SIXTH ANNUAL REPORT

N. C. STATE - INDUSTRY COOPERATIVE

FOREST TREE IMPROVEMENT PROGRAM

School of Forestry
North Carolina State College
Raleigh

June 1962

SIXTH ANNUAL REPORT

N. C. STATE - INDUSTRY COOPERATIVE

FOREST TREE IMPROVEMENT PROGRAM

Introduction

As many of you know, writing Annual Reports can become a real chore, a much-dreaded task from one year to the next. We at North Carolina State started out with this traditional attitude in tackling our first several Annual Reports. But much to our surprise, we find the task becoming easier yearly. This year we have actually looked forward with considerable eagerness to writing the Sixth Annual Report. Our change in attitude has come about rather subtly, and the reason for the change was not immediately clear. On reflection, however, it appears that the real reason for the change in outlook lies in the kind of material that we are accumulating and are proud to reveal. In the early years, the Annual Reports were devoted to what was planned and what we hoped to accomplish; later the reporting has given more and more opportunity to emphasize accomplishments and to disseminate information about solid results.

The N. C. State - Industry Cooperative Tree Improvement Program is characterized by a genuine vitality---we are working together with industry as a team, and are "doing things", obtaining results, and, what is particularly satisfying to a researcher, seeing research findings put into practice. The College - Industry team approach has worked out better than any of us had dared hope, and with increased contacts, experience and respect for each other, we are now doing things effectively together and better than any of us could have predicted or would have anticipated when the program first got underway.

HIGHLIGHTS OF THE PAST YEAR

Our enthusiasm about the progress of the program can best be illustrated by listing a few highlights of the past year. Many significant events and things took place, none of which can be covered in detail, but a brief mention will show what is happening.

1. The first control-pollinated seed from the production seed orchards were collected for progeny testing to determine the value of the trees in the orchard. We expected the first attempts at control crossing to be rather poor, due to lack of experience in making crosses, young age of the grafts, and difficulty of obtaining good pollen. Although all these facets still leave much room for improvement, the first year's seed collections exceeded all expectations, and we already have sufficient seed from a surprisingly large number of crosses. In addition, we have learned more about pollen storage, and have obtained good results when use is made of the methods outlined by Bud Saylor at the November 1961 Contact Men's Meeting.

2. The pine heritability study, possible only through a National Science Foundation Grant, coupled with special and close cooperation of the International Paper Company, has progressed very well. The last controlled crosses were made by Dr. Franklin Cech and his helpers at Southlands Experiment Forest, and the first planting of the control-pollinated seed was made this spring. The 40+ acres of open-pollinated progeny have survived well, and some interesting early results have been obtained despite a fall drought and a "plague" of rabbits in part of the area.

3. A "pilot plant" directed hybridization program has been started cooperatively with the Union Bag-Camp Paper Corporation. A number of hybrids will be produced for special problem sites in both the Georgia and Virginia areas. Several crosses were made this spring by Mr. Ed Hinkle, of Union Bag-Camp, and also by Mr. Bob Adams of West Virginia Paper Company, who is cooperating in

making crosses between selected slash pine (Pinus elliottii) and selected pond pine (P. serotina). The objective of the hybridization program is to attempt introduction of special desired characteristics from other species into slash or loblolly pine as the case may be, to enable these species to become "merchantable" when grown on problem sites, where they now do not obtain merchantability or very good yields.

4. At the suggestion of Jim Hill of the Bowaters Southern Paper Corporation (Hiwassee Land Company), several companies have undertaken sponsorship of a pine seed collection trip to Mexico, which will take place in late November and December, 1962. Joining Jim on this trip will be Ed Hinkle of Union Bag-Camp Paper Corporation, Vernon Knight of Coosa River Newsprint Company, Don Cole of Continental Can Company, Inc., and Bob McElwee and Bud Saylor from N. C. State. This "pilgrimage" has two objectives:

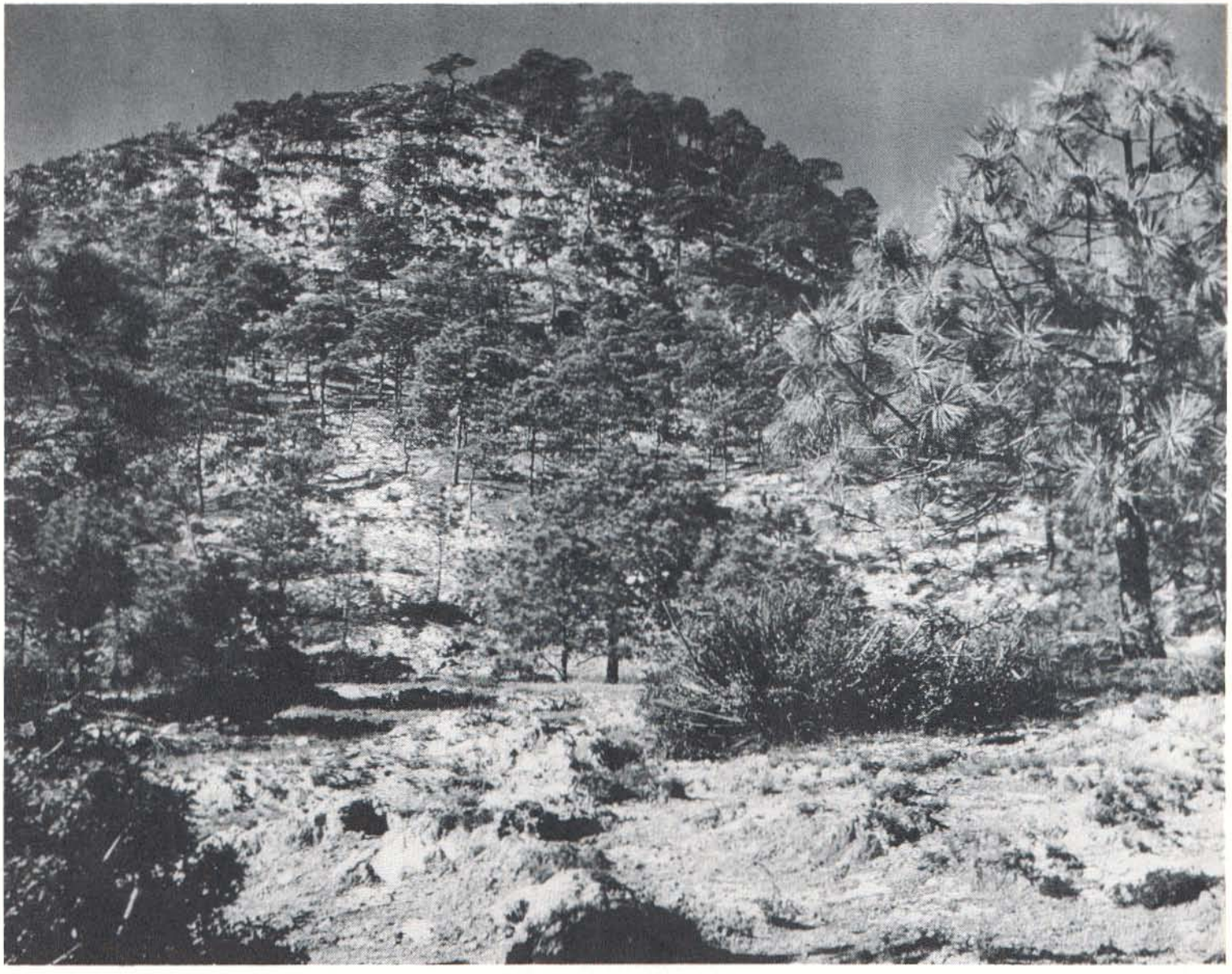
(a) Collect seed of selected species to grow as "pilot plant" tests in certain special problem areas on company lands, as well as to test their performance in more mountainous areas;

(b) Collect seed and botanical specimens for studies of speciation, evolution and introgression, as well as to obtain material for detailed cytological studies and small-scale wood studies of the numerous, very fine species of Mexican pines.

5. Several of our advanced Ph. D. candidates are completing their degrees soon, resulting in some new and interesting research findings and well-trained manpower for the tree improvement work. The graduate student program is still going at capacity, and much good basic research is underway by the large group of enthusiastic, vigorous student researchers. At the present time, seventeen degree aspirants are studying forest genetics or are undertaking closely-related research projects.

6. During the past year several staff changes at N. C. State have helped strengthen the program immeasurably.

(a) Mr. LeRoy Saylor was given a joint appointment between the Genetics



4. The purpose of the collection trip to Mexico is to obtain seed from trees growing under conditions that might be useful for planting under some of our problem sites in the southeast. The above photo shows a species of Mexican pine collected by Zobel in 1954 in the state of Nuevo Leon, where the trees were growing in a very shallow soil with rock outcrops so poor that little vegetation was found on the ground. Such trees must be very hardy to grow under such rigorous conditions.

5. There are large areas of forest growth in Mexico, with a number of different species. Many of these have never been thoroughly studied or tested, such as the one shown above at 12,000-foot elevation in Nuevo Leon. Chances for genetic improvement from such material are very great.

Department and the Forest Management Department. His program involves studies on cytogenetics, speciation and evolution, as well as on hybridization. Under his direction the first portion of a 50-acre "living herbarium" has been started. This area added to the Halifax Paper Company arboretum, in which Dr. J. G. Hofmann and Mr. Ray Brown report over 35 species of pine have already been established, very nicely supplements Saylor's program.

(b) Mr. Gene Namkoong is being stationed at N. C. State as an employee of the Southern Institute of Forest Genetics at Gulfport, Mississippi. Gene's special interest is in quantitative genetics, and his full-time assignment in this field, with emphasis on forest genetics, will be a great help to the advancement of tree improvement work. His own research will deal with phases of quantitative genetics, being closely associated with research of the forest geneticists in the U. S. Forest Service.

(c) The appointment of Dr. John Duffield as Silviculturist in the School of Forestry at N. C. State is being received with much enthusiasm. Although John will not be directly associated with the Tree Improvement Program, we look forward to considerable guidance and advice from this outstanding forest biologist when he arrives in Raleigh in July, 1963. John's work in the silvicultural and ecological phases of southern forestry will give the entire forest management research program at the School of Forestry added balance.

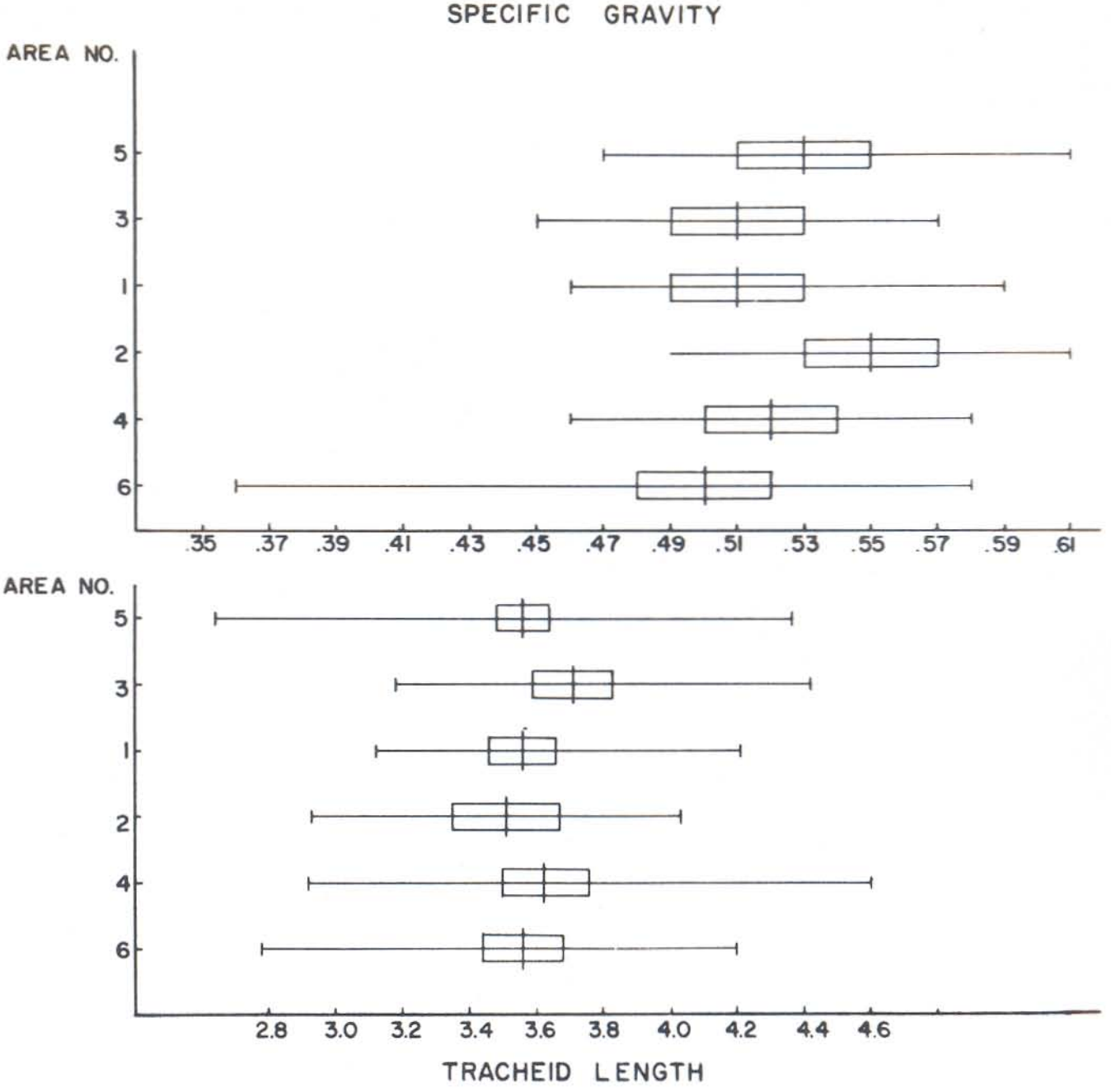
(d) Dr. Eric Ellwood has joined the School Faculty as the Head of the Wood Products Department, encompassing both Wood Technology and Pulp & Paper Technology. His presence greatly strengthens our program, for he has expressed his desire and willingness, as well as that of his staff, to work with the companies on assessment of wood quality and its effect on pulp and paper. Several companies are interested in pulping certain of their select trees, either for study as hand sheets, or on the small paper machine, and Dr.

Ellwood's Department is prepared to conduct both types of study.

7. The increased interest of the industries in the effect of varied wood properties on pulp and paper properties has generated considerable thought and research. If the industries evince enough interest, a symposium will be scheduled for late fall, jointly sponsored by the Wood Technology and Forest Management Departments of the School of Forestry at N. C. State, in which industries' needs and desires, as well as wood variability and its control, will be the theme. Bruce Zobel has attended meetings of a somewhat similar nature in the other parts of the U. S. and in Canada, and he reports them as being very worthwhile.

THE COOPERATIVE PROGRAM

During the past year we havehad a number of requests to outline specifically just what research has been done, and is now being done, in the N. C. State - Industry Cooperative Forest Tree Improvement Program. Also, we have had a number of requests to list all publications that have been made since the program was initiated. We have, therefore, decided to devote the major portion of this Sixth Annual Report to such an outline. Careful reading will show that all work done directly with industry funds is listed, as well as that done with National Science, Agricultural Experiment Station and other funds. The Tree Improvement Program is so coordinated, that it is not possible to draw a line separating the various research projects. The bulk of work shown is directly done through the Management Department in the School of Forestry, with the cooperating industries, but joint efforts between two departments such as that undertaken by Mr. Saylor, are also included. Additionally, several activities are shown that are essentially joint activities between Dr. Ellwood's Wood Technology Department and the Management Department. Therefore, such studies as those relating wood qualities to pulp and paper qualities consist of the wood analysis being done by the Wood Technology Department, while the trees analyzed



6. A recent study on pond pine has shown considerable variation from plot to plot for both specific gravity and tracheid length. The manuscript reporting these results has been submitted for publication. Specific gravities and fiber lengths for pond pine are quite comparable to those found for loblolly growing in the same general area. All six areas tested were in North Carolina ranging from deep peat to mineral soil.

such as select trees used in the seed orchards or progeny of these trees are supplied by the companies through the Management Department. Such a close relationship will be of real benefit to all concerned.

Perhaps the best method to make such an outline is to separate the overall Tree Improvement Program into broad subject-matter areas or phases, and to briefly list individual studies being conducted under each phase. Included with this breakdown is a list of publications, by staff and students at N. C. State, and Industry personnel, which relate to the project.

DEVELOPMENT AND TESTING OF SEED ORCHARDS FOR COMMERCIAL USE SELECTIVE BREEDING FOR MASS PRODUCTION OF IMPROVED SEED

Introduction

In the southeast trees are grown like crops--i.e., the management procedure often is one of clear-cutting followed by planting or direct seeding. This type of intensive forestry requires tremendous amounts of seed; the cooperative companies in the Tree Improvement Program have a real and immediate need for better seed. Even small, early improvements will yield large added incomes at time of harvest. Thus, the seed orchard project is somewhat of a "crash program" to obtain as much gain as possible in as short a time as possible.

Current Studies

1. To grade and select trees used in the establishment of seed orchards of the supporting industries which serve as the commercial source of seed or planting or direct seeding of company lands. Such orchards have been established for loblolly, slash, pond and Virginia pines, and for sweetgum and yellow poplar. Already, 33 separate orchards covering about 500 acres have been established, with grading completed on over 900 trees initially used in grafting into these orchards. Ultimately, about 800 acres of seed orchard will be established for the companies now in the cooperative Tree Improvement Program. Although this activity is primarily one of production for industrial use, many important and interesting facts are being uncovered that help immeasurably with the more basic phases of research of the Tree Improvement Program.

2. To progeny test the phenotypic selections in the seed orchards for their genetic worth. This is being done by (a) open-pollinated seed, and (b) control-pollinated seed. Already over 200 acres of open-pollinated tests have been established, and ultimately over 2,000 acres of progeny tests will be planted to

assess the individual worth of the present selections in these orchards. More than 4,000 artificial pollinations were made prior to the spring of 1962, and several times this number were made in the spring of 1962 since, in most cases, "flowering" was good. These crosses are made using a "4 tester" system, which will give a good estimate of general combining ability, considerable information on specific combining abilities of the selected parents in the seed orchards.

3. To develop more useful selection indices by using data from the progeny tests from results of our earlier selections, and from results of the basic studies on inheritance. Also needed are evaluations of the economic worth of tree and wood characteristics as determined by the industries. From these data we will be able to develop selection indices that are much more efficient than the grading system now in use. For each different species, a new grading system (selection index) must be developed.

4. To develop and test "seed production areas" until seed orchards come into commercial production. There are now about 500 acres of such seed production areas from which the cooperating companies are obtaining seeds, and several companies use such seed to satisfy the bulk of their planting or seeding needs.

5. To develop seed orchard management procedures, fertilizer schedules and irrigation schedules to produce the greatest volume of desired seed as soon as possible. A great deal orchard management details remain to be worked out. Such management studies are usually a cooperative venture, with the industries taking the lead.

Publications

1. Zobel, B. J., Barber, J., Brown, C. L. & Perry, T. O. 1958. Seed orchards - their concept and management. Jour. of For. 56(11):815-825.

2. Zobel, B. J., Maki, T. E. 1958. Comments on "Annual variation in seed crops of loblolly pine" (with reply from K. F. Wenger, defending and modifying original thesis). Jour. For. 56(2):144-146.

3. Zobel, B. J. 1960. Tree improvement and the southern forest industries. 7th Northeastern For. Tree Imp. Conf.:9-13.

4. Perry, T. O. 1960. Pruning of slash and loblolly pine grafts. Jour. For. 58(4):323.

5. Zobel, B. J. 1961. Development of better poles by forest tree breeding. South Atlantic Wood Pole Conference, Raleigh, N. C.: pp. 19-37.

6. Zobel, B. J. 1962. Impact of forest genetics on plantation management. Amer. Pulpwood Association, Gulfport, Mississippi (In press).

7. Cech, F., Barber, J. & Zobel, B. J. 1962. Comments on "Who wants tree seed certification and why." Jour. of For. 60(3):208-210.

3. Flowering in most company seed orchards has been much earlier than expected. Shown above is a three-year loblolly graft in Champion's orchard at Newberry, South Carolina. Each pollination bag contains one to several flowers. Such early flowering will make initial testing possible much sooner than anticipated.

BASIC RESEARCH ON VARIATION AND INHERITANCE OF WOOD PROPERTIES

Introduction

Our main research contribution has been on the studies of variation and inheritance of wood properties. On this phase of work many papers which have a significant effect and value for the supporting industries have been published. Considerable time is spent meeting with, and talking with, groups of industrial people all over the U. S. and Canada. Oftentimes, these groups have titles such as "Pulpmill Superintendents Association", "American Pulpwood Association", and others that have little interest in genetics per se, but are very interested in the added knowledge of wood available from the genetics research. Because of the tremendous interest and demand for information, it would be easy to spend all our efforts in this field. Immediately valuable though this work is to the industries because of its "practicality", some important "basic" research findings have evolved from it. Much of our budget for laboratory analyses is expended directly on the mass of routine measurements necessary in making wood studies of this nature.

Current Studies

1. Variation in wood properties of natural stands throughout the species range. The objectives are to determine differences between geographic races, local strains within geographic races, and individual trees within local strains, for each of several species. Such studies are costly and time consuming. Much supplementary information about natural variation in wood properties is obtained from an analysis of the wood of selected trees used in the seed orchards. A nested sampling procedure has proved very suitable, and the following species are being worked on:

(a) Loblolly pine - from Alabama to Delaware to Tennessee. Results of one major study have been published.

(b) Pond pine - from various areas in North Carolina. The manuscript is in press.

(c) Virginia pine - throughout the southern portion of its range. The study has just been started.

(d) Yellow poplar - throughout N. C. from seacoast to mountains. The study is half completed.

(e) Sweetgum - throughout the species range. The study is half completed.

2. Determination of wood variation within a tree. Knowledge of within-tree variation is of basic importance to genetic studies on wood. It would seem natural to assume that these variations would have been already determined and known by wood technologists. Unfortunately, this has not been so. In order to determine a proper sampling procedure for the genetic studies, these within-tree variation patterns had to be established. Such studies are very time-consuming, but have been completed for specific gravity and cellulose yields of loblolly pine, as well as for wood characters of sweetgum and yellow poplar. The concept of core, or juvenile, wood now seems to be quite generally accepted, but when first reported in our publications, it aroused controversy. This concept was certainly not our original idea, and many others have recognized and worked on it previously; however, our genetic studies on wood have awakened wide interest in it and have emphasized its extent and importance.

3. A "breakdown" of the complex character of specific gravity. Resolution of specific gravity into its "basic" inheritance patterns for each of these is underway. A paper will soon be published by Mr. Floyd Goggans showing the "heritabilities" and the genetic components of these "basic units" of specific gravity for loblolly pine.

4. Inter-relation of characteristics of wood. For example, does high specific gravity wood always have long tracheids, thick walls and wide cells? Or are these characteristics inherited independently? Two papers have been published on loblolly pine showing that cell length, cell width and specific gravity seem to very somewhat independently, making it possible to produce trees with the desired combinations of the three. Similar studies are also being done for sweetgum and yellow poplar.

5. Determination of gross heritabilities and parent-"progeny" relationships of wood for vegetatively-reproduced material. One major study is just being completed in cooperation with Don Cole of the Continental Can Company, on 39 clonal lines including 250 individual 5-year-old grafts.

6. Determination of the extent and seriousness of compression wood and the possible aids to reduce its occurrence through the genetic approach. One early study was made, and results will be summarized in a forthcoming Technical Report. It has been found that the "corkscrew" spiral of loblolly is serious and strongly inherited, and the amount of compression wood varies directly with the occurrence of the corkscrew growth of the tree's bole.

7. Determination of the effect of certain wood and fiber qualities on the final product so the geneticist can know what to emphasize in his breeding program. Although the Genetics project personnel are neither trained nor equipped to do very much on this type of investigation directly, studies are being carried out in cooperation with the pulp and paper laboratory of the Wood Products Department. However, we have been able to make a start. As an example, one mill produced good paper from one type of wood, a poor paper from another type. We undertook analysis of these two products using our own crude and inefficient method, and found a real difference in cell length, cell width and wall thickness. In the future, such analyses will be done by arrangement and cooperation with the Wood Products Department.

Publications

1. Zobel, B. J. 1957. Inheritance of wood properties in pine. Proc. 4th South. Conf. on Forest Tree Improvement Tech. Paper 17, pp. 27-29.

2. Zobel, B. J. 1957. Results of research on genetic phases of wood properties of loblolly pine. 3rd Lake States Tree Impr. Conf., Sept.:61-64.

3. Zobel, B. J. & McElwee, R. L. 1958. Variation of cellulose in loblolly pine. Tappi 41(4):167-170.

4. Zobel, B. J. & McElwee, R. L. 1958. Natural variation in wood specific gravity of loblolly pine and an analysis of contributing factors. Tappi 41(4): 158-161.

5. Haught, E. A. 1958. An exploratory study of compression wood of loblolly pine (Pinus taeda L). MS Thesis, N. C. State College, Raleigh. (Unpublished).

6. Zobel, B. J.; Webb, C. D. & Henson, F. 1959. Core or juvenile wood of loblolly and slash pine trees. Tappi 42(5):345-356.

7. Zobel, B. J. 1960. Selection and breeding coniferous trees with superior wood characteristics. 5th World For. Cong., Seattle, Washington. 10 pp.

8. 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.

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

10. 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.

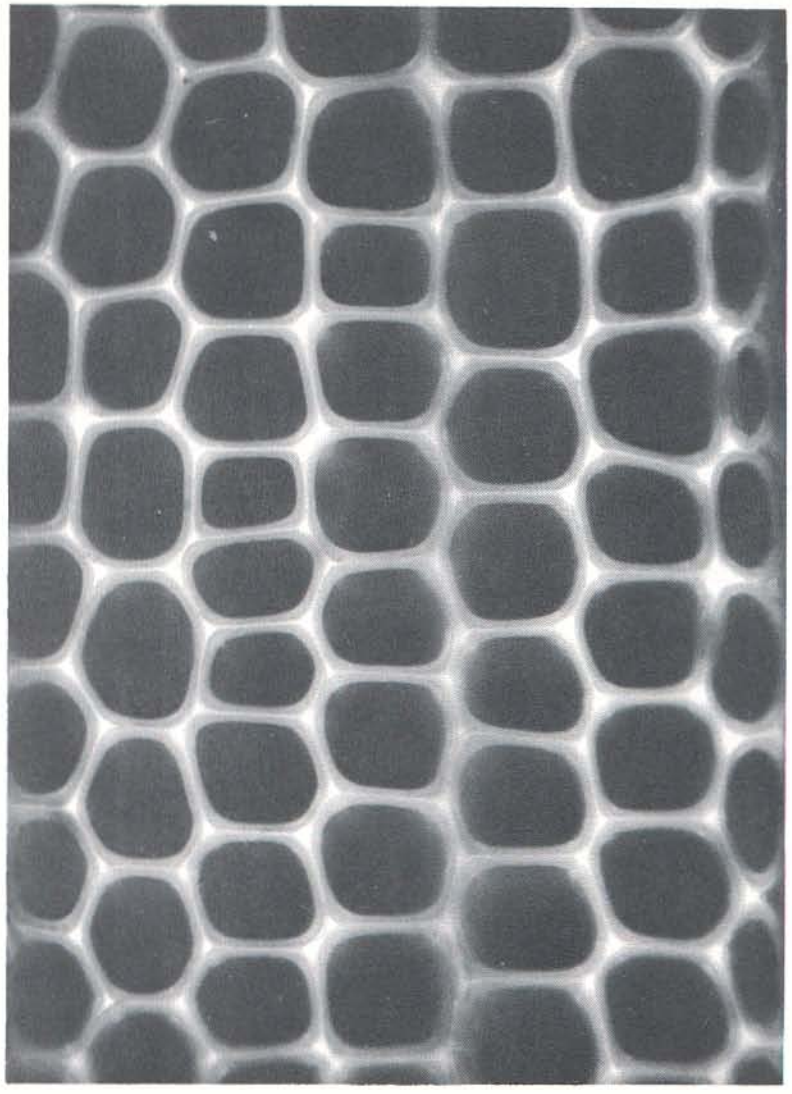
11. Zobel, B. J. 1961. The Consultant's concern with wood quality. Consultant 6(2):4-10.

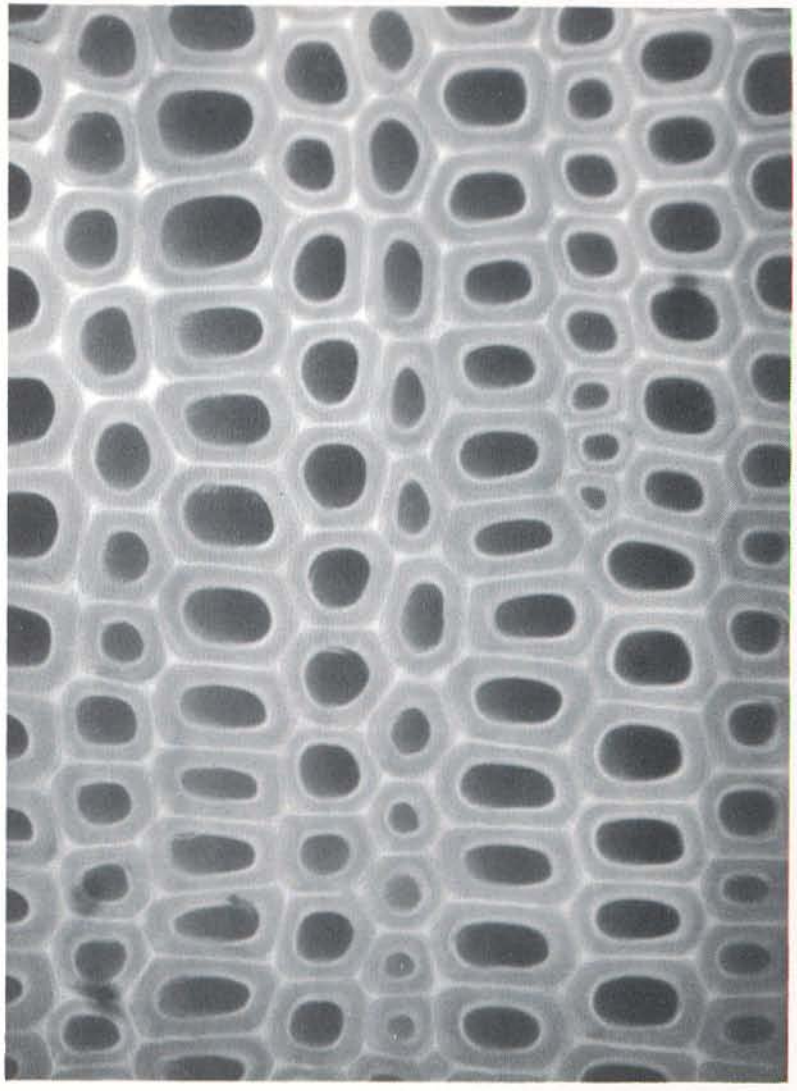
12. van Buijtenen, J. P.; Zobel, B. J. & Joranson, P. N. 1961. Variation of some wood and pulp properties in an even-aged loblolly pine stand. Tappi 44(2): 141-144.

13. Zobel, B. J.; Goggans, F. & Maki, T. E. 1961. Wood properties affected by fertilizers. Forest Farmer, May. pp. 6-7, 18.

14. Zobel, B. J.; McElwee, R. L. & Browne, C. 1961. Interrelationships of wood properties of loblolly pine. Sixth South. For. Tree Improvement Conf., Gainesville, Fla. pp. 142-162.

15. Zobel, B. J. 1961. Inheritance of wood properties in conifers. Silvae Genetica 10(3):65-70.





Early work on genetics stressed work on specific gravity. In order to make maximum progress, it is necessary to break specific gravity into its component parts. Pictured here is summerwood and springwood of the fifth annual ring supplied by Mr. Floyd Goggans. He is just completing his Ph. D. thesis on inheritance of tracheid length, wall thickness and tracheid width.

16. Goggans, J. F. 1961. The interplay of environment and heredity as factors controlling wood properties in conifers--with special emphasis on their effects on specific gravity. Tech. Rept. #11, School of Forestry, N. C. State College, Raleigh. pp. 1-56.

17. McElwee, R. L. & Zobel, B. J. 1962. Variation in wood qualities of pond pine. (In press).

18. McElwee, R. L. & Zobel, B. J. 1962. Silvical and wood characteristics of loblolly pine in the southeast. (In press).

19. Zobel, B. J. 1962. Wood quality improvement through better trees. Tenth Annual Forestry Symposium, Louisiana State U. (In press).

20. Zobel, B. J.; Cole, D. E. & Stonecypher, R. W. 1962. Inheritance of wood qualities in clones of slash pine. (In press).

HYBRIDIZATION, INTROGRESSION AND CYTOGENETICS OF PINES AND HARDWOODS, INCLUDING ARBORETA ESTABLISHMENT. COMPATABILITY AND PHENOLOGICAL STUDIES.

Introduction

Much of the work on this project is being done as a cooperative effort with Mr. LeRoy Saylor and the Genetics Department, aided by a modest National Science Foundation Grant obtained by Mr. Saylor. It is truly cooperative in all aspects, with both the Genetics Department and Management Department contributing time, money, facilities and manpower. Portions of this project are being done with direct cooperation of the cooperating industries, making possible scope and kinds of studies not otherwise possible.

Current Studies

1. A survey of the chromosome morphology in the Genus Pinus. Investigations are being pursued by Mr. Saylor with advice from Dr. Ben Smith of the Genetics Department. We have jointly obtained seed of nearly 70 species of pines, which are under study.

2. Determination of the chromosome pairing patterns among wide crosses in the pines. Saylor is doing this work obtaining much of his research material from hybrids growing at the Western Institute of Forest Genetics, Placerville, California. The outstanding cooperation of Dr. R. Z. Callaham and Dr. W. Critch-

field from the W. I. F. G. has made possible a much more complete study of pine chromosomes by Mr. Saylor.

3. A "directed breeding", hybridization project, in cooperation with Union Bag-Camp Paper Corporation. This large-scale study was initiated last year, and first crosses have been made. It has two objectives:

(a) To produce a hybrid suitable to grow in certain problem sites owned by the company. Normally, these sites do not now produce merchantable timber—what is needed is to introduce different chracteristics enabling the trees on these problem sites to grow to merchantable size. Parents used for the crosses are selected for suitability of wood and growth characteristics for the companies' particular needs. Tests of the various hybrids will be on a fairly large scale--on a pilot plant basis, but designed so that much basic information will also become available.

(b) To attempt crosses not previously made. Such crosses have the potential characteristics needed. If these succeed, they will be incorporated into the program of (a) above.

4. Procurement and testing of exotics in the southeast, with special emphasis on the Mexican pines. Four companies are sponsoring a collection trip to Mexico in November and December, 1962, to obtain material for plantations on certain of their problem sites and on higher elevations. We intend to go through IUFRO, along with several foreign countries, to get a central collection agency established in Mexico, hopefully sponsored by FAO. This effort will be truly international in scope, with Mr. Thulin from New Zealand, Mr. Matthews of England and Bruce Zobel spearheading its initiation.

5. Study and collation, through a biosystematic approach, of members of the Genus Pinus. Special early emphasis will be on Mexican pines collected jointly on the Industry-sponsored trip as described under 4., above. Species obtained will be related to material already collected by Zobel in 1954 and 1955, and growing at Raleigh and near the coast in North Carolina. This project is a major long-term one, and we are hopeful of obtaining funds for followup studies to pull together the necessary information enabling determination of the evolutionary and introgression aspects, and a satisfactory cataloguing and classification of the trees. As in the cytogenetic studies, this venture is a cooperative one with the Genetics Department.

6. Establishment of a breeding arboretum and "living herbarium" where various exotics and the plants studied by Saylor will be outplanted. At present, 35 acres have been cleared and planting will soon start. The area developed, near Raleigh, will ultimately comprise about 50 acres. In addition, Halifax Paper Company has a parallel arboretum with the same species near Roanoke Rapids, N. C. They have already over 40 species established on a 30-acre tract that is especially well developed and laid out for an arboretum.

7. Intensive study of introgression based on Sonderregger pine (the hybrid between loblolly and longleaf pine). Gene Namkoong has nearly completed this investigation in partial fulfillment of the requirements for the doctoral degree.

8. Study of morphological and growth characteristics of sweetgum through its range in the U. S. (and also in Mexico to Guatemala). This study, started last year, will determine individual, clinal and ecotypic variation patterns.

9. Dr. and Mrs. Sax, retired from Harvard University, spent one semester at N. C. State teaching and carrying on their long-term research. They were co-sponsored by the Genetics Department and the School of Forestry. Their advice and help were of great value to both staff and students.

10. Determine better methods of control pollination for pine. Yields and quality of seed from control pollinations of pines are often somewhat disappointing. We need to know more about different kinds of pollination bags and what happens within them. Such a study, with emphasis on the basic factors involved, has been underway for several years by Mr. Brooks Polk.

11. Methods to control pollinate sweetgum and yellow poplar. Before control pollinations could be done, methods of bagging, emasculation and pollinating flowers had to be determined. This has been done by Mr. Kingsley Taft for yellow poplar and Mr. Dan Schmitt for sweetgum.

12. Determination of degree of self-compatibility for yellow poplar and sweetgum. Such information is vital to all genetic studies, and use of trees in seed orchards. Dan Schmitt has nearly completed studies on sweetgum and Kingsley Taft on yellow poplar in which they are assessing the effects of selfing.

Publications

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

2. Zobel, B. J. 1961. Pines in the tropics and subtropics. Sect. 22, 13th IUFRO Congress, Vienna, pp. 1-13.

3. Saylor, L. C. 1961. A karyotype analysis of selected species of Pinus. Silvae Genetica 10(3):77-83.

4. Sax, H. & Sax, H. J. 1961. The effect of age of seed on the frequency of spontaneous and gamma ray-induced chromosome aberrations. Radiation Botany 1: 80-83.

5. Taft, Kingsley A. 1961. The effect of controlled pollination and honeybees on seed quality of yellow poplar (Liriodendron tulipifera L.) as assessed by X-ray photography. MS Thesis.

DETERMINE THE INHERITANCE PATTERNS, VARIANCE COMPONENTS AND BEST BREEDING PROCEDURES FOR SEVERAL SPECIES OF PINE AND HARDWOODS

Introduction

This is our largest "basic" research effort, and takes the skills of a number of full-time workers, plus many more technical and unskilled workers seasonally. Such studies are long term, but will be a major contribution from the Cooperative Tree Improvement Program.

Current Studies

1. The largest and most intensive phase of this project is referred to as the IP Heritability Study. It currently requires the full-time efforts of four workers, plus several seasonal workers. This large-scale, intensive program has been made possible through a 5-year, NSF Research Grant, and through the cooperation of the International Paper Company and use of their 20,000-acre Southlands Experiment Forest. The IP Heritability Study has the following objectives:

(a) To determine the variance components (additive, dominance, epistatic, interaction, etc.) of loblolly pine for a large number of characteristics such as needle anatomy, growth habit, wood properties, physiological reactions, disease resistance, etc. In order to obtain the effect of different environments (the genotype-environment interaction), plantings are made on both Piedmont and Coastal Plain soils, doubling the planting but enhancing the value of the experiment.

Both greenhouse and field plantings have been made, and results are now becoming available. Field phases of this study are under the direction of Dr. Frank Cech of Southlands, and Mr. Roy Stonecypher at N. C. State handles the design and statistical work. Variance components are determined by two methods:

(1) Use of control-pollinated seed. The design being used was outlined by Dr. H. F. Robinson and co-workers, and is called N. C. State Design I. It consists of making "male groups", i.e., one male is used on each of four females. Final crossings that resulted in the completion of all 64 groups were done this spring, and 14 such "male groups" already have been planted. The test, when complete, will comprise approximately 40 acres of experimental planting on the two differing sites. The entire test is on lands of the Southlands Experiment Forest.

(2) Use of open-pollinated seed from the same trees as employed in the male groups. Two years ago, 28,000 seedlings of this material were planted; then, last year this material transplanted into field plots encompassing nearly 50 acres. First analyses of certain growth and wood characteristics are now nearing completion.

(b) To determine parent-progeny and juvenile-mature relationships. The study is so designed that these inter-relationships can be clearly measured and brought out--in fact, one method employed in estimating the variance components is by parent progeny relationships. One of the greatest needs in forest genetics is to establish juvenile-mature correlations, which require intensive study of each parent; such studies have been completed on more than 350 trees.

(c) To compare the efficiency of the use of open-pollinated v.s. control-pollinated seed in estimating variance components of the complex, "multi-gene" characteristics with which we in forestry usually deal.

(d) To cut selected parent trees and some of their progeny and to pulp them, for determining the relationships of certain wood characteristics to those of their progeny to find how strongly these characteristics are passed from parent to offspring. Such studies will necessarily be donein cooperation with the Wood Products Department.

2. Progeny for trees at present in company seed orchards have been established over considerable acreage. Shown above is a three-year field planting of loblolly pine on the lands of West Virginia Pulp & Paper Company from open-pollinated seed from parents in the seed orchard. This is on a good site, and growth has been excellent. Differences in Cronartium among progenies of parent trees has been quite great.

2. To determine variance components of yellow poplar by means of diallel crosses. All crosses have been completed, and will be planted this spring by Mr. Kingsley Taft. A smaller exploratory and incomplete diallel was harvested last year, and was outplanted in the field the spring of 1962.

3. To determine inheritance patterns in sweetgum and yellow poplar. A series of open-pollinated progeny from variation studies in sweetgum and yellow poplar are planted in such a way that inheritance patterns can be determined. Several students are undertaking these studies.

4. To study variance components from seed orchard crosses. The control-pollinated crosses used to test trees in the seed orchards will give an almost unlimited source of material for studies of variance components from selected trees as compared to unselected populations in the IP Heritability Study. Eventually, control-crosses between 3000 parents will be available for this analysis; over 100 combinations have already been made.

Publications

1. Cech, F. C. & Zobel, B. J. 1960. What is inherited--how can we tell. Forest Farmer, July, pp. 2.

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

INHERITANCE OF PHYSIOLOGICAL AND CLOSELY RELATED CHARACTERISTICS

Introduction

Most of the physiological studies will be done by Dr. Perry, Dr. Maki and their students. However, one can scarcely separate these investigations from strictly genetic and wood research projects because physiological and environmental considerations must always bekept in mind. In general, most of these studies contribute to over-all tree improvement.

Current Studies

1. To determine the extent and causes of "photosynthetic efficiency" and cause for differential growth rate in forest trees. This is a portion of Dr. Perry's major research effort.

2. To study the extent and results from differential photoperiodic reaction. This area of inquiry is also one of Dr. Perry's main interests.

3. To determine variation in nutrient and dry matter content of needles among individual trees and also their inheritance patterns. One preliminary study has been completed on this phase, and it will be followed up on the heritability study.

4. To determine whether salt-tolerant races of loblolly pine exist. This study has been underway one year, but no definitive results have yet been obtained.

5. To determine whether drought-tolerant races of loblolly pine are manifested in seedlings immediately following germination. Extensive direct seeding in forest management makes this type of information imperative. This study has been underway for two years, and will be terminated next year.

6. To determine variation and inheritance of bark thickness in young loblolly pine. First phase of this study will be completed within 6 months.

Publications

1. Zobel, B. J. 1960. Seed sources for direct seeding. Symposium - Direct Seeding in the South, Duke University, pp. 27-30.

2. Zobel, B. J. 1960. Narrowing the genetic base. Symposium on "Possible Consequences of Southern Pine Monocultures." 4th Conf. on South. Indus. Forest Management, Duke University, pp. 32-35.

3. Perry, T. 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.

4. Steinhoff, R. J. 1961. An investigation of the nutrient and dry matter content concentrations in the foliage of loblolly pine (Pinus taeda L.), MS Thesis, School of Forestry, N. C. State College, Raleigh.

5. Perry, T. O. 1961. Physiological-genetic variation in plant tissue. Sixth South. Conf. on Forest Tree Improvement, Gainesville, Fla., pp. 60-64.

STATISTICAL METHODS MOST APPLICABLE TO QUANTITATIVE GENETICS AND TESTING OF FOREST TREES

Introduction

We in forestry have many special problems of time and space not encountered by the crop plant geneticist. In addition, nearly every characteristic on which we work is a complex, multi-gene one. Little is known about genetics of trees, and it is difficult to plan experiments without a knowledge of the kind and extent of variation. Thus, a chronic and recurring problem is the determination of how many plants to use and what constitutes the smallest size and the simplest design for the most efficient experiment. The larger the experiment, the more variation in site conditions is likely to be encompassed; moreover, with time, losses will occur in a non-random fashion. Assessment of efficient designs and analysis are

among our most needed project studies.

Current Studies

1. To determine the optimum plot size for study of various characteristics. One phase of this study will be completed this year by Mr. Tom Conkle.

A considerable part of the work outlined above for determination of inheritance deals with this project. For example, information will become available on the relative importance and efficiency of control v.s. open-pollination, large v.s. small blocks, use of individual seedlings v.s. plot averages, etc.

Publications

1. Zobel, B. J. 1957. Progeny testing for drought resistance and wood properties. Der Zuchter 4:95-96.

PROVENANCE STUDIES IN PINES AND HARDWOODS

Introduction

One first step in studying a species is to determine the existence of different provenances--or geographic races. Such studies are done in two ways:

(1) Studying the stands in their natural habitat.
(2) Bringing seed from different geographic sources into uniform environments to determine the degree of genetic control.

We are doing both kinds of studies on a rather large scale, especially for wood properties, as outlined in that project. In addition, three large studies are underway dealing with provenance variability in growth, morphology, physiology and pathological characteristics.

Current Studies

1. Variation in loblolly pine. This exhaustive study has been completed and published for natural stands and for juvenile characteristics of seed from these stands. Plantations will yield data on the characteristics of older trees. Early results indicated most variation to be by individuals and much less by site or provenance--except, of course, certain characteristics directly tied to survival.

2. Variation in sweetgum. This study is in its third year. First plantings of sources within N. C. have been made; next year plantings will be made from sources throughout the species range. This study is a supplement to wood variation studies of this species nearing completion by Mr. Charles Webb.

1. Above is a stand of spruce of German origin growing in southern Sweden. Much helpful information was gained from observing stands of this type and other research work in Europe by Zobel on his recent trip to northern Europe. Interchange of ideas, and research findings is essential to making progress in the field of forest tree improvement.

3. Provenance in yellow poplar. This study has been initiated and will consist of two parts:

(a) Study of wild stands in N. C. from seacoast to mountains.
(b) Growing of seed from these stands in areas on the Coastal Plain and Piedmont.

One earlier yellow poplar study was completed; also, a study of wood variation by provenance is being made for this species by Mr. Fred Taylor.

4. A local provenance study in loblolly pine was established four years ago. It is closely tied to No. 1, above, and fifth-year measurements will be available soon. This study has 20 acres of outplantings in the Coastal Plain, replicated in the Piedmont. Each provenance is replicated eight times.

Publications

1. Barber, J. C. & Zobel, B. J. 1959. Comments on "Genetic Variation within Geographic Ecotypes of Forest Trees and Its Role in Tree Improvement." Jour. of For. 57(6):439-441.

2. Sluder, E. R. 1960. A yellow poplar seed source study. MS Thesis, N. C. State College, Raleigh, pp. 1-39.

3. Thorbjornsen, E. 1960. Variation in loblolly pine (Pinus taeda L.).Ph. D. Thesis, School of Forestry, N. C. State College, Raleigh, pp. 1-188.

4. Thorbjornsen, E. 1961. Variation patterns in natural stands of loblolly pine. Sixth South. Conf. on Forest Tree Improvement, Gainesville, Fla. pp. 25-44.

POLLEN FLIGHT STUDIES--USE OF RADIOACTIVE TRACERS IN PINES

Introduction

We need a method to mark pine pollen to determine its spread, isolation distances necessary, and extent of inbreeding occurring. Early studies of free flight of pollen were made. A study using radioactive phosphorus was started two years ago, and last year techniques were "perfected." McElwee is in charge of this work, and has a license for handling radioactive material. Both he and Zobel have clearance to work at Savannah River Project. One phase on marked pollen flight will be completed this spring.

Current Studies

1. To determine how far pollen flies from a single tree in a stand. This investigation will indicate for seed orchards both the inbreeding dangers and effective pollination distances of individual trees.

2. To determine the isolation distance between stands to prevent contamination from outside sources. This information is essential as a guide to isolation distances and barriers around seed orchards.

3. To study differential pollination by different parent trees for the purpose of determining if such a differential in vigor (that undoubtedly influences number of fertilizations) takes place during the lapse of about 13 months when the pollen "grows" between pollination and fertilization.

4. To study movement of radioactive material in wood and possibly to get a wood "marker" enabling response to different treatments applied to the tree to be marked within a tree.

Publications

1. McElwee, R. L. 1960. An analysis of the factors contributing to the flight patterns of loblolly pine pollen. MS Thesis, N. C. State College, Raleigh, pp. 1-64.

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

METHODS USED TO VEGETATIVELY PROPAGATE FOREST TREES

Introduction

It is necessary to know how to propagate tree species in order to use them for research and seed orchard purposes. Therefore, many empirical studies were made to find out how to do this job, but not necessarily to determine the basic underlying factors causing success or failure.

Current Studies

1. How to field graft on a commercial scale. In field grafting we faced one of the most difficult preliminary jobs and one that we were told could not be done. First-year results on loblolly averaged about 25 per cent successful takes; now the industries graft about 20,000 scions a year with over 60 per cent successfully established. This problem has been licked for pine, but needs serious study for hardwoods. We are on the second year of such a study for sweetgum and yellow poplar, both for grafting in the field and in the greenhouse.

Publications

1. Webb, C. D. 1961. Field grafting loblolly pine. Tech. Rept. #10. School of Forestry, N. C. State College, Raleigh, pp. 1-33.

BUILD UP A GERM PLASM OR "CLONAL" BANK OF WIDELY DIVERGENT AND TESTED GENOTYPES

Introduction

As forest management practices change, new insects or diseases become epidenic and new problems are encountered. In addition, product needs vary. To adjust to these changes, future seed orchards may need genetic types much different than we have today. In order to satisfy this demand, a "gene pool" must be brought together and test to be used as the new conditions dictate. This project has been less well developed than the current development of seed orchards because of the strong urgency to get production orchards started now so their seed will be available at an early date. However, if the long-term seed orchard program is to be thoroughly sound, it must be developed around an adequately diverse gene pool.

Current Studies

1. Establish those well-formed, fast-growing individuals with properties not now desired for commercial uses, in clone banks. For example, trees that react well to fertilizer or intensive management or cultivation are not as yet needed, but probably will be in the forseeable future. Currently, we have several hundred such reserve clones already established in holding areas on which controlled crossing and testing will soon be done.

2. Make within-species crosses from widely different provenances. Such wide crosses will create many "new" genotypes which will be tested and the best maintained in holding areas until needed for commercial seed production of trees with their special characteristics.

3. Make between-species crosses to obtain many new genetic combinations. Special disease or drought resistance can be obtained by directed breeding.

Publications

None

COOPERATING COMPANIES

Company	Working Units and States
Catawba Timber Co. (Bowaters Southern Paper Corp.)	One - S. C., N. C.
Champion Papers Inc.	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 Paper Corp.	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., West Va., Ohio Md.
Weyerhaeuser Co. (North Carolina Division)	One - N. C., Va.