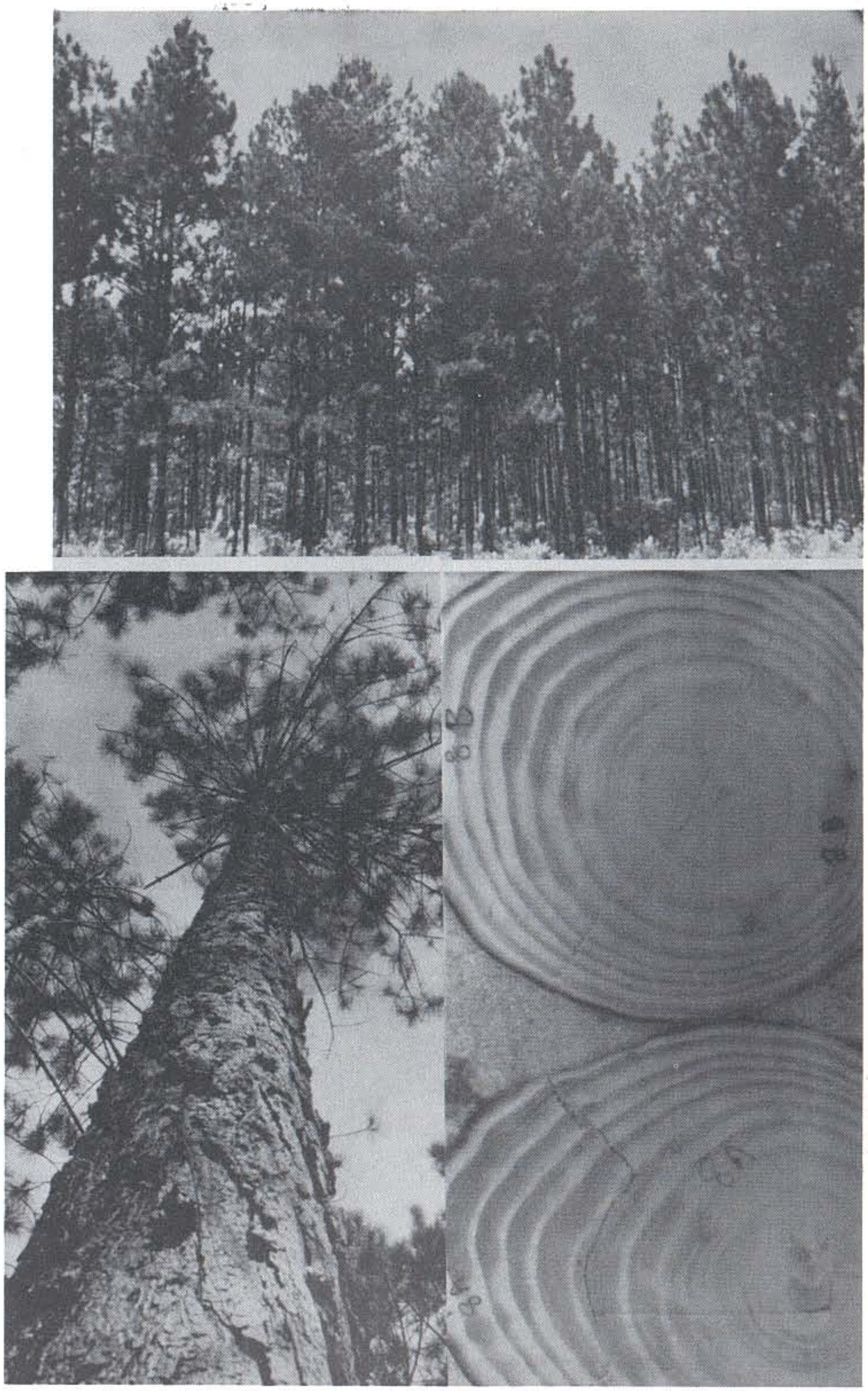
Tree growth in Australia and New Zealand ranges from average to fantastic. Stands representing outstanding growth are shown above. The top photograph illustrates outstanding growth of slash pine in Queensland. The central photograph is of a fine young stand of Eucalyptus regnans in Victoria, and the bottom one illustrates the wonderful growth and form of Douglas fir in New Zealand.

WOOD STUDIES

It often seems that the area of greatest activity has the least said about it. In this Tenth Annual Report, stressing progeny testing and seed production, such a statement would appear to be true about wood studies. Activities involving wood studies are numerous and involve nearly every company in the Cooperative. There is great interest in dry wood production per acre for stands of different age on different sites, information necessary to make decisions as to what age stands should be harvested for maximum return on the investment. Great interest is also evident as to when a tree, or log, is worth more for sawtimber than for pulpwood, thus helping differentiate final product usage. Value of topwood, moisture content, specific gravity and tracheid length differences are being investigated. Several companies are pulping trees with special wood characteristics or pulping specific portions of a tree.

Although details will not be included in this report, a number of papers have been prepared on results obtained (See Publications section). For example, papers have been published dealing with (1) variation of tracheid length and width, (2) differences in wood, including specific gravity, tracheid length, moisture content and cellulose yields, among several species growing on the same site, (3) differences in wood qualities caused by soil and site variation, (4) a dry wood weight yield table. Several companies have banded together to support a cooperative study with the N. C. State Wood Sciences Department on pulping characteristics of trees with varying wood and growth characters. Trees used in their studies are superior trees used in the industrial seed orchards of the Tree Improvement Program.

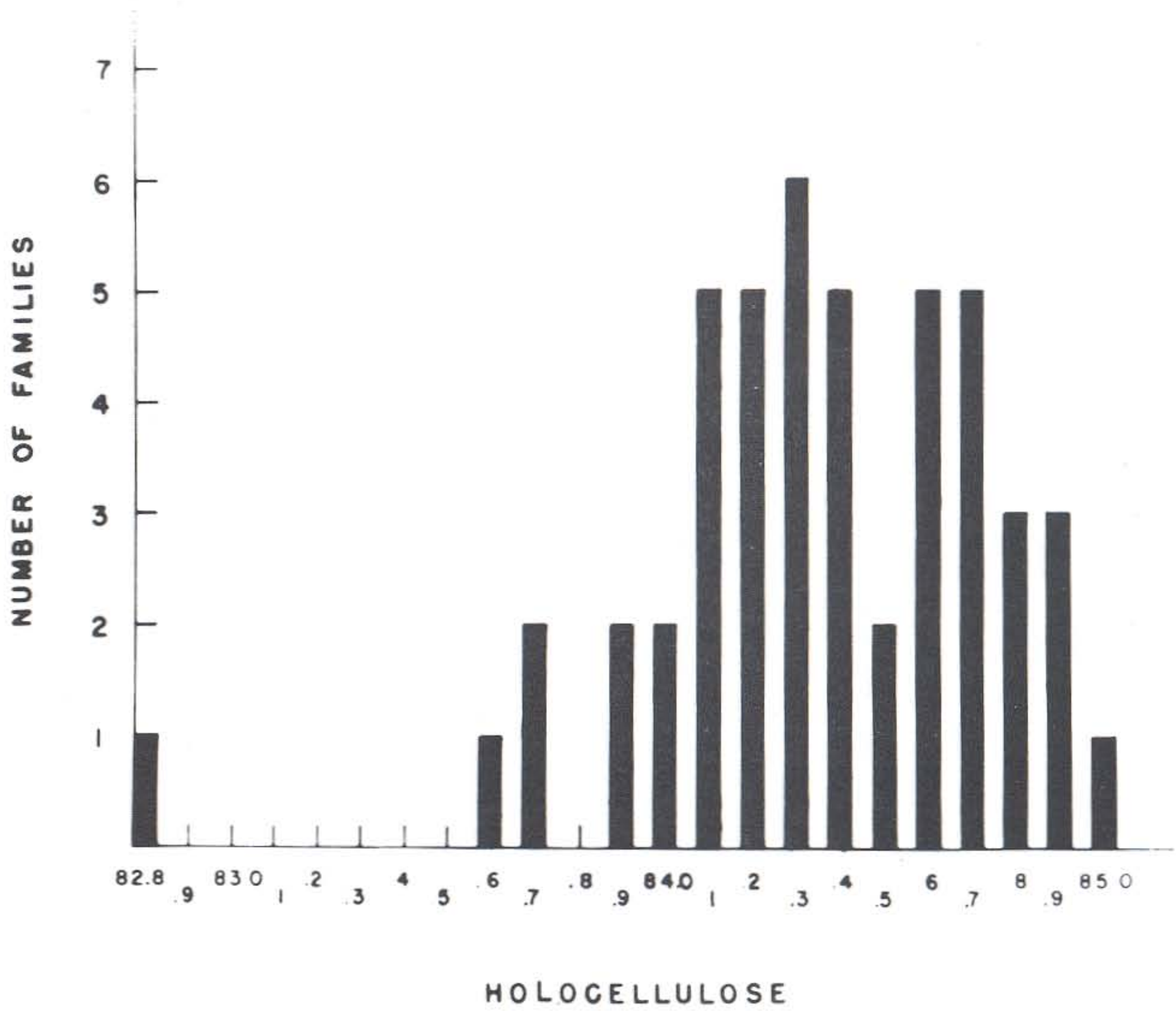
Wood studies are expanding and interest could be classed as being at a "white heat" and there is no sign of lessening interest - on the contrary, it appears that wood studies will increase during the coming year.



Wood studies have expanded rapidly. The photograph shows a mixed stand of loblolly, slash, longleaf and pond pines on the lands of Continental Can Company which were studied intensively. Also illustrated is one of the better trees sampled and the compression wood found in one of the more poorly formed trees. Such wood studies have taken up a large part of the Cooperative Tree Improvement Program activities.

I.P. HERITABILITY

CELLULOSE YIELD BY FAMILIES



A number of wood studies have been made in the Tree Improvement Program. One study of ten years' duration involves inheritance of cellulose. The work, done as part of the International Paper Company-N. C. State Heritability Study, showed that differences in cellulose yields between families were present (See graph) but the variation within families was so large that the inheritance of cellulose yield was negligible.

MEMBERSHIP IN THE COOPERATIVE

At the June, 1965 Advisory Committee Meeting the decision was made to admit the Virginia Forest Service as a full member of the Cooperative Program. They brought with them a well-established, functioning tree improvement program, with many trees selected and several orchards under establishment. Several members of the Cooperative had previously worked closely with the Virginia Forest Service and we were well acquainted with their program. We say "W E L C O M E" to such a valuable member of the Cooperative.

During the year several other organizations have talked with us about becoming members of the Cooperative, but no decisions have yet been made regarding additional membership in the Tree Improvement Program.

PERSONNEL

Several important changes have taken place during the past year:

1. During Dr. Waldy Maki's year-long stay in Finland, Dr. John Duffield has taken over Waldy's duties in supervision of research and graduate study, and thus has worked closely with us. I think he sometimes wondered what kind of "two-headed monster" he inherited but he has been most helpful during a critical time. For example, plans for our new building have been in the process of development and Jack has watched out for the interests of the Tree Improvement Program. He has helped a great deal in working with graduate students and with our program in general. We welcome Waldy Maki back home and hope we can continue drawing help from both of these men during the forthcoming year.

2. Dr. Leroy (Bud) Saylor has worked closely with us, handling pollen studies, hybridization programs, cytological studies and the arboretum. We were

most pleased at the announcement of his appointment as assistant to Dean Preston in the School of Forestry. The new duties will require half of Bud's time; the other half of his time will continue to be devoted to research.

3. For some time we have had Mr. Jim Roberds working with us on design and analysis of studies in the Cooperative Program. He handles the control-pollinated progeny tests. Jim has been working full time on a double assistantship, but as of January 1, 1966 he was given a regular Instructor appointment as a full-fledged faculty member. Jim has completed his Master's degree and, along with the job, is well along on the Ph. D. Degree. His research deals with progeny test design and analysis. WELCOME as a full member of the team, Jim!

4. For a number of years we have had research studies under way, both outside and on industry lands, but often the studies have been neglected because of insufficient competent help. This year we employed Mr. Alvis Walker, a field technician, to take over this work. The addition of Alvis will allow Bob, Jim and Bruce more time to devote to special problems of interest to members of the Cooperative. Alvis will be helping on incompatibility studies, systemic spray studies, and inheritance of "fertilizer reaction" studies, to name just a few.

5. We have worked closely with Dr. "Chuck" Davey and Waldy Maki on soils and fertilizer for several years. These studies have really grown during the past year and Chuck has been very busy helping develop new designs. He has been drawn much more closely into the Cooperative Program and is making a really large contribution to it. Also working more closely with us are Dr. Ellis Cowling and Dr. Dave French from the Pathology Department. Dr. French has been very helpful and we hate to see him finish his year's leave of absence from Up North (Minnesota). The good cooperation with other disciplines is made possible by the system of joint (interdepartmental) appointments used at N. C. State and by our close relationship with the N. C. State Agricultural Experiment Station.

6. The editor of the NEWSLETTER and our loyal liaison geneticist, Bob Kellison, is moving along on his degree work. His M.S. has been completed and he will go to school full time in the fall semester to complete coursework for the Ph.D. If he doesn't hurry, the yellow poplar he is studying for his thesis will be so large he won't be able to see their tops.

7. The permanent laboratory and office personnel have not changed during the year. All six of them are very busy and we have had two to four extra, part-time helpers in the lab to help with the flood of wood studies. The lab and office are humming with activity - All are looking forward to the new quarters in the new building (now in the drawing board stage).

PUBLICATIONS

Each annual report lists publications from the past year, either done by members of the Cooperative Program or of special interest to members of the Cooperative.

1. Barefoot, A. C., Hitchings, R. G., and Ellwood, E. L. 1965. Wood Characteristics and Kraft Paper Properties of Four Selected Loblolly Pines. III. Effect of fiber morphology in pulps examined at a constant permanganate number. Third For. Biol. Conf., TAPPI, Madison, Wis. (In press)

   In 1964 these authors reported on the effect of wood qualities on paper properties for pulps cooked at constant conditions. They reported cell wall thickness had the greatest effect on paper properties. For the same pulps, cooked to a constant permanganate number, results were essentially the same.

2. Beineke, W. F. and Perry, T. O. 1966. Genetic variation in ability to withstand transplanting shock. Proc., South For.Tree Impr. Conf., Savannah. (In press)

3. Byrd, V. L., Ellwood, E. L., Hitchings, R. G. and Barefoot, A. C. 1965. For. Prod. Jour. 25(8):313-320.

   Last year the most interesting study of four loblolly pines made in the Wood Sciences Department, partially financed by the International Paper Company, was reported (Barefoot, et al., 1964). The follow-up of this study, involving chemical constituents of the wood, showed that fiber morphology and wood chemical characteristics were very closely related, with the possible exception of lignin. This suggests that wood with relatively low lignin content but with thin walls may be possible.

4. Cole, D. E., Zobel, B. J. and Roberds, J. H. 1965. Slash, loblolly and longleaf pine in a mixed natural stand; a comparison of their wood properties, pulp yields and paper properties. Third For. Biol. Conf., TAPPI, Madison, Wis. (In press)

   Comparative yields of different species from trees of the same age growing intermixed on the same site were previously reported. Loblolly pine had the largest volume, while the wood of the three species was not too different. Pulp yields and paper strengths were reported for trees selected for having special wood properties. These were pulped in the Continental Can Research Laboratory in Augusta, Georgia.

5. Duffield, J. W. 1965. Some influences of genetics on the thinking of foresters. In Forestry in Science and Society. Univ. of Calif., School of Forestry. 66 pp. multilith.

A general account, for the practicing forester, of the importance of modern concepts of population genetics and evolution in forest management.

6. Duffield, J. W. 1965. An evolutionary view of wood. Seminar on genetics and wood quality. Oregon State University. (Unpublished)

A speculative discussion of the causes of wood property variations within the tree stem.

7. Kellison, R. C. 1966. A geographic variation study of yellow poplar (Liriodendron tulipifera L.) within North Carolina. M.S. Thesis, N. C. State University, School of Forestry, Raleigh.

Mensurational, wood, seed, leaf and soil data from nine geographic areas of North Carolina were collected and analyzed. The greatest amount of variation observed was among trees within stands, indicating that meaningful gains for this species can be obtained by genetic means. A lower Coastal Plain area was so significantly different in all morphological characteristics studied that it is believed to be a deep-peat ecotype.

8. Ledig, F. T. and Perry, T. O. 1965. Physiological genetics of the shoot-root ratio. Proc. SAF, Detroit.

Use of a standard physiological measurement, the shoot-root ratio, is shown to lead to erroneous conclusions in the comparison of genetic or treatment effects on plant growth. Reinterpretation of variation by using the allometric equation shows that there is genetic variation in relative growth of shoot and root in loblolly pine.

9. Perry, T. O. and Baldwin, G. 1966. Genetic variation in the winter breakdown of the photosynthetic apparatus of evergreens. Forest Science (In press).

10. Perry, T. O. Wang, C. W. and Schmitt, D. M. 1965. Height growth of loblolly pine provenances in relation to photoperiod and growing season. Silvae Genetica (In press).

11. Roberds, J. H. 1965. Patterns of variation in several characteristics of sweetgum (Liquidambar styraciflua L.) in North Carolina. M.S. Thesis, N. C. State University School of Forestry, Raleigh.

Fruit and seed characteristics, obtained from eight geographic locations within North Carolina, were found to vary among mother trees within locations. Differences among progeny within locations, which were kept separate by parent tree, were found for extent of bark corkiness, time of leaf

abscission, and stem diameter of one-year-old, open-pollinated seedlings. Wood specific gravity of the seedlings varied greatly, as values extended from 0.34 to 0.47; however, no differences were found among sources or among families of the same geographic location.

12. Saylor, L. C. and Smith, B. W. 1966. Meiotic irregularity in species and interspecific hybrids of Pinus. Amer. Jour. Bot. (May-June issue)

This paper describes a comparative analysis of meiotic conditions in 61 trees representing 21 species and 22 hybrid combinations. Irregularities occurred in all species and hybrids but were considerably more frequent in certain of the hybrids.

13. Saylor, L. C. and Koenig, R. L. 1966. The slash x sand hybrid. Submitted to Silvae Genetica.

Five hybrids were analyzed and compared to open-pollinated seedlings from the parental trees at different times over a 22-month period. This cross is one of the few successful intergroup crosses in the genus Pinus and represents the first well documented hybrid between a species of Australes and a species from any other group.

14. Stonecypher, R. W. and Zobel, B. J. 1965. Inheritance of specific gravity in five-year-old seedlings of loblolly pine. Third For. Biol. Conf., TAPPI, Madison, Wis. (In press)

As a follow-up to two- and three-year analysis, the five-year-old trees were harvested. Inheritance of specific gravity continued to be strong, with the third and fifth year results being nearly identical. Continued results of this nature indicate good potential gains from breeding for specific gravity.

15. Stonecypher, R., Cech, F. and Zobel, B. 1966. Estimates of components of variance and covariance in root and shoot characteristics of loblolly pine after one growing season. Conf. South. For. Tree Impr. Comm., Savannah, Ga. (In press)

A number of control-pollinated crosses from the heritability study (International Paper Company-N. C. State University-NSF-NIH) were assessed for inheritance of root characteristics. Most inheritance values were low, but "degree of fibrousness" showed considerable differences among crosses.

16. Stonecypher, R. W. 1966. Estimates of genetic and environmental variances and covariances in a natural population of loblolly pine (Pinus taeda L.). Ph.D. dissertation, N. C. State Univ., School of Forestry, Raleigh.

This thesis by Roy Stonecypher pulls together the techniques and methods of analysis in both the open- and control-pollinated progeny in the heritability study. The programs used, interrelationship of characteristics (mostly for second and third year characters), and the genetic and biological interpretation are intensively treated in this study. It presents the background methods already used on later measurements of the heritability material. This is the first comprehensive report on the main inheritance studies at Bainbridge.

17. Taft, K. 1965. An investigation of the genetics of seedling characteristics of yellow poplar (Liriodendron tulipifera L.) by means of a diallel crossing scheme. Ph.D. thesis, N. C. State Univ., School of Forestry, Raleigh. pp. 1-57.

Taft reports on the effects of selfing and outcrossing in this insect pollinated species. Although it is limited to seed and seedling characteristics, considerable light is shed on the breeding system of an insect-pollinated species such as yellow poplar.

18. Wheeler, E. Y., Zobel, B. J. and Weeks, D. L. 1965. Tracheid length and diameter variation in the bole of loblolly pine. Third For. Biol. Conf., TAPPI, Madison, Wis. (In press)

Twenty-five trees were intensively sampled from base to top to determine the relationship of tracheid length and width within a tree. Patterns were reported. It was found that breast height values are very closely correlated with total tree values, especially for tracheid width. This is part of the juvenile wood study with International Paper Company, reported as Tech. Rept. No. 26.

19. Whitesell, C. D., Zobel, B. J. and Roberds, J. 1966. Specific gravity and tracheid length of loblolly pine in Maryland and Delaware. Tech. Rept. No. 29, School of Forestry, N. C. State Univ., Raleigh. pp. 1-11.

This adds to our knowledge of wood variation of loblolly pine. Also, no ties were found between soil type and wood qualities. This study was part of a larger soil-site study, so the opportunity of comparing soil-site was excellent.

20. Woessner, R. A. 1965. Growth, form and disease resistance in four-year-old control- and five-year-old open-pollinated progeny of loblolly pine selected for use in seed orchards. Tech. Rept. 28, School of Forestry, N. C. State Univ., Raleigh. pp. 1-67.

The early industry open-pollinated plantings were assessed. Growth and form were usually better than commercial checks, while disease resistance was not so. One group of four-year-old control-pollinated seedlings from West Virginia Pulp & Paper Company showed marked differences in all characteristics studied. This study was most helpful in making a decision as to what (and how) characteristics would be measured in the main progeny tests of the cooperating organizations.

21. Zobel, B. J. 1965. Inheritance of spiral grain. IUFRO Conf. on Wood, Melbourne, Australia, October. (In press)

This paper was given at the conference and is to be included as a part of the proceedings. It summarizes what is known on genetics of spiral grain.

22. Zobel, B. J. 1965. Inheritance of fiber characteristics in hardwoods - a review. IUFRO Conf. on Wood, Melbourne, Australia, October. (In press)

As part of the symposium on inheritance of wood characteristics this paper deals exclusively with the little that is known about inheritance in hardwoods. More information is being obtained each year.

23. Zobel, B. J. and Kellison, R. C. 1965. Biological research by forest industries. Jour. For. 63(6):424-429.

To familiarize the forester with research by industry this paper was prepared using the Cooperative Tree Improvement Program as an example. It was written in a nontechnical manner.

24. Zobel, B. J., Ralston, J. and Roberds, J. 1965. Wood yields from loblolly pine stands of different age, site and stand density. Tech. Rept. No. 26, School of Forestry, N. C. State Univ., Raleigh. pp. 1-22.

As part of an intensive study involving over 900 trees in 44 plots, a "dry wood weight" yield table was constructed. This publication has been much in demand and only a few copies are left.

25. Zobel, B. J. 1966. Tree improvement and economics: a neglected interrelationship. Sixth World Forestry Congress, Madrid, Spain, June. (In press)

This request paper is the work of many. It outlines the problems confronting economic studies in tree improvement. Most advisory committee members made comments and suggestions about the paper and a number of outside researchers also made suggestions. The ideas expressed therefore include those of over 30 persons. The paper deals with philosophy of general techniques and does not go into many details.

26. Zobel, B. J., Stonecypher, R. and Browne, C. 1966. Variation and inheritance of cellulose in loblolly pine. TAPPI, New York. (In press)

Ten years' work is reported involving both variation patterns and inheritance patterns. The method of analysis is outlined briefly. Variation patterns within trees are not very evident but are large between trees. Inheritance at five years of age appears to be so small that improvement from selection is not feasible. Better analytical methods are needed.

27. Zobel, B. J. and Kellison, R. C. 1966. The future of southern hardwoods. SAF, Appalachian Section, Raleigh. (In press)

The hardwood problem as seen from the outside was discussed. Due to increased use of good hardwood lands for other purposes and increased demands the problem of suitable available hardwoods appears to be quite critical. The need for more work and studies is great.

COOPERATING ORGANIZATIONS

Organization	Working Units and States
Albemarle Paper Mfg. Co. (Roanoke Rapids Div.)	N. C., Va.
American Can Company (Naheola Mill)	Ala.
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.
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., Ala. Franklin Div. - N. C., Va.
Virginia Forest Service	Va.
West Virginia Pulp & Paper Co.	South - N. C., S. C. North - Va., West Va., Ohio
Weyerhaeuser Co. (North Carolina Div.)	N. C., Va.