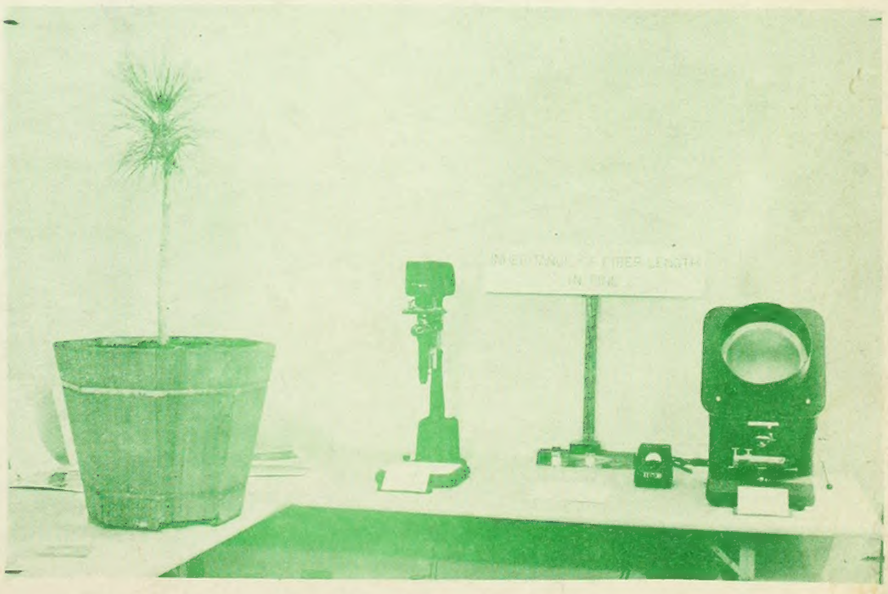
Proceedings Of The

FOURTH SOUTHERN CONFERENCE ON FOREST TREE IMPROVEMENT

Held at

ATHENS, GEORGIA

January 8 and 9, 1957



THE FOURTH SOUTHERN TREE IMPROVEMENT CONFERENCE

The George Foster Peabody School of Forestry, at the University of Georgia, upon the advent of its fiftieth anniversary, extended to the Southern Forest Tree Improvement Committee an invitation to hold its fourth southwide conference on tree improvement at Athens. The invitation was accepted and The Fourth Southern Tree Improvement Conference was the first to be held at the newly constructed Center for Continuing Education at the University of Georgia. Its fine facilities, and the efficiency and graciousness of its personnel contributed greatly to the success of this gathering.

The Fourth conference emphasized the accomplishments of all those engaged in tree improvement work in the South. The high caliber of the papers presented was noteworthy, and praiseworthy of the great strides toward making tree improvement possible.

Officers of the Committee on Southern Tree Improvement:

T. E. Bercaw, Forestry Department,
Gaylord Container Corporation,
Chairman.

E. G. Weisehuegel, Division of Forestry Relations,
Tennessee Valley Authority,
Vice-Chairman.

George I. Garin, Department of Forestry
Alabama Polytechnic Institute,
Secretary.

Conference Committee:

L. Hargreaves, Georgia Forestry Commission,
Chairman.

Keith W. Dorman, Athens-Macon Research Center
Southeastern Forest Experiment Station,
U. S. Forest Service.

Berch W. Henry, Southern Institute of Genetics,
Southern Forest Experiment Stations,
U. S. Forest Service.

Program Committee:

Keith W. Dorman, Chairman.
Berch W. Henry

Local Arrangements:

W. A. Campbell, Athens-Macon Research Center,
Southeastern Forest Experiment Station,
U. S. Forest Service.

B. Zak, Athens-Macon Research Center,
Southeastern Forest Experiment Station,
U. S. Forest Service.

M. Reines, School of Forestry, University of Georgia

Exhibits:

B. Zak
M. Reines
R. McAlpine, Athens-Macon Research Center,
Southeastern Forest Experiment Station,
U. S. Forest Service.

This is the seventeenth technical paper released under the sponsorship of the Committee on Southern Forest Tree Improvement.

C O N T E N T S

THE SCOPE AND MAGNITUDE OF FOREST GENETICS RESEARCH

by

V. L. Harper, Assistant Chief for Research
Forest Service, U. S. Department of Agriculture

This large group of scientists and practicing foresters meeting here to discuss forest tree improvement is one of the outstanding recent developments in American forestry. Twenty years ago such a meeting would not have been possible. Even 10 years ago, we would have been hard-pressed to have found more than a dozen or so persons in our whole country sufficiently interested to attend a meeting concerned with forest genetics or forest tree improvement. Now, however, there are five regional forest tree-improvement committees or associations actively organized and holding meetings regularly to talk over problems and projects in this relatively new and fascinating subject-matter field.

Why this rapidly developing interest in tree improvement? Why has it taken forest tree improvement so long to catch on? In comparison with farm crops, the interest in improving forest crops has taken a long time to develop. The basic reason, I suppose, is that up until recently there hasn't been a widespread interest in growing timber as a crop. But now that we are concerned about forest production, it is only natural that we turn to tree-breeding, selection, and all the other factors of tree improvement as a promising means to the end of better quality forest trees and trees that are faster growing and pest-resistant.

We have faith in what tree-improvement research can do for forestry. Plant improvement has done a great deal to improve agriculture, so, why can't we improve forestry along the same line? I certainly think we can. But at the same time, I wouldn't want any of you to expect overnight miracles. If we make real progress it will come from substantial and sustained effort of competent scientists who have the understanding and cooperation of the forestry industries, the State and Federal forestry agencies, and the forest land owners interested in producing better crops of timber.

Fortunately, we have the benefit of early efforts in tree improvement on which to build. These early efforts give substance to our feeling that tree improvement is important and can be counted upon to fulfill promising expectation. For example, some 30 years ago, Phil Wakely began his study of the growth and development of loblolly pine from different seed sources. The results of this study, not large or time-demanding but executed with care, have been so impressive that few foresters in the South are now unaware of the great importance of planting seed obtained from the proper source. I'm not saying we know, as yet, anywhere near as much as we should about the proper seed source; but surely, this study pointed-up the problem and the need to find a solution. I suspect that Wakeley's early study had a significant bearing on the decision--in which you as a group made--a few years ago to launch a cooperative, South-wide seed-source study which extends from Maryland to Texas involving participation of many agencies and individuals.

Other early efforts aimed at tree improvement are: The racial studies of Douglas-fir in the Pacific Northwest, started before World War I by the Forest Service; the development of hybrid poplars by the Oxford Paper Company in the 1920's; the preliminary work in the 1930's by the Forest Service in exploring the possibility of selecting slash and longleaf pine for high gum-yield; the establishment of the Eddy Tree Breeding Institute at Placerville, California, in the 1920's--established by Mr. Eddy, a lumberman, and later deeded to the Forest Service. These are only a few of the early efforts which were the beginnings of the larger programs of forest tree-improvement research which we have today that are being conducted by Federal, State, and private agencies.

Just how big has this research program become? In the Forest Service research organization we have at the present time about 24 man-years of technical time going into forest genetics and the closely related work in tree improvement of forest physiology, forest pathology, forest entomology, and wood anatomy. Assuming a cost of about $12,500 per technical man-year--including besides the salary of the technical man the cost of clerical, subprofessional help, and other expenses--the total annual expenditure of the Forest Service for tree-improvement research is about $300,000. The research is conducted at 7 of our regional forest experiment stations and at our Forest Products Laboratory. Some of our Forest Service projects are concentrated at centers such as at our Institute of Forest Genetics at Placerville, California, and at our Southern Institute of Forest Genetics near Gulfport, Mississippi, and at a new center being developed at Rhinelander, Wisconsin. At these centers we maintain a team of scientists drawn from the various disciplines needed in a well-rounded attack on the problems of tree improvement. Others of our projects are conducted at lesser installations. Some are pretty small. Much of our work is conducted in cooperation with other agencies. A good example of such cooperative research is that going on here in the State of Georgia where a private foundation, forest industry, the State forestry agency, the University of Georgia, and the Federal Government combine their efforts in a well coordinated program.

A recent survey of forest genetics in the United States by Jonathan Wright showed that in 1955 there were 28 colleges or universities with one or more tree-improvement projects underway. In addition, 8 states had projects being conducted by their State forestry agencies. The survey also showed 8 private foundations and industry groups working in this field of research. This survey did not show dollar amounts being expended. A fair estimate of the non-federal expenditure, however, is about $600,000 per year.

The Forest Service's annual expenditure for tree-improvement research is believed to be about one-third of the total expenditures of all agencies for such research. It was about one-third in 1953 when Kaufert made his survey for the Society of American Foresters. Since 1953, all agencies have increased their expenditures. Assuming the increases have been somewhat uniform among agencies, I accordingly estimate that all agencies together are now spending about $900,000 per year on this type of research.

In contrast, according to Kaufert in 1953, the money being expended yearly for breeding and improvement programs on such farm crop plants as cotton and corn is in excess of $5,000,000. He asks whether we should not be spending more for forest crop plants considering their relatively higher economic value in our economy. I would say yes.

Nevertheless, $900,000 per year for forest genetics and closely related research is a sizable outlay and we are all naturally concerned that we get as much for the money as possible. The fact that these expenditures are spread over many agencies and projects lends weight to the concern and has caused some people to wonder whether coordination is as good as it could be, i.e., whether there might not be some wasteful duplication of research going on.

Frankly, my own study of the question leads me to believe that the coordination of tree-improvement research is good and that, considering the newness of the expanded effort, there is less waste motion than one would normally expect.

First of all, some aspects of tree-improvement research, such as determining the bearing of geographic races on breeding of superior strains of trees, require replicating the research in several localities, and this can best be done through the participation of several agencies, often through small outlays on the part of each. For example, most, if not all, species of southern pines are made up of several distinct geographic races. Loblolly pine from Maryland and from Texas seed, tested in both Maryland and Texas in connection with the Southwide pine seed-source study of the Committee on Southern Forest Tree Improvement, showed startling different responses in the two places. In a Maryland nursery, seedlings of Texas origin were conspicuously killed back by low winter temperatures which left Maryland stock uninjured. In Texas, by contrast, the majority of Maryland seedlings succumbed the second summer after planting to high temperatures under which Texas seedlings throve. None of the foregoing important information could have been obtained except by layering out test plantations in both Maryland and Texas. The second plantation was not wasteful duplication, but necessary replication.

Secondly, our regional stations have the benefit, as do the States and other agencies involved, of advisory committees including Tree Improvement Committees such as this one meeting here today. It is especially good for the program as a whole for research workers and representatives of action agencies to get together and discuss each other's projects and problems. In this way research administrators can determine gaps in the tree-improvement research program and where current program may need reorientation to meet as squarely as possible the important problems disclosed. So far as the Forest Service is concerned, there is a pretty good mechanism in effect which helps to assure coordination. In Washington we maintain a record of all Forest Service projects in tree-improvement research and seek to coordinate this activity among our various regional stations.

Finally, the selection of projects with the desire to avoid wasteful effort is an inherent quality expected of competent scientists. No scientist worthy of his profession, would care to unnecessarily duplicate the research of another. Each wants to make an original contribution. It is hollow glory to him who merely confirms someone else's findings without extending the general knowledge of tree improvement. A scientist's standing is determined by his contributions to knowledge and by the regard in which he is held by his colleagues. There are no second prizes for research.

So, I say that I believe there is pretty good coordination and a minimum of wasted effort going on in the tree-improvement research field. In summary, my reasons are that what may appear superficially to be duplication may, in truth, be needed replication required by the biological nature of the material dealt with; that the system established for achieving coordination, including advisory committees and very active regional tree-improvement committees, is functioning very well; and that the scientists concerned want a coordinated program and by themselves naturally strive to avoid duplication.

In closing, I want to pay tribute to the large amount of cooperation which is going on in this important field of research. I have already mentioned the Southwide seed-source study of southern pines involving many agencies and individuals throughout the entire South. Similar studies are underway or being started in other sections of our country with eastern white pine and ponderosa pine. The exchange of hybrid seed and of information on techniques and progress in forest tree breeding is not only on a regional and national basis in this country, but is on a world-wide basis.

I especially want to express my deep appreciation to all of you who are giving your time and effort as members of and participants in the Southern Tree Improvement Committee. It is a fine thing for the South that it has such a public-spirited group. It is a fine thing for forestry. It augurs well for the future progress of tree improvement.

GENETICS AND ITS RELATIONSHIP TO THE IMPROVEMENT OF PLANTS

by

A. A. Fleming, Associate Professor
of Plant Breeding, University of Georgia

As we look around this room, we can easily see that differences are occurring between the individuals here. What do you think is causing these differences? The variation may be genotypic or environmental or a combination of the two.

No two individuals in this room have the same genetic make-up or genotype. No two people here had exactly the same environment in development. There is a quotation, "Heredity deals the cards and environment plays them." For an organism to develop into a superior individual, the genetic potential must be there first of all. No matter how good the environment is, if the genetic potentiality is not there, the individual is limited in its development. Dorman (4) has discussed hereditary variation as the basis for selecting superior forest trees in a 1952 paper. Later today we will be hearing more about hereditary variations in slash, loblolly, and shortleaf pines.

Genetics as a Science

Genetics is the science of heredity and variation. However, genetics was not always a science. In fact, the word genetics was not suggested until the year of 1906 by Bateson. The foundation for genetics as a science burst forth in 1900 with the rediscovery of Mendel's famous 1866 paper by three men working independently of each other--Correns (Germany), DeVries (Holland), and von Tschermak (Austria).

Thousands of generations of farmers and herders tried to improve their crops and herds by trial and error. These ancient people knew something about reproduction, but their concepts were often incorrect. Some 5,000 years ago the Babylonians and Assyrians carried out the process of pollination to obtain fruit set in their date palms (dioecious plant). They did not know why they were doing this other than the fact that it had to be done before any fruit was produced. Likewise, the ancient people did not understand animal reproduction, although they knew that animals mated before offspring were produced.

In 1694 man discovered sex in plants. In 1719 Thomas Fairchild produced a new variety of pinks by artificial hybridization. A number of workers made successful crosses of varieties within various crops before 1900. Nevertheless, most of the results were unpredictable until the rediscovery of Mendel's paper. With the turn of the century a new era in plant breeding began. Breeders became interested in the development of new varieties for a specific purpose. Our methods of breeding today are based upon a knowledge of genetics.

Since 1900 countless experiments and discoveries have been made in the field of genetics. This basic information is being applied in many ways for the improvement of plants and animals. Fundamental genetic principles are the same for all organisms. A knowledge of the genetic fundamentals, mode of inheritance, linkage relationships, and heritability enables the breeder to plan the most effective breeding program. Many of the most important economic characters are inherited in a quantitative manner and controlled by a large number of genes. Nilsson-Ehle from Sweden and East from the United States were the first to show that this group of characters is inherited in a Mendelian manner. They published in 1908 and 1910, respectively, their papers.

Economic Importance of Plant Breeding

The development of hybrid corn has been termed the outstanding scientific accomplishment of the 20th century. Its value must not be restricted to corn alone. Principles applied to the development of hybrid corn and its utilization of heterosis are being applied now to many other plants and animals.

In the words of Paul C. Mangelsdorf (10) of Harvard, "In my opinion hybrid corn is the most far-reaching development of this century, not only in applied genetics, but in the entire field of applied biology. It has already affected more lives, I venture to guess, than any of the epoch-making discoveries in medical biology of the same period. Insulin and penicillin have saved thousands of lives in the past twenty-five years, but the new abundance of foodstuffs which hybrid corn has created has saved millions of lives in this same period of the world's history.

Approximately 90% of the corn acreage in the U. S. today is planted to hybrid corn. In 1933 less than 1% of the corn acreage was planted to hybrids. American farmers are producing more corn today on 82 million acres than was produced on 103 million acres a generation ago. Extra bushels produced by hybrid corns in one year are worth enough to pay for all the research ever performed with cereal crops (11).

Improved varieties of wheats have increased the production of this vital bread grain by 20% on a given acreage. This gain is represented by approximately 200 million bushels worth $400,000,000 per year.

There are over 50,000 crop diseases. In 1950 the most vicious race of stem rust (*Puccinia graminis tritici*) found in North America hit the northern wheat belt. The race, known as 15B, was a hybrid produced by a natural cross on barberry bushes. At that time all the commercial wheats, both spring and winter, were suceptible to 15B. An estimated 10 million bushels of wheat were lost in 1950 due to the stem rust. Over 13,000 different varieties and strains of wheat in the U.S.D.A. world collection were subjected to tests in the greenhouse to find resistant germ plasm. After finding resistance, plant breeders began transferring genes for this resistance to otherwise adapted varieties.

In the 300 years that tobacco has been cultivated in this country, disease problems have multiplied. To help overcome three of these problems U.S.D.A. scientists made selections for resistance to nematode root rot, root knot, and Granville bacterial wilt. It took a year of travel by two trained collectors and six years of intensive testing and selection before adapted strains were found to control these diseases. Adequate control has been obtained for these diseases and three other diseases--all of which caused an estimated loss of 10% of the tobacco crop or $23,000,000 in 1940 (2).

Dr. Glenn Burton, Principal Geneticist, Georgia Coastal Plain Experiment Station, has obtained 50-75% increases in yields of single crosses of cattail millet over commercial millet.

Coastal Bermuda grass is immune to the root-knot nematode and produces 116 pounds more beef per acre than common Bermuda (1). Coastal Bermuda is a hybrid between Tift Bermuda and an introduction from South Africa.

Corn breeders are transferring cytoplasmic male-sterility and fertility restoring genes to inbred lines to reduce detasseling cost in the production field. Detasseling in the double-cross production field usually costs from $10 to $20 per acre without the use of cytoplasmic male sterility. The cytoplasmic male sterility is transmitted by plasmagenes through the cytoplasm. However, certain genes on the chromosomes have the ability to restore fertility when present in the genotype.

Hybrid grain sorghum is being developed through the use of male-sterile lines. The estimated potential value of hybrid grain sorghums in Texas alone is easily $20,000,000 annually.

Hybrid Bahia grass, utilizing self-sterility, is in the experimental stage. Alfalfa breeders have produced a number of synthetic varieties. Hybrid alfalfas, similar to double crosses in corn, may be produced commercially in the future by planting self-sterile clones in isolated blocks. By using asexual reproduction in the maintenance of clones, I believe that some self-sterility might be advantageous in a tree-breeding program.

One of the broad general ways in which plants serve the needs of man in addition to providing necessities of life is the provision of raw materials for industry. Let us take the story of rubber. In 1830 the entire world consumed only 156 tons of it (10). Today the world consumes 1,000,000 tons or more annually. Our modern methods of transportation are completely dependent upon it. In peace time alone some 50,000 different articles are made from it. Man has not solved the problem entirely with synthetic rubber. Natural rubber is still needed for blending with the synthetic. More than 95% of the world's natural rubber comes from a tropical tree, Hevea brasiliensis. The yield of rubber from this tree has been increased from a few pounds per acre in the wild state to 400 pounds per acre per year. Hybrid strains promise to increase the production up to 2000 pounds per acre per year.

Methods of Breeding

There are three general methods of breeding: (a) introduction (b) selection (c) hybridization.

Introduction is merely testing and introducing a variety or strain into a new area. Korean lespedeza is an example of an introduction in the southern states. One source of plant introductions is through the Primary Plant Introduction Station. Four of these stations are located in the United States. The one for the southern region is at Experiment, Georgia. From its establishment in 1949 until 1955 approximately 9,000 introductions had been obtained by this station (8).

Selection, another general method of breeding, may be made on an individual-plant basis or on a group mass basis. Selection has yielded some outstanding varieties in the past. Rustproof-14 oats is a selection from the Appler variety. Grimm alfalfa, which at one time was one of the leading alfalfas in the U. S., was developed by mass selection. Mr. Grimm planted some alfalfa from Germany on his Carver-County Minnesota farm. Most of the resulting plants were killed by the severe winter. A few of the plants were sufficiently winter-hardy to survive. Mr. Grimm saved seed from these plants. The end product became Grimm alfalfa.

Selection apparently offers one of our first steps in forest tree improvement. Too often, superior trees have been cut, leaving only the inferior ones to produce future generations. With cross-pollinated plants, selection has two primary disadvantages: (a) selection is based on the phenotype of a plant (b) selection is generally restricted to half the total inheritance because the male parentage is not considered.

Hybridization is the most widely used general method of plant breeding today. Hybridization as a method of breeding does not necessarily mean that the final product of the program will be a hybrid. As an example--many of our small grain varieties which are naturally self-pollinated were developed by the hybridization method. Yet, these varieties are not hybrids.

The objective in utilizing hybridization is to combine in a single variety desirable characteristics of two or more lines, varieties, or species. Some of the specific methods of breeding classified under the hybridization method are: (a) the pedigree method (b) backcross method (c) bulk method (d) multiple crosses (e) recurrent selection. Time does not permit a discussion of each one of these methods here.

Combining ability and genetic diversity must not be overlooked in a breeding program. Combining ability as defined by Hayes, Immer, and Smith (7) is the relative ability of a biotype to transmit desirable performance to its crosses. Thus, an evaluation of combining ability is actually based on the progeny test which was advocated by Vilmorin around 1850.

If a line combines well with a source of heterozygous germ plasm such as an open-pollinated variety, we say that this line has good general combining ability. Specific combining ability refers to the performance of a line in a cross with another specific line. Some lines will combine much better with each other than with other lines. Lines or strains which constitute a hybrid or synthetic variety should be tested for combining ability before putting them together in the new product. By doing so, the lines with poor combining ability may be eliminated. Perhaps some of the older synthetic varieties would have given much better performances if the lines had been evaluated for specific combining ability as well as for general combining ability.

Gentic diversity may be even more important than combining ability. Results by Eckhardt and Bryan (5) Johnson and Hayes (9), and Cowan (3) along with a number of other investigations in both the plant and animals fields emphasize the importance of genetic diversity. Crosses between inbreds that originate from different varieties, in general, are superior on the average to comparable crosses from inbreds that originate from the same variety. Crossing two genetically diverse individuals provides more heterozygosity and a greater accumulation of favorable dominant growth genes, which in turn, provide more heterosis or hybrid vigor. Animal breeders have begun to take advantage of this fact by using rotational crossbreeding instead of crossing within the breed.

We mentioned synthetic varieties a few minutes ago. Someday in the future commercial hubrids may be used on a wide scale for reforestation. However, before that stage is attained, maybe we should consider the possibility of developing synthetic varities. Synthetic varieties are used extensively today in forage crops which are open-pollinated as are our southern pines.

A synthetic variety is produced by the combination of selected lines or plants, followed by normal pollination in an isolated area. Tysdal and Crandall (14) define a synthetic variety as a variety developed by crossing, compositing, or interplanting two or more strains or clones; harvesting and replanting the bulked seed of successive generations.

Genetic principles as applied to a forage breeding program of a naturally cross-pollinated plant are similar to those developed in our corn-breeding programs. I think that we can safely expect the same principles to apply to the breeding of trees. Richey (12) gives a review of corn breeding. Tysdal, Kiesselhack and Westover (13) outline an alfalfa breeding program. They discuss the use of synthetics and double-cross hybrids in alfalfa. Hanson and Carnahan (6) review the breeding of perennial forage grasses in a recent U.S.D.A. technical bulletin.

With improvement by selection and the evaluation of clones by progeny tests one of the next logical steps in a tree-breeding program could be the development of synthetic varieties. Use of synthetic varieties will probably precede the use of hybrids on a commercial basis. Synthetic varieties could be used in the seed orchards to supply nurseries with seed.

Louisiana S1 White Clover

Let us turn our attention now to a specific example of improvement in one of our southern forage crops--white clover, a naturally cross-pollinated plant. As we briefly discuss the development of Louisiana S1 white clover, let us think how the genetic principles and breeding methods as used in corn and forage crops may be applied to the improvement of our forest trees.

Louisiana S1 white clover was developed by the Louisiana Agricultural Experiment Station to produce a good forage yield and to tolerate the hot, dry weather. Heat toleration increases length of grazing season. Louisiana S1 is a synthetic variety made by intercrossing five clonal lines selected from Louisiana stocks of white clover. Improvements over common white clover enable Louisiana S1 to live through the summer and fall of most years and to revive from stolons in the fall. It can be grazed six to eight weeks earlier than ordinary white clover. It also may be grazed several weeks longer in the late spring and early fall.

This white-clover breeding program was initiated in 1945 by making a survey of the clover fields in the state from plants which had survived the summer. From approximately 4000 progeny seedlings transplanted in the nursery in April, only 25 were selected the following October to be evaluated as clones in the polycross nursery.

From agronomic notes and the polycross test finally five superior clones were selected. The next step was to combine these five superior clones into a synthetic variety. Clones were transplanted into an isolated intercrossing block, allowing random pollination to occur with the aid of honey bees. Seed was harvested from all clones and bulked for planting seed increase fields (seed orchards in forestry) of the new synthetic.

Summary

In summary we have discussed:

(a) genetics, the science of heredity and variation
(b) application of the principles of genetics to all organisms
(c) utilization of fundamental principles of genetics in the improvement of plants
(d) economic importance of plant breeding
(e) some methods of breeding
(f) combining ability and genetic diversity
(g) synthetic varieties and an example in forage breeding in which methods may be directly related to a tree-breeding program.

Literature Cited

1. Burton, Glenn W., Coastal Bermuda Grass. Ga. Agr. Expt. Sta. Bul. N.S. 2 1954.

2. Clayton, E. E. New kinds of tobacco. U.S.D.A. Yearbook of Agriculture: 363-368. 1943-47.

3. Cowan, J. R. The value of double cross hybrids involving inbreds of similar and diverse genetic origin. Sci. Agr. 23: 287-296. 1943.

4. Dorman, Keith W. Hereditary variation as the basis for selecting superior forest trees. Southeastern Forest Experiment Station. Paper No. 15 1952.

5. Eckhardt, R. C. and Bryan, A. A. Effect of method of combining the four inbred lines of a double cross of maize upon the yield and variability of the resulting hybrid. Jour. Amer. Soc. Agron. 32: 347-353. 1940.

6. Hanson, A. A. and Carnahan, H. L. Breeding Perennial Forage Grasses. U.S. D.A. Tech. Bul. 1145. 1956.

7. Hayes, H. K., Immer, F. R. and Smith, D. C. Methods of Plant Breeding. Sec. Ed. New York. McGraw-Hill Book Co., Inc. 1955.

8. James, Edwin., Progress and Potentials in Plant Introduction for the South Southern Cooperative Series Bul. 27, Section of Plant Introduction, A.R.S. U.S.D.A. 1955.

9. Johnson, I. J. and Hayes, H.K. The value in hybrid combinations of inbred lines of corn selected from single crosses by the pedigree method of breeding. Jour. Amer. Soc. Agron. 32: 479-485. 1940.

10. Mangelsdorf, Paul C. "Plants and Human Affairs." Nieuwland Lectures, Vol. V. University of Notre Dame. 1952.

11. Quisenberry, Karl S. "How Good Can We Make Our Crops?" Country Gentlemen: August, 1951.

12. Richey, F. D. Corn breeding, Adv. in Genetics 3: 159-192. 1950.

13. Tysdal, H. M., Kiesselbach, T. A., and Westover, H. L. Alfalfa Breeding. Neb. Agr. Expt. Sta. Res. Bul. 124. 1942.

14. Tysdal, H. M. and Crandall, B. H. The polycross progeny performance as an index of the combining ability of alfalfa clones. Jour. Amer. Soc. Agron. 40: 293-306. 1948.

THE PULP AND PAPER INDUSTRY LOOKS AT FUTURE WOOD REQUIREMENTS

by

James F. Spiers
Southern Pulpwood Conservation Association

During the past 20 years the growth of the pulp, paper and paperboard industry has been very rapid, especially here in the South. From a small beginning in the middle 1930's it has grown by leaps and bounds into the large industry it is today.

I will not attempt to predict just what the future wood requirements for the pulpwood industry will be, but I will try to project from the information we have on the past and present situation, what it is likely to be in the future.

The production of paper and paper products has risen about 55% during the last 10 years. The amount of pulpwood used in this country increased during the same period from less than 17 (16.9) million cords to approximately 33 million cords. The industry produced a total of 29.9 million tons of paper and paperboard during the year of 1955. It is (was) expected that mill expansion and construction of new mills in 1956 will increase this production by an additional 1.6 million tons per year.

In 1956, in the south, at least 15 mills were busy expanding their manufacturing facilities. Eleven (11) new mills were listed for starting construction during 1956. Of these, seven (7) have definitely indicated their location here in the south; one (1) in South Carolina, four (4) in Alabama, and two (2) in Arkansas.

HISTORY

Pulpwood consumption in 1906 for the United States was 3,661,176 cords. The south produced 164,000 cords or approximately 4.5%. In 1931, the U. S. total was 6,722,766 cords. The south produced 1,750,000 cords or 26% of the total.

Now in 1955 the National production was 33,300,000 cords, of which the south produced approximately 19 million cords or about 60% of the total. You are probably familiar with the figures just quoted. We use them to emphasize two things: (1) the tremendous increase in the production and consumption of pulpwood during the last 20 to 25 years and (2) the huge increase, percentage wise, of the total amount produced in the south.

The use of paper and paper products has had a rapid increase during the period from 1931 to 1955. This was caused, primarily, by the many new uses found for paper and paper products. In 1931 the per capita consumption of paper in the United States was 183 lbs. This figure has risen to 415 lbs. in 1956 and it is predicted that it will be 500 lbs. per capita by 1975. Even if the per capita figure does not increase, the increase in population, estimated at 212 million in 1975, will require additional production of paper products as well as most all other products from our forests.

HARDWOOD

The pine tree, of course, will continue to furnish the bulk of pulpwood, but the use of hardwood, including almost all species, is likely to increase. The forest survey shows that hardwood production for 1955 increased 17.5% over 1954, while pine increased 9.8%. This doesn't mean much in cord volume, but it does indicate that we will be using more and more hardwood in the future.

In 1949 the hardwood production in the south was 808,700 cords. The hardwood production in 1955 was 2,526,900 cords, an increase of 68% in 7 years. During this same period pine increased approximately 58%. At present the amount of hardwood pulpwood is increasing percentage wise, about twice as fast as pine. Several mills have started using hardwood during the last two or three years. I understand that more mills will start using hardwood in the near future. We believe more and more hardwood will be used during the years ahead. Pulpwood production for 1956 will probably show a substantial increase over 1955. With the development of the semi-chemical pulping process the chances are that we will use more and more hardwood for pulp.

One report predicts that we will use 30 million cords of pulpwood in the south by 1975. We believe this figure is low. This same report predicts that we will be using 21.1 million cords by 1960. It looks like we may reach this figure by the end of 1956 when the information is all in, and should surpass this amount in 1957.

In our projections and predictions, in this paper, we are going on the assumption that we will have continued prosperity in this country. There are some other factors that must also be considered that may affect the demand for pulpwood as well as other products from our forests.

1. Competing Materials - The industry is not immune from competition of other materials. At the present time, rayon and acetate, which have enjoyed an ever increasing market, are meeting with competition from man made fibers (nylon, orlon, dacron, acrilon, etc.) and also from cotton which is getting an increasing share of the clothing market as a result of research in new finishes, new uses and new designs. It has been predicted that more of the man made fibers and less rayon will be used in the textile industry in the future.

2. Price - We must keep price of finished products of our forests

as low as possible if we expect to remain competitive. We must improve our practices in all phases of Forestry and find more efficient ways of manufacturing and handling the products of our mills.

If we do this the demand for pulpwood and other forest products looks extremely bright for the future.

The pulpwood industry is doing quite a bit of work in tree improvement. Some of the mills have their own men working on this in their own nurseries. The industry is cooperating with State and Federal agencies in Forest Genetics Programs throughout the south and the United States. We feel sure that these programs in tree improvement will result in faster growing trees of better quality and will help supply the ever increasing demand for pulpwood and other forest products.

THE LUMBER INDUSTRY LOOKS AT FUTURE WOOD REQUIREMENTS

by

V. W. Cothren
Southern Pine Association

Any industry which employs a fourth of a million workers is important to the well-being of any nation. And, when it is concentrated in a particular area, its value to that area is enhanced. The southern pine lumber industry occupies this impressive position.

According to unofficial industry estimates, the total 1956 production of southern pine lumber will approximate 8,556,000,000 board feet, enough to build more than a million homes. This figure is only 1.7 per cent under the estimated 8,696,000,000 board foot figure of 1955. And in 1955, the southern lumbermen had a boom on their hands rather than a housing slump, that we now have. New housing starts during the first 10 months of 1956 were 16 percent less than for the corresponding period last year, so the 1956 estimated production, shipments and orders are all the more remarkable. Shipments and orders were close to actual production, indicating a healthy balance between supply and demand. This production has been maintained with fewer operating units as increased operating costs have caused many units, some large as well as small, to close down.

To what do we attribute the apparently minor effect on production caused by a 16% decline in the industry that uses more than 70% of our production?

Vigorous campaigns in the South for the proper seasoning and grading of lumber are generally credited for the stronger appeal southern pine exerted among more selective buyers. Conducted by groups of lumbermen in various southern states with the help of the Southern Pine Association, these campaigns have pressed hard for high standards within and without the lumber industry. For consumer protection, the use of grade-marked lumber has been urged. These localized programs are in addition to the SPA advertising program.

You gentlemen are modifying our natural product through selection and breeding. It would be helpful if you knew how much and what kind of wood will be needed when the seedlings you are developing will be mature and ready for harvest. You need a prophet. I am not it. Many have tried and a large part were made to appear ridiculous. Many delivered a funeral oration for the southern pine lumber industry with slow music. But it is still strong and has indications of becoming stronger. Any prediction that does not consider the tremendous power and initiative of our free enterprise system has two strikes against it.

The fallacy of timber famine predictions was illustrated by the recent TRR. Members of our industry had their beliefs verified when it was reported that southern pine sawtimber is growing 22% faster than it is being harvested. This feat was accomplished while southern pine sawtimber furnished 24% of the Nation's requirements for sawtimber.

Do not think that all is serene in the southern pine lumber industry. It is plagued by the selfsame rising production costs that plague all industries, and in addition some that are unique to the lumber industry. Even though wages in our industry may be low compared to other sections and other industries, labor costs per thousand board feet of production are higher here. It has not been easy to pass along increased costs to the consumer because competitive products and other species that have lower stumpage costs, lower labor costs, and lower freight costs are ready and willing to take our market.

When we realize that stumpage cost may be from 20 to 40 percent of the total production cost, depending on type operation, we can readily see that quality trees are of utmost importance to lumber manufacturers. Mills that purchase all or part of their sawlog requirements say they are having a difficult time. As we can not economically change the tree we have today, one avenue for cost reduction has been in man-power requirements. It is difficult to give a figure for our entire industry, but it is believed that about 35 man hours are required to manufacture a thousand board feet of southern pine. This is 2 1/2 times that required in other sections. The increase in minimum wage from 75¢ to $1.00 an hour resulted in an average increase in manufacturing cost of about $7.

A few years ago the southern pine industry embarked on a large scale mechanization program. This trend is continuing. One firm of consulting engineers reported their clients alone have invested more than 80 million dollars in plant modernization and improvement during the past three years. Other sources believe our industry will spend as much as half a billion dollars on mechanization in the next few years.

Of course, the industry is far from anything approaching automation, but, in the past few years we have witnessed the reduction of man-power required for many mill operations. Sawmill carriages required four men to operate them. Now the Sawyer can do the entire job. Hand stacking has been replaced by automatic stacking. Lumber buggies replaced by fork lifts or straddle trucks.

Part of the mechanization program consists of installing barking and chipping equipment. The first barking and chipping unit was installed in 1952. By the end of 1954, 23 units were in operation. Then at the end of 1955, 63 units were in operation with an annual capacity of chips equal to more than 400,000 cords. Now their number is well over a hundred and still increasing rapidly. It is estimated that the southern pine lumber industry will eventually achieve a pulp chip capacity of 2,500,000 cords per year. If lumber production increases, or improvements are made in barkers, and many believe both will happen, that potential is higher.

In the pre World War II era most southern pine lumber was shipped outside the South. Since that time the South has seen rapid industrialization which requires tremendous quantities of lumber.

During the first six months of 1956, 72.8% of southern pine production has been utilized in the South. Illinois, Indiana, and Ohio, once major consumers, used only 10.3% of production during this period.

Of total southern pine production 71% is used for house construction; 10% for box and crating, and 17% for industrials and railroads.

It might be well to stop and consider just what qualities are desirable for specific uses. Southern pine is a preferred species. It justly merits the designation "Supreme Structural Wood of the World." It ranks first among softwoods in the various strength properties.

HOUSE FRAMING LUMBER requires strength to carry the loads imposed and stiffness to prevent deflection. It should have high nail holding power because the joints are the weakest part of the framework. The high specific gravity of southern pine gives it advantages for this use. Specific gravity is important because if it is increased 25%, the crushing strength as a post is increased 25%, but the strength as a beam is increased 37 1/2% and the hardness increases 100%.

As a general rule, the specific gravity of southern pine ranges from .40 upward. It is figured as weight oven dry and volume green. Only occasionally is a piece lower than .40 encountered, although the strength calculations contemplate that some pieces may be as low as .35.

Dense lumber has much higher bending, compression and tension stresses. The calculations for dense quality contemplate the possibility of some pieces being as low as .40 specific gravity, yet most of the lumber that is excluded by the application of the density rule will be well over .40. The average for dense southern pine is .54.

The grading rules for southern pine dimension require: MEDIUM GRAIN lumber to average on either one end or the other not less than four annual rings per inch.

DENSE lumber to average on either one end or the other not less than 6 annual rings per inch with not less than one-third summerwood, and the contrast in color between summerwood and springwood must be distinct. Pieces averaging less than 6 rings per inch and not less than 4 meet the requirements of dense if averaging one-half or more summerwood.

LONGLEAF to be produced from trees of the botanical species of Pinus ellottii and Pinus palustris, and average on either one end or the other not less than 6 annual rings per inch and not less than one-third summerwood and the summerwood must be dark in color, except in pieces having considerably above the minimum requirements for summerwood.

These requirements are made in order that the exceptionally weak pieces may be excluded from dimension. Also, tests have shown that those pieces having less than 4 annual rings per inch have abnormal longitudinal shrinkage. This abnormal shrinkage may result in crooking, especially in those pieces exhibiting unequal growth rate.

Research has shown that the fibril angle is greater in the faster grown material. Fibril angles of 10° or less are associated with small longitudinal shrinkage, while relatively large fibril angles and abnormal compression wood are associated with excessive longitudinal shrinkage. It is this abnormal longitudinal shrinkage that results in crooking--a serious problem of the southern pine industry.

As the correlation between fibril angle and width of annual rings is essentially linear, the restriction of 4 or more annual rings per inch for dimension should stop excessive crooking.

However, that is not the case because not all southern pine production is graded according to the SPIB rules. Also the grading rules require that dimension be dried to 19% or less and that should cause most of the shrinkage and any resultant crooking to occur before the lumber is shipped, but not all lumber is dry before shipment.

The desirability of southern pine for piling and poles is due to its high specific gravity.

Box and crate lumber should be strong, tough, hard and have high nail-holding power. Here again Southern pine fills the bill, and about one billion board feet per year is used for this purpose. Of course the high specific gravity that gives Southern Pine its desirable characteristics also results in increased weight that must be considered. Usually though, the shipper's primary thought is safe delivery and they prefer southern pine. The U. S. Army Ordnance Department recognized the superior nail-holding power of southern pine and permits the use of pointless nails for southern pine which give only 59% of the nail-holding power of diamond point nails.

In finish lumber for siding, window and door frames, interior trim and millwork, appearance is an important factor. Many users want clear lumber. This lumber will be finished natural or painted so paintability is important. Specific gravity probably has very little effect on paintability. The important thing is to have a minimum of wide bands of summerwood, so again extremely fast growth is not the most desirable.

From these uses and desirable characteristics we might theorize and describe what might be called the ideal sawlog tree. It might be a tree in which the average log is about 18" in diameter at the small end. It could have approximately 6 to 8 rings per inch for the first 6 inches of diameter and 4 to 6 rings per inch for the remainder of the diameter. That could give a diameter of about 6" dbh at 21 years and a dbh of 24 inches in 66 years.

This hypothetical tree could be expected to yield a high percentage of finish grades and produce dimension that would be strong and remain straight. The growth rate is such that there would be a good return on the volume. We must realize that this ideal tree is somewhat like full stocking, that is, it is a goal and although we may not attain it, the nearer we get to it the better.

Foresters, for the most part, have been concerned primarily with growing volume. Forestry in the U. S. is young. We are learning more about forest management and are realizing more and more that we must manage our forests ... not for volume alone, but for quality which denotes value. The lumber industry forester must be conscious of what the consumer wants and needs in his lumber. He is demanding quality. If we are to retain and expand markets, we must furnish that quality.

Some foresters in the lumber industry are acutely aware of the requirements for quality lumber, and are so managing their forest stands. One is aiming toward a uniform growth rate of about 6 rings per inch. On one area of natural reproduction he clear cut a small area for a house site. This area seeded in 1909 with a well stocked stand. At the age of 25 it was thinned for pulpwood and at 35 it had a light sawlog cut followed by another pulpwood cut to remove tops and some smaller trees. It received another sawlog cut in 1956 and is scheduled for final harvest in 1966. From this clear cut area, three random truck loads of logs were selected and followed through the mill. They produced 99.97% useable lumber. The lumber graded 30% #1 and better, and the stand was only 46 years old. The remaining growth will have a very high percent of clear lumber.

Of course that was a well stocked natural stand. It might not be the same in a plantation. Plantation management for maximum value return is a fertile area for serious study. We know that if we thin heavy there will be increased diameter growth, but are we getting the maximum growth per acre ... not only in volume but in value in grade yield or in pounds of pulp.

We have been considering the needs of the lumber industry. The pulp and paper industry forester must satisfy his consumer ... the paper mill. Let us study the qualities that made an ideal sawlog tree. How do they compare with an ideal pulpwood tree?

Specific gravity, all important to the lumber industry, is also important to the pulp mill. A cord of low specific gravity Southern Pine wood will yield about 847 pounds of kraft pulp, whereas a cord of high specific gravity wood of the same species will produce about 1,477 pounds --- almost twice as much.

The fibril angle is important because it determines the tear strength of pulp -- large fibril angles result in lower tear strength.

Knot free wood is of less relative importance to pulp production but it cannot be considered a detriment.

But what of the volume growth rate. Tests on Loblolly Pine show that an unthinned stand gives more volume at age 33 than thinned stands. Then, mortality causes a loss in volume. It would be helpful if we had information on the average specific gravity of these test stands and could calculate the yield of pulp.

From this it appears that what is good for lumber is also good for pulp. It is fortunate that is the case because many companies, both lumber and pulp, some of which are intergrated, are growing both. Pulp and paper companies have a greater stake in growing quality sawlogs because in many cases they are getting the slabs and edgings back in the form of chips.

It is entirely feasible that the future may bring more methods of changing some physical characteristics of the wood after it is cut. There are ways to do that now, but they are expensive. Would it not be better to grow it right.

It will be tragic if we fail to recognize the consumer needs, because he holds our future ... be he a contractor, do-it-your-selfer, or pulp mill.

Private forest management is controlled by economics. It must show a profit. Forest managers have a golden opportunity to demonstrate their worth. Some are doing so. Others will follow.

You, the geneticist, may produce strains of trees that will astound us. But let us not lose sight of what our customers need and demand --- it may be easier to change our trees than to change our customers.

THE OPPORTUNITIES AND RESPONSIBILITIES OF
THE REGIONAL FOREST GENETICS COMMITTEE

by

E. V. Smith, Dean, School of Agriculture and
Director, Agricultural Experiment Station
Alabama Polytechnic Institute
Auburn, Alabama

Mr. Chairman and members of the Fourth Southern Forest Tree Improvement Conference, I am happy to have the opportunity to discuss regional research with you, including the opportunities and responsibilities of the S-23 Regional Forest Genetics Committee. To begin with, we should realize that many biological problems do not recognize state boundaries. For example, little leaf disease of pine is not limited to Alabama by the Georgia-Alabama line. The solution to such problems is frequently to be found through cooperation. These facts form the background for regional research.

Most simply, regional research is defined as research on problems of interest to two or more states and in which two or more states cooperate. Cooperation, however, should be in the form of division of labor among cooperators, or conscious and needed replication, not duplication of effort nor a series of unrelated activities.

Many types of problems are amenable to attach through regional cooperative research. Fundamental research which may be concentrated at a few locations but the results of which may have widespread application is especially suitable to the regional approach. A second type is that which may be influenced by environmental factors and which may require widespread replication throughout the region. A third is research that is too costly in terms of numbers of subjects or amounts of equipment to be undertaken by a single institution.

The passage of the Research and Marketing Act of 1946 (now known as the Hatch Act, Amended) gave great impetus to regional research but cooperation did not await the passage of that Act nor is all cooperative research supported by RRF funds. The authors of the Research and Marketing Act recognized the importance of cooperation, stipulated that not more than 25 per cent of the funds appropriated thereunder to the State Experiment Stations be used for regional research, and directed the U. S. Department of Agriculture to cooperate with the States wherever feasible. One of the advantages of regional research is that a few Stations, working cooperatively, can frequently attack a problem of regional concern; few problems need involve all Stations of the region when attacked on a regional basis.

Since Schools of Forestry in some of the Southern Land-Grant Colleges apparently have no direct administrative or organic relationship to the Agricultural Experiment Stations of those institutions, and since many of you interested in forest tree improvement are not directly associated with colleges or the U. S. Department of Agriculture, it is desirable that we discuss the general philosophy, organization, and functioning of regional RRF research. To begin with, all regional RRF projects are supported partially by RRF funds appropriated by the Congress for research in the State Experiment Stations. Thus the Experiment Station directors in a region are administratively responsible for RRF projects in much the same way that they are for other research projects. Although the RRF funds are not appropriated directly to any State Experiment Station, by agreement each Southern Director knows the total amount of RRF funds that will be allocated to the Station that he serves.

Proposals for new regional projects are reviewed by the Southern Regional Research Committee (composed of three elected Directors) and then submitted to the Southern Experiment Station Directors. If approved, a Director is appointed as Administrative Adviser who is authorized to call a meeting of the Technical Committee for the purpose of developing a regional project outline. The Technical Committee is composed of representatives of interested State Experiment Stations and of the appropriate agencies in the U. S. Department of Agriculture.

The Technical Committee is an entity formed to develop a regional outline and to conduct cooperative research. Being an entity, it is not subordinate to or under the jurisdiction of a broader group, although liaison with other groups having related interests is highly desirable. It should not attempt to become a scientific society. The regional project should be designed to attack problems of broad regional concern but it should have definite objectives; in very rare instances should a Technical Committee attempt to write so broad an outline as to preempt an entire field of work. After the regional project outline is developed, it is reviewed by the Southern Regional Research Committee, approved by the Chairman of the regional directors, and forwarded to the Committee of Nine for review and approval before submission to the State Experiment Stations Division. Each Experiment Station Director has an opportunity to assess the importance of the problem to his State, to evaluate the special interests of his staff, and to weigh other factors in determining whether his Stations should participate. Each participating State Stations submits a state contributing project to cover the work that it will undertake.

The RRF budget consists of the RRF funds allocated to the project from the total of such funds available to the several Experiment Stations. Few regional projects, however, are supported entirely by RRF funds. The U. S. Department of Agriculture supplies funds to support its participation.

With this background, we should be better able to understand the responsibilities, opportunities, and limitations of the Technical Committee for the S-23 regional project entitled "The Application of Genetics and Cytology to the Improvement of Southern Pines." No one can quarrel with the assertion that the need for the improvement of Southern pines is a problem of wide regional importance. The fundamental sciences of genetics and cytology have been shown to fit one of the truest definitions of regional research as they have been applied to the improvement of other crops. The number of foresters trained in genetics and cytology is limited. Even if it were desirable for every State Station to have forest geneticists and cytologists on its staff, the supply would not equal the demand.

It is obvious, therefore, that the S-23 project meets the best criteria for regional research. The opportunities and responsibilities of the Technical Committee are self-evident. From this cooperative research can come results of far-reaching importance to Southern Forestry.

HEREDITARY VARIATIONS IN SLASH PINE TRACHEIDS

by

L. W. R. Jackson and James T. Greene
Professor of Silviculture and Research
Assistant, respectively, University of Georgia
Athens, Georgia

Variation in tracheid length in conifers and fibers in hardwoods has been a subject of investigation throughout the world for over 80 years. Interest in tracheid dimensions was started by Sanio, who in 1872, reported that the variation in tracheid length of Scotch pine (Pinus sylvestris) was closely related to the position in the stem. Briefly, the laws set forth by Sanio were as follows: (1) tracheids increase in size from the pith in an outward direction until a constant size is attained, and (2) the size increases from the base of the stem to a maximum at a certain height and then decreases to the top.

Since Sanio's pioneer work, a large number of investigators, particularly in the United States, Canada, Australia and Japan, have made contributions to our knowledge of tracheid dimensions in forest trees. Most of the investigations fall into the following categories; (1) continuation of the work on the relation of tracheid length to position in the stem, (2) variations within stem tissues such as springwood and summerwood, (3) tracheid length in branches and roots, and (4) effect of growth rate on tracheid length. In 1954, Spurr (7) published a fairly comprehensive review of the literature on wood fiber studies.

Most of the investigators were in agreement that at any given height in the stem the tracheids are shortest near the pith. On any give radius, the length increases rapidly with an increase in the number of rings from the pith to the first maximum. From the point of this first maximum outward, there is considerable variance in the results obtained by the various investi gators. The length maxima may remain fairly constant as found by Sanio, or the length may tend to increase slightly, or show a tendency to fluctuate.

Most of the investigators found that the shortest tracheids occur in the lower levels of the stem. In any given annual increment, the length increases to a peak at a certain height and then it decreases toward the top of the crown.

There is general agreement that the tracheids in the branches are shorter than those in the stem. Most of the investigators concluded that tracheids in the summerwood are slightly longer than those in the springwood. Gerry (4) however found that the tracheids in the springwood of longleaf pine (Pinus palustris and Douglas fir (Pseudotsuga taxifolia) were in general, longer than those in the summerwood. It should be stated at this point that as far as could be ascertained from published results, the conclusions drawn by the early investigators were not confirmed by statistical methods.

Only a limited number of investigations have been made of tracheids of southern pine species. Gerry (4) in 1916 found that the tracheid length of longleaf pine increased rapidly from the pith outward through the first 20 rings but then it fluctuated widely beyond that point. Bailey and Shepard (6) in 1914 reported also that the tracheid length in longleaf pine increased rapidly outward from the center to a peak but then it fluctuated widely in the outer rings instead of remaining constant. In 1934, Berkeley (2) stated that rate of growth had an influence on the tracheid length of certain southern pine species. In a recent study, Bethel (1) found that the variation in tracheid length in the stem of loblolly pine agreed with the first two laws laid down by Sanio. Echols (3) reported in 1955 that he had found evidence of rigid control of tracheid length in slash pine (Pinus elliottii). Open pollination had an equalizing effect which resulted in progeny with average tracheid length. He concluded from the results of this investigation that the breeding of slash pine for long fibers should be feasible. Of particular interest too was the fact that ring width was not related to tracheid length. In 1955, Zobel and Rhodes (8) reported on a study of the relationship of wood specific gravity in loblolly pine to growth and environmental factors. These data also lead to the inference that the genetic factor may be of importance. They concluded that such factors as age, rate of growth and site characteristics accounted for only a small part of the specific gravity variation observed. The foregoing resume of research on tracheid dimensions in coniferous species has offered strong evidence that variations in length may be genetically controlled.

On the basis of this inference a project under the S-23 Regional Research Program was set up to determine the reliability of certain anatomical and cytological features of the southern pine species as criteria for the selection of breeding stock. Slash pine was selected for the first phase of the work because of the availability of parents and their open-and cross-pollinated progeny. All the parent progeny material used in the study has been propagated by Mr. James Greene at the Ida Cason Callaway Foundation, Hamilton, Georgia. Trees used for natural variation in tracheid length within the stem were taken from plantings on the University Forestry School forests, located in the vicinity of Athens, Georgia. The entire investigation, thus far, has been concerned with an evaluation of the tracheid length of parents and progeny as a tool for the selection of breeding stock.

Several problems in technique and sampling methods were encountered when the project was started that had to be solved before definite progress could be made. In the first place, a method of tracheid measurement had to be developed that was not only rapid and accurate but would also minimize the eye fatigue of the operator. The wood samples were macerated by means of Jeffery's (5) chromic-nitric acid solution. After maceration, the tracheid suspension was prepared in a solution of 4 per cent formaldehyde. Temporary dry uncovered mounts of the tracheids were prepared by coating microscope slides with a very thin smear of Haupt's (5) adhesive. Then about 2 or 3 drops of the suspension were immediately spread over the surface of the slide. The slides were dried on a warming table at 40° C. A microprojector called the Rayoscope* with a mechanical stage proved in practice to be the most ideal for the length measurements. A 15 X wide field ocular in combination with a 3.5X objective will give a 100X projection of the tracheids which can be measured directly with a millimeter rule to an accuracy of 0.01 mm. This procedure practically eliminates the error caused by including any fibers with broken tips.

Another major problem was how best to collect wood samples for the tests without causing too much damage to the selected parents and their progeny. For this reason, one of the main objectives has been done to determine whether the first ring tracheids of branches could be used for comparative purposes.

Trachied length of the springwood and summerwood was taken in the first, fifth, tenth and nineteenth ring from the center of single discs from each of two trees. There was no significance difference in the length of springwood and summerwood tracheids in either of the discs. From this point on in the investigation, only springwood tracheids were used.

Variation with height and age was obtained by measuring tracheids in the first, fifth and tenth rings of 9 discs taken at equally spaced levels from 4 to 40 feet from single tree. Tracheid length in the first ring was fairly constant at all heights, varying from only 1.86 to 1.96 mm. In the other rings, the length increased from the base to a certain height and then decreased toward the top. These data lead to the decision to use the first ring tracheids of stems and branches for comparative purposes.

Tracheid length of the outermost ring was measured at 9 equally spaced levels from 4 to 51 feet in single tree. Length increased from the base to a maximum of 4.97 mm. at the 26 foot level and then decreased to 1.70 mm. in the 1-year-old shoot at 51 feet. These data indicated that it is better to take the tracheid measurements from the outside to the center.

A single disc was taken at 4 1/2 feet from a 45- and a 60-year-old tree. Tracheid measurements were made at 5-ring intervals from the center to the outside. Length increased rapidly from the center to the first peak of 4.18 mm. in the fortieth ring and then remained fairly constant to the outermost ring.

In two 9-year-old trees, the first ring tracheids of the branches were significantly shorter than those in the stem at all the height levels sample.

The first ring tracheids in the 1955 branches were significantly shorter than those in the stem of the 3 loblolly pine and 5 slash pine parents that were used in this study. These data showed that the first ring tracheids of branches can be used for comparative purposes.

A determination was made of the average branch tracheid length of 7 slash pine parents and 10 one-year-old open-pollinated progeny from each of the parents. Tracheid length of the progeny was significantly shorter than that of the parents in 6 of the 7 combinations. An analysis of these data showed that the parents with relatively long tracheids produced progeny that had longer tracheids than the progeny from parents with short tracheids. Of the possible

* / Manufactured by Rayoscope, 358 N. Sandusky St., Delaware, Ohio.

21 comparisons of parents and progeny, the parents with longer tracheids produced progeny with longer tracheids in 14 or 67 percent of the combinations. For one of the parents which had the longest tracheids, the progeny had longer tracheids than 5 of the 6 possible progeny comparisons. The same results were obtained for 2 of the 3 loblolly pine combinations that were included in the study. Thus, it appears that open-pollination tends to equalize the tracheids of the trees in the forest.

In the controlled pollination study, branch tracheid measurements were taken on 10 one-year-old progeny from each of 7 parental combinations. The crosses were as follows: (1) 1 slash X slash (2) 2 loblolly X loblolly, and (3) 4 slash X loblolly. In 6 of the 7 combinations, the tracheid length of the progeny was intermediate to that of the parents but much closer in the female parent than to the male parent. In the other combination, the progeny was close to the male parent. These data showed that tracheid length of the progeny from 83 percent of the combinations was influenced more by the female parent than the male parent. In conclusion, the results obtained, thus far, indicate that the genetic factor does have a controlling influence on tracheid length in slash pine. Therefore it appears that breeding pines for long or short tracheids should be feasible.

Literature Cited

1. Bethel, J. E. 1941. The effect of position within the bole upon fiber length of loblolly pine (*Pinus taeda* L.) Jour. For. 39 (I): 30-33.

2. Berkley, E. E. 1934. Certain physical and structural properties of three species of southern yellow pine correlated with the compression strength of their wood. Ann. Mo. Bot. Gard. 21: 241-338.

3. Echols, R. M. 1955. Linear relation of fibrillar angle to tracheid length, and genetic control of tracheid length in slash pine. Tropical Woods No. 102. pp. 11-22.

4. Gerry, Eloise. 1916. A comparison of tracheid dimensions in longleaf pine and Douglas fir, with data on the strength and length, mean diameter and thickness of wall of the tracheids. Sci. 43 (1106): 360.

5. Johansen, D. A. 1950. Plant microtechnique. First edition. 523 pp. Illus. McGraw-Hill Book Company, N. Y.

6. Shepard, H. B. and I. W. Bailey, 1914. Some observations on the variations in length of coniferous fibers. Proc. Soc. Am. For. 9:522-525.

7. Spurr, S. H. and M. J. Hyvarinen, 1954. Wood fiber length as related to position in tree and growth. Bot. Rev. 20 (9): 561-575.

8. Zobel, B. J. and R. R. Rhodes, 1955. Relationship of wood specific gravity in loblolly pine to growth and environmental factors. Texas Forest Service Tech. Bul. No. 11.

INHERITANCE OF WOOD PROPERTIES IN PINE

by

Bruce Zobel, Associate Professor of Forest Genetics
School of Forestry, N. C. State College

Recently an increased interest in the genetics of wood properties of forest trees has been evident both by the researchers and members of the forest industries. The forthcoming TAPPI-sponsored discussion between geneticists and industry representatives is a good example. Although interest in this subject is high, factual knowledge is low. A survey of the literature indicates that for conifers, only few critical research results have been reported, although there is much circumstantial evidence presented. Studies have been made on inheritance of spiral grain, "abnormal" grain patterns, wood specific gravity, fiber characters and a few others. Results are scattered, however, and in some cases, rather inconclusive.

In the south, very little past work has been done on our pines regarding genetics of wood properties. Studies of only a few organizations have progressed far enough to enable the reporting of specific results, although a number of researchers are now either making intensive or incidental wood studies. Dr. Jackson's paper on tracheid length that we just heard, Echol's work on tracheid length inheritance and our work in Texas on wood specific gravity of loblolly pine are some that have been reported on. It is my understanding that Perry is soon to publish some work regarding specific gravity, as is Larsen. But overall, the results of work on genetics of wood properties for the southern pines are not plentiful.

It is the objective of this paper to discuss as yet unpublished information on work done in Texas and on one of the jobs we hope to do in North Carolina.

Dr. Jackson just discussed fiber length in slash pine. Several years ago fiber length studies were started on loblolly pine in Texas. Before we could proceed on genetic studies, however, we soon learned that more basic information about fiber variation from tree to tree and within a tree was necessary. Therefore, Paul Kramer, head of the Forest Products Department of the Texas Forest Service, initiated an intensive study to analyze the tracheid length variation pattern in Texas loblolly pine. This study was more comprehensive than most others on this subject, and the results are now in press.

The Australians showed that there is considerable difference in initial tracheid length* from tree to tree and that this initial difference

*/ Length of tracheids in the first or second growth ring.

would continue to evident, throughout the life of the tree. If such holds true, it would suggest the possibility of selecting for tracheid length in very young trees. The Australians found, futhermore, that the tracheid length of a branch was similar to that of the initial tracheid length of the bole at the point where the branch was attached. This fact enabled sampling of young trees without destroying them, simply by analyzing a branch.

Unfortunately, for the 12 trees Kramer intensively studied, no high correlation was found between initial tracheid length and tracheid length of the tree when mature. However, he did find some correlation between the tracheid length of the fifth annual ring and mature wood tracheid length, and he found very high correlation between tracheid length at the tenth year and mature wood tracheid length. This finding suggests, then, that analysis of 10-year-old or slightly younger trees might serve for evaluating the results of selections or crosses, a very helpful concept in genetic studies. It appears that the curves of tracheid length between trees of loblolly pine (even-aged stand, same site, dominants and codominants) tend to become more or less parallel to each other at about 10 years of age, though some are relatively higher than others.

Time here does not permit even a complete summary of the several interesting results of Kramer's tracheid study. However a few of his findings were:

(1) The longest tracheids in each growth ring were found in the latter part of the summerwood. This result is similar to those published by several other workers.

(2) The commonly reported decrease in fiber length with increased growth rate within an individual tree was not found. Outside the core of juvenile wood (with the curve tending to break at 8 to 12 years) wide rings and narrow rings within the same tree had about the same tracheid length.

(3) No correlation could be found between growth rate from tree to tree and tracheid length of the tree, i.e., slow growth trees did not always have the longest tracheid and vice versa.

(4) Trees grown under nearly identical environments, of the same age, and of similar phenotypes had very different tracheid lengths.

Perhaps the most widely studied wood characteristic is that of specific gravity. Many of you are familiar with our studies of this characteristic in loblolly pine. There is now in press an article describing some additional studies that I will summarize here:

(1) The limb-to-bole specific gravity relationship holds on trees up to 12 years of age, i.e., there is a high correlation in the specific gravity between limb wood and bole wood at least in trees up to 12 years of age.

(2) The limb estimation method of determining specific gravity was checked on 4-year-old progeny from high and low specific gravity mother

trees. High correlations were found as reported in the original study of average specific gravity mother trees.

(3) It was found that progeny of an open pollinated high specific gravity mother tree produced higher bole and limb specific gravities than progeny from a low specific gravity mother tree. Unfortunately, progeny of only two parent trees (20 seedlings from each) were available, so the results cannot be regarded as conclusive although they certainly are encouraging.

(4) Progeny groups of 25 trees, 12 years of age, were analyzed from three isolated mother trees. Presumably the progeny were all the result of selfing. As shown for the open-pollinated trees above, the parents with the highest specific gravity produced progeny with the highest specific gravity.

(5) Limbs of 4-year-old grafts, whose scions originally came from trees with extremes of specific gravity, were analyzed. No significant differences in specific gravity of graft limbs were found. These grafts were from the same parent trees that produced the open-pollinated progeny discussed above, in which a pattern of inheritance seemed to be evident. Perhaps this lack of pattern in grafts but presence in progeny may point up the importance of the root system in the determination of specific gravity.

In North Carolina, we have underway a study similar to that on specific gravity in which we are going to work on the cellulose - lignin ratio. The first step is to make a field survey to find out how much variation there is from tree to tree within a species, the trees being similar as to age, form, growth rate and environment. Depending on results, genetic studies may be initiated to determine the inheritance pattern of the cellulose - lignin ratio. We hope, of course, to find a characteristic here with which the geneticist can work, but as far as I can find out, practically nothing is presently known about this relationship. It is encouraging, however, to read reports of poplar clonal studies in which large differences in cellulose content were found consistently evident between clones. Such studies on cellulose, though long term and complex, should help us know more about wood properties of trees in which we are interested.

SELECTING DROUTH RESISTANT LOBLOLLY PINE IN TEXAS

by

Franklin C. Cech and R. E. Goddard
Assistant silviculturists, Texas Forest Service

Because weather conditions the last several years have been such that pine plantation establishment has been poor or a complete failure due to low amounts of rainfall, the Texas Forest Service started a program to investigate drouth resistance in loblolly pine. This investigation was initiated by Dr. Bruce Zobel and his associates.

Earlier workers (Meuli, 1936 and Meuli and Shirley 1937) had shown that drouth resistance does occur in green ash depending on seed origin. There was no reason to believe that such a situation did not exist in pine trees. In fact, there was very good evidence that drouth resistance probably did exist in the "Lost Pines" of East Central Texas. These "Lost Pines" consist of several islands of loblolly pine growing between 100 and 130 miles west of the western edge of the pine belt, on a dry, sandy, often rocky soil under conditions of low rainfall. The trees in this area presented ideal material for the study since natural selection had obviously been active in favor of drouth hardy types during the establishment and existence of these isolated loblolly pine stands. The stands have all ages represented and are reproducing themselves, making it apparent that the newly established seedlings must be somewhat drouth resistant.

Three different stands were selected to represent this area in the study; one in Bastrop County near Bastrop State Park, the second in Fayette County near Warda, and the third in Caldwell County near MacMahon. The trees in Bastroup and Caldwell county are typically loblolly, while those in the Fayette county group are loblolly with a semblance of shortleaf characters.

To round out the study, a typical coastal plain flatwodds type area was chosen in Tyler County, and two areas of the drier upland sites of the western edge of the pine region were selected in Leon and Angelina county. In addition, seed from two Louisiana areas and from one area each in Florida and North Carolina were used. The Tyler county and eastern states representing high rainfall areas were used as checks.

For testing purposes, six areas were located in widely separated parts of East Central Texas and a seventh at the A. J. Hodges Research Area near Many, Louisiana was selected. Replicated plantings were made on these test areas, representing each of the sources. These areas are all on deep sand with a minimum depth of 20 inches. Most of them are on old abandoned fields. The Lavaca County area is the most southerly, the Caldwell County area the farthest west and most drouthy, the Robertson

County area is in the center of the Post Oak region, the Navarro County area is the furthest north and located on a high gravelly hill. The Cherokee County site is located on the Temple Research Area near Alto, Texas, (the main test area for Texas Forest Service genetics program) and is very drouthy due to the deep sand there. The last Texas area is in Trinity County near Groveton, Texas, an area that is too wet in the winter and too dry in the summer, being especially dry after a prolonged drought. The Many, Louisiana site is on a dry sand ridge. Thus all areas present extreme conditions after a prolonged dry period.

In this study at leat four of the phenotypically best trees were selected from each seed source area as seed trees. Selection was made on this basis to insure getting a representative sample of seed from the best trees in the area.

The original plan was to repeat plantings from each seed source at each test area for three successive years. A fairly good quantity of seed was obtained from most sources in 1951 but since that time we have had some difficulty due to poor seed years. The 1955 collection was the first where we got seed from every source being tested.

Seedlings were grown at the Indian Mound Nursery near Alto, Texas and handled generally speaking, in the same manner as commercial seedlings. Lots were planted randomly in the seed beds and were tested identically. All lots were lifted the same day and planted on the subsequent day.

Both row and block plantings have been used in the test area but due to the special aims of the project, it is now felt that rows are better than blocks. The row design enables us to have more replications with fewer seedlings hence a better cross section of site variation (better sampling), makes inventory easier, and is applicable to statistical analysis with more accuracy due to the greater numbers of replications. It is true that for the study of form, edge effect will give some bias, but this again is minimized by the greater number of replications; further this project is primarily short term and edge effects are not detrimental for several years.

Results of the study have become apparent sooner than had been hoped due to the drouths of 1954 and 1956. It would seem that first year survival would be most critical and that plantations established for one year would not be as greatly affected by drouth. This has not been the case since as much of the mortality has occurred during the second year as the first. For example, in 1953, the first year the plantations were established, survival in Robertson County averaged 95%, except for the North Carolina source which averaged 75%. The second year i.e. 1954, a definite pattern was established as follows. The survival of the Bastrop source was highest (73%), the Fayette source was next (66%), Western edge (Leon and Angelina Counties) was third (54%), the Louisiana source fourth (51%), while the North Carolina and Florida sources ranked fifth and sixth (17%) and (8%) respectively.

This situation was repeated in the plantation at Fastrill established in 1954. In this case the North Carolina source had the best survival at the end of the first year, 83% with no drought, followed by the Bastrop source 67% and Fayette source 63%. At the end of the growing season of 1956, following a severe drought, this had changed so that the Bastrop source survival was highest, being 45%, the Fayette source with 43$ was second, and North Carolina source fifth at 27%.

On an overall basis, summarizing the seven plantations, the Fayette County source is best followed by Bastrop County source, Western edge source, Texas coastal plain source, Louisiana source, North Carolina source and Florida source. This same pattern is not followed exactly in each test area, so that the results of each area would have to be presented to see the whole picture. However, in every case but one, at the end of two years the Bastrop or Fayette sources had the highest survival. And, at Many, Louisiana, the Western edge source had the highest survival followed by the Fayette, coastal plains, and Bastrop sources. Notable was the fact that both Louisiana sources were inferior on this test area.

The growth rate of the seedlings from the "Lost Pines" source compares favorably to all others up to date. In fact at Many, the Fayette source is outstanding in height. Diameter differences are so small as to be negligable.

We feel that we have demonstrated the superior drouth hardiness of the "Lost Pines" sources, up to this time at least. Complete plantings, having all sources, have been made this year and should give additional confirmation if the established pattern is followed. The next step will be to examine the drouth hardiness of trees from all sources which have survived the past drouth years. For example, at the Temple Research Area, from the 1952 planting, two trees of the North Carolina lot are still alive and two Louisiana trees are alive. Generally speaking, both of these sources are non-drouth resistant, but these trees are vigorous and apparently drouth resistant. These trees should be reproduced vegetatively and studied on a clonal basis to test them for drouth resistance and hardiness.

In closing, it must be mentioned that several avenues are being explored by the Texas Forest Service as well as other agencies to ascertain the physiological reasons for drouth hardiness. Holger Brix, a graduate student at Texas A. and M. is studying root development with reference to the drouth hardiness. Socrates Kaloyereas at L. S. U. has developed tests for bound water contents and chlorophyll degradation in connection with drouth resistance. A. R. Gilmore at Alabama Polytechnic Institute is working on the relationship of root constituents to drouth resistance and E. Stone at the University of California at Berkeley, California, is studying drouth resistance in reference to "inverse transpiration."

On the basis of the field tests, a seed orchard has been established from grafted clones of the most drouth hardy material. Thus, in the future seed will be produced which we expect to lesson the hazard of establishing plantations on drouthy sites in years of low rainfall. Planting may therefore be done successfully even under adverse climatological conditions.

PHYSICAL AND CHEMICAL CHARACTERISTICS OF LOBLOLLY PINE SEEDLINGS ASSOCIATED WITH DROUGHT RESISTANCE 1/

by

A. R. Gilmore, Department of Forestry
Alabama Polytechnic Institute, Auburn, Alabama

Much has been said and written concerning genetics; but little has been said about the hows and whys of genetics, that is, the physiology of the plant as controlled by inheritance.

The purpose of this report is to point out some differences in the external and internal makeup of two groups of plants known to differ genetically in drought resistance. As stated in the title, these differences have been divided into two categories, namely, physical characteristics and chemical characteristics.

First, let us define the term, drought resistance. It means the ability of a seedling to survive and become established when outplanted under droughty conditions.

Loblolly pine (*Pinus taeda*) seedlings were furnished by the Texas Forest Service. The seedlings came from mother trees at a number of geographic sources. Previously, progeny of the same mother trees had been tested for ability to survive when outplanted under adverse conditions. On the basis of these source tests, later substantiated by tests in the greenhouse, the seedlings were separated into two groups designated more drought resistant and less drought resistant.

Physical Characteristics

Representative sample seedlings from each group were planted in cans filled with sand and kept in a greenhouse. Minimum daily temperature never exceeded 75°F., and maximum daily temperature sometimes exceeded 100° F. After the seedlings became established, water loss by transpiration was measured daily. The soil was sealed so that no evaporation occurred, and the entire mass was weighed to determine the water loss. On the basis of the finding of Tiren 2/ that Scotch pine needle area was directly proportional to dry weight, water loss by the seedlings under study was expressed as daily transpiration per gram of needle, oven dry weight.

Figure 1 shows the average daily transpiration per gm. of needle when

1/ A preliminary report of progress on Regional Project S-23.

2/ Tiren, L. 1927. Ueber die grösse der Nadelfläche einiger Kiefernbestände. Statens Skogsforsoksanst (Sweden), Meddel, 23: 295-336.

the moisture content of the soil was high. It shows that more moisture per gm. of needle was lost by the less drought resistant seedlings than by the more drought resistant seedlings. If the average total weight of needles per seedling for each group, 1.55 gm. and 2.86 gm. for the less and the more drought resistant seedlings, respectively, is taken into account, it can be seend that the more drought resistant seedlings extracted more moisture from the soil than the less drought resistant seedlings. The moisture loss by transpiration at a low soil moisture content is also indicated on figure 1. These curves show that at a low soil moisture content the more drought resistant plants lost only half as much moisture per gm. of needle as the less drought resistant plants during the few days that transpiration was measured.

Figure 2 brings out more vividly the picture of water loss. When the two groups of seedlings are compared on the basis of accumulative loss of moisture by transpiration, it is at once noticeable that the less drought resistant seedlings lost more moistue per gram of needle at both the high and the low soil moisture content.

Chemical Characteristics

There is abundant evidence that genetic differences between varieties of cultivated plants include constitutional differences that affect mineral composition, even when the plants are grown under similar conditions.

Sample seedlings from each group were divided into three parts; roots, stems, and needles. All portions of the plants were dried in an oven and sub-samples taken for chemical analysis.

Table 1.--Average carbohydrate content of two groups of loblolly pine seedlings, expressed as per cent, O.D. weight

Plant Part	Less drought resistant				More drought resistant			
	CHO1/	Reducing sugars	Sucrose	Starch	CHO1/	Reducing sugars	Sucrose	Starch
Roots	11.7	0.9	0.4	10.4	14.0	1.1	0.3	12.6
Stems	7.0	1.0	0.3	5.7	8.9	2.0	0.4	6.5
Needles	5.0	0.6	0.2	4.2	5.1	1.2	0.4	3.5

1/ Total carbohydrates.

Differences in carbohydrate content of various parts of seedlings in the two groups are apparent from Table 1. The stems and needles of the more drought resistant plants contain nearly twice the concentration of reducing sugars as the stems and needles of the less drought resistant plants. The sucrose content of the two groups is about the same. When the total carbohydrate content is examined, it is apparent that the amount that accumulates in the roots is much smaller in the less drought resistant seedlings than in

Figure 1.--Average daily transpiration per gram of needle (O.D. weight) for less drought resistant and more drouth resistant loblolly pine seedlings grown under conditions of high and low soil moisture conditions.

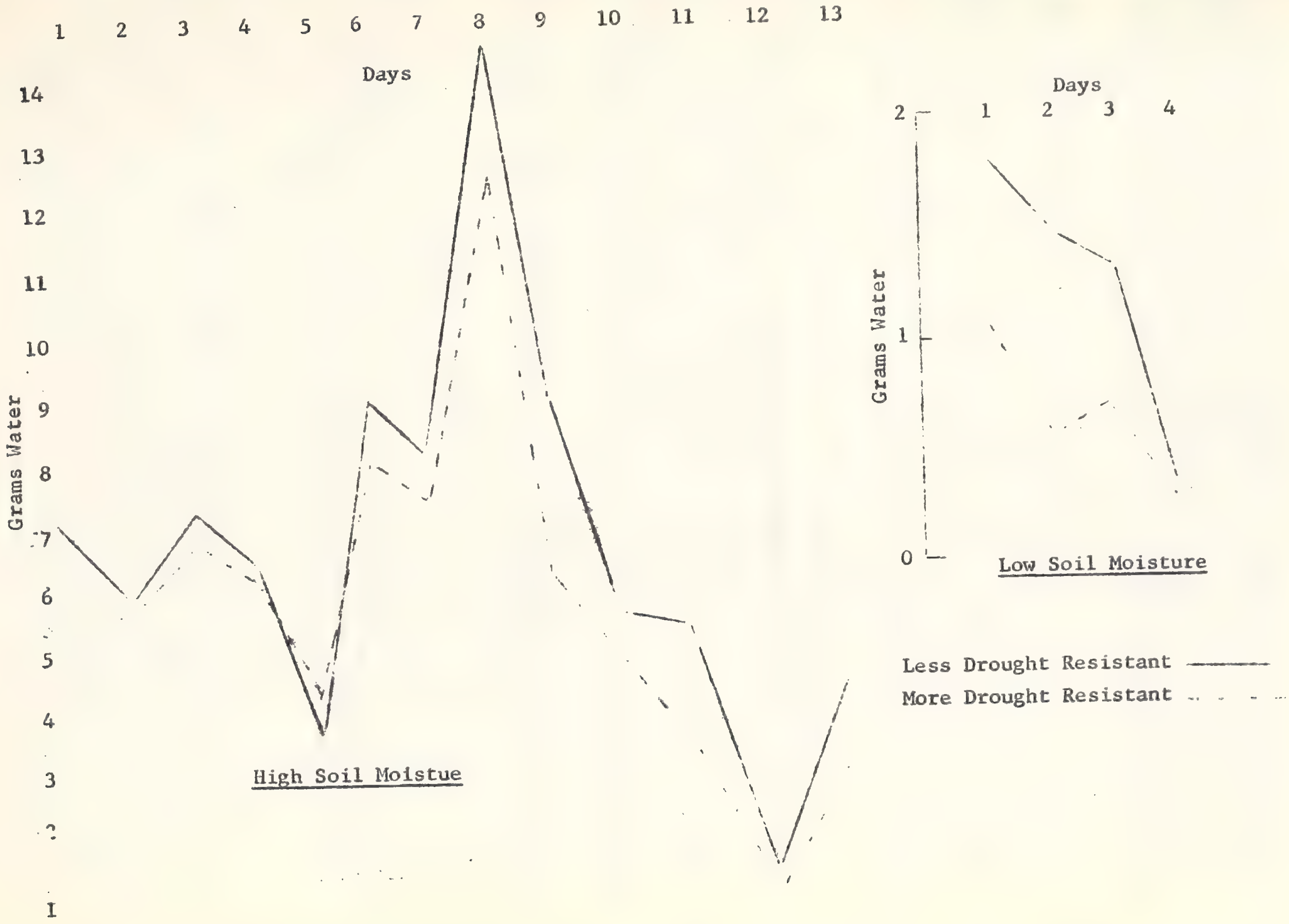
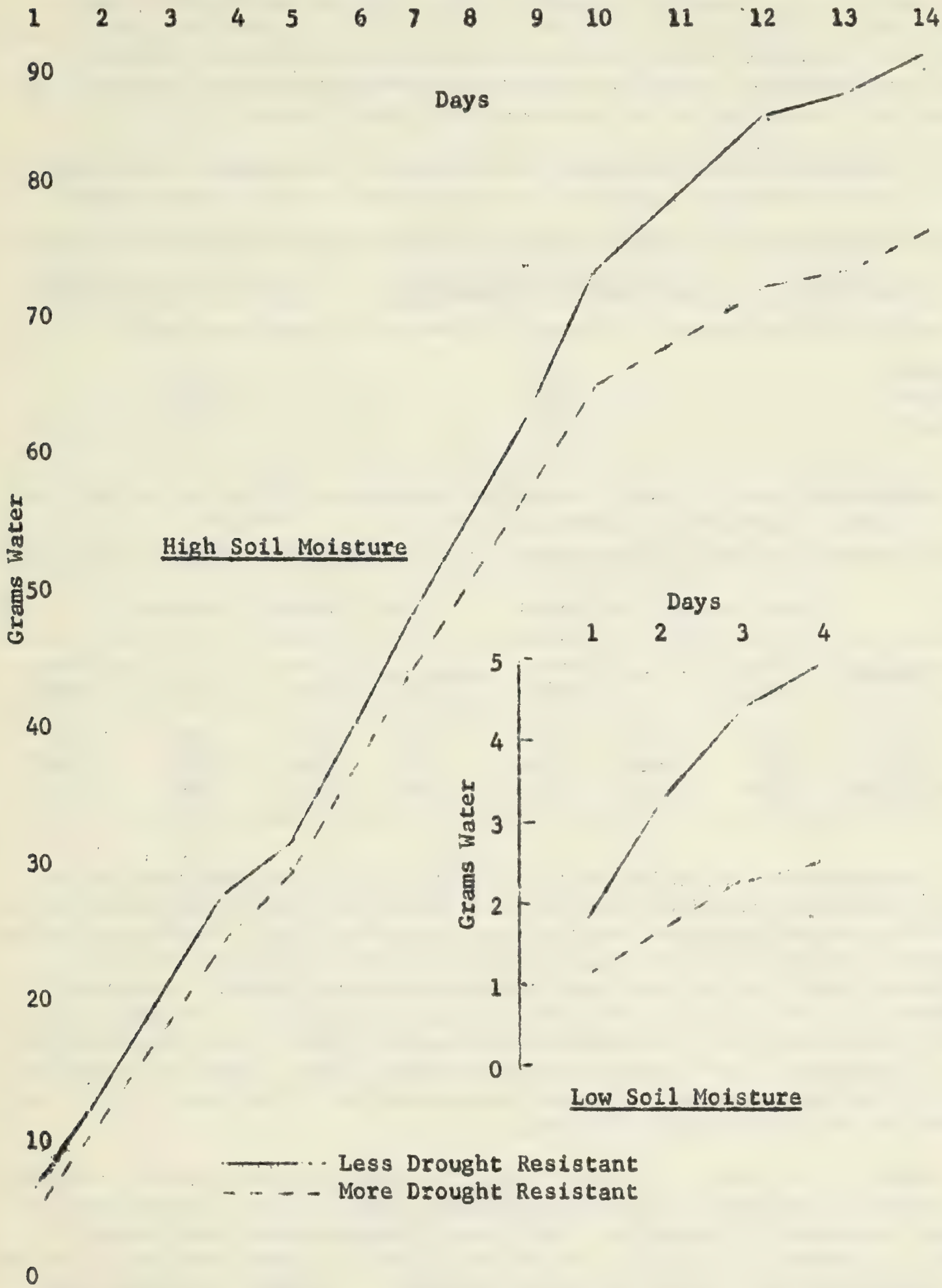


Figure 2.--Average daily accumulative transpiration per gram of needle (O.D. weight) for less drought resistant and more drought resistant loblolly pine seedlings grown under conditions of high and low soil moisture conditions.



the more drought resistant plants.

The ability of a seedling to survive when outplanted depends largely upon its ability to produce new roots immediately. A number of physiologists believe that this ability to produce new roots depends largely upon the amount of carbohydrates stored in the roots at the time of outplanting. The findings here presented are in agreement with this theory.

Table 2.--Average thiamine (Vitamin B_1) content of two groups of loblolly pine seedlings, expressed as micrograms per gm., O.D. weight.

Plant part	Less drought resistant	More drought resistant
Roots	.013	.013
Stems	.079	.045
Needles	.151	.068

Table 3.--Average total mineral content of two groups of loblolly pine seedlings, expressed as parts per million, O. D. Weight.

Plant	Less drought resistant				More drought resistant			
Part	Nitrogen	Potas-ium	Calcium	Phos-phorus	Nitrogen	Potas-sium	Calcium	Phos-phorus
Roots	9,600	5,500	600	1,620	7,600	5,100	700	1,590
Stems	12,100	5,800	1,000	1,640	8,300	5,500	800	1,600
Needles	18,500	5,800	1,400	1,810	13,800	4,400	900	1,470

Concentrations of thiamine (Vitamin B_1), nitrogen, and three major mineral elements in the different parts of seedlings in the two groups do not follow the same pattern as do carbohydrate concentrations. The concentration of thiamine (Table 2) in the stems and needles was higher for the less drought-resistant than for the more drought-resistant group. Concentration of thiamine in the roots was the same for the two groups. With one exception, the lower concentration of nitrogen and minerals (Table 3) was found in all parts of seedlings in the more drought-resistant group. Roots of the more drought-resistant group had a calcium concentration 17 per cent higher than did roots of the less resistant group.

There is no reason to assume from these results that greater drought resistance of seedlings is associated directly with a lower accumulation of vitamins, nitrogen, or minerals. The lower concentrations are, in all probability, merely a result of the dilution effect of the more rapid growth of the seedlings with greater drought resistance. On the other hand, the higher concentration of calcium in the roots of the larger, more drought-resistant seedlings must indicate a higher accumulation of that element. It seems possible that calcium accumulation in the roots is significantly associated with drought resistance.

Summary and Conclusions

The objectives of this investigation were to evaluate the physiological processes of seedlings in the light of present knowledge of plant physiology and to establish certain specific short-term tests for drought resistance that could serve in place of field testing that requires two to three years. The preliminary results of this investigation indicate that such tests might be developed.

From this study of transpiration, we may say that the more drought-resistant seedlings have more efficient transpirational apparatus than the less drought-resistant plants. This is to say that the plants can absorb water almost as fast as they lose water, even at high soil moisture stress.

The total carbohydrate content and the calcium content of the roots appear to be associated with drought resistance.

I would like to close this talk with a quotation from a paper written a few years ago by Dr. Paul J. Kramer of Duke University: "Until it is known why a given practice is successful, foresters are unable to generalize concerning the probable usefulness of a given practice beyond the particular set of conditions under which they have tested it."

LOUISIANA AGRICULTURAL EXPERIMENTAL STATION *

by

A. Bigler Crow, Associate Forester

The Louisiana phase of the Regional Project was begun in 1956 and is a study of geographic races in loblolly pine. The sources are local since only seed from Louisiana parishes and a few adjoining counties in other states are or will be used. The object is to discover if there are any important differences among sources which would warrant delineating seed collection zones within the state. A preliminary study established several years ago is being used as a base and the work is being expanded to include more sources and additional planting sites.

NORTH CAROLINA STATE COLLEGE AGRICULTURAL EXPERIMENTAL STATION *

by

T. E. Maki, Professor of Forest Management

The North Carolina project was organized in July 1956 and is entitled: Selection and Testing of Certain Pine Species for Desirable Qualities. To date considerable progress has been made in devising a suitable scheme of rating selections. An outplanting area on the Schenek Memorial Forest near Raleigh has been prepared for use in field grafting of desirable selections.
Raleigh has been prepared for use in field grafting of desirable selections.
Dr. Bruce J. Zobel is project leader and is assisted by R. L. McElwee.

---

* Two additional Stations supporting projects are part of Regional Project S-23 but were not reported on at the conference. A brief summary of each is given so that all the work to date under the Regional project will be included.

RESISTANCE TO LITTLELEAF IN SHORTLEAF PINE

by

B. Zak, Pathologist, Athens-Macon Research Center
S. E. Forest Expt. Sta., in cooperation with the
School of Forestry, Uni. of Ga., Athens, Georgia

Today, we lack adequate control measures for many of our important forest diseases; measures which might effectively and economically reduce or stop damage on thousands of acres of forest land. Often certain silvicultural treatments aid in reducing extensive losses to the stand but often, too, they are not easily applied and may offer only partial control of the disease. If we are to reduce disease losses on a forest scale, we must develop methods which can be applied readily to large areas and not merely to the individual tree. For many of our tree diseases, the individual tree can be successfully treated and brought back to good vigor. Such means are suitable for yard trees and those employed as ornamentals but not for extensive stands of diseased timber.

Such is the case with littleleaf today. We know the cause of this widespread Piedmont disease of pine but we have yet to find an effective cure for application to the many thousands of acres on which it occurs. We can successfully rejuvenate individual diseased trees, if not too far advanced, by application of heavy dosages of nitrogenous fertilizer. This, of course, is out of the question for use over extensive areas.

Yet, we are not without means of reducing losses from this serious disease in our forest stands. Losses may be considerably reduced by the application of salvage rules based on the severity of littleleaf in the stand. Instead of leaving trees to die and rot they are removed at periodic intervals consistent with good economics.

We also have a littleleaf hazard rating system based upon an evaluation of a few simple soil characteristics which enables the forester to tag a particular site with a littleleaf hazard rating. If the hazard is high he will not plant shortleaf but some other species of pine much less susceptible to this disease. In the case of natural stands, a high littleleaf hazard rating would dictate management away from shortleaf pine.

One answer to littleleaf and other forest tree diseases needing better control lies in the field of forest genetics--in the development of disease resistant strains. Work has been going on for some time toward developing blight resistant chestnut, canker resistant poplar, phloem necrosis and Dutch elm disease resistant American elm, blister rust resistance white pine, and fusiform rust resistant slash and loblolly pine. Not only is resistance to disease being sought but better all-around strains of these trees are being developed. Disease and insect resistance research goes hand in hand with other forest genetics and tree improvement work today.

Resistance studies on littleleaf began five years ago even before work on the causal factors was complete. An indication of natural resistance to this disease was first noted on severe littleleaf areas where practically all but a few trees escaped attack. Especially striking were those trees which persisted in a healthy condition despite their being immediately surrounded on all sides by littleleaf-killed and dying shortleaf pine. Other indications were observed during artificial inoculation tests when certain individual seedlings appeared to be only mildly or not at all affected. These observations strongly suggested that a weapon against littleleaf was available through the development and propagation of resistant strains of pine.

Before going further, it would be well to briefly review what we know of the cause of littleleaf. It has been demonstrated that this disease of pine is the result of a combination of factors. Primary among these is damage to the root system by Phytophthora cinnamomi, a soil fungus. Adverse soil conditions such as poor aeration, low fertility, and periodic moisture stress contribute to the weakening of the trees. The soil pathogen destroys the growing tips of extending and short roots preventing not only extension of the root system but also checking the formation of mycorrhizae so essential to nutrition particularly on poor sites. Major root damage is believed to occur for a few weeks in spring and later during the fall when soil temperatures and moisture are favorable for the parasite. The fungus can be isolated from soil on good sites bearing healthy shortleaf pine. Although the fungus probably causes the same root damage on good as on poor sites, littleleaf does not develop because the trees, healthy and vigorous, readily recover from this relatively minor damage to their root systems.

In developing resistance to littleleaf, therefore, we must consider not only the primary agent, a fungus, but also the associated unfavorable soil conditions. The resistance to littleleaf must then include resistance to attack by P. cinnamomi and the capacity to grow on poor sites. It must include the ability within the tree to readily regenerate a damaged root system.

Research on littleleaf resistance began with the selection of apparently resistant shortleaf pine on some extremely severe littleleaf sites. These trees were chosen primarily for disease resistance and secondarily for excellence of growth and form characteristics. This is a continuing operation and to date several areas in Georgia and South Carolina have been surveyed for promising selections. Where loblolly is present in littleleaf stands it also is being selected and catalogued. Selection is rather critical--it is estimated that only about one tree is chosen per 40 to 50 acres examined in littleleaf stands.

After a tree is selected, open-pollinated seed is gathered for later progeny tests to evaluate its genotype. Scion material is taken and grafted onto seedling stock. These grafted clones, each of 10 or 20 trees, are established in a central area for later use in control-breeding work. Although some control-pollinations have been made in the field on the original trees, future work in this phase will be carried out on the grafted clones in the central areas when flowering becomes adequate. This will not only reduce costs but should considerably improve results.

Progeny from selected trees are first tested in the nursery and then those which appear to exhibit resistance are outplanted on severe littleleaf sites. For the nursery test one-year-old seedlings are transplanted into tank-like beds filled with heavy soil from a littleleaf area and reinforced with inoculum of the soil pathogen. The soil is flooded twice weekly during the growing season. In effect, this represents a severe littleleaf site but with an intensification of the causal factors.

After one growing season of this treatment the two-year-old seedlings are carefully lifted and evaluated for littleleaf resistance on the basis of their root systems. Seedlings judged resistant must bear dense fibrous roots with abundant mycorrhizae and little dieback. Those judged as susceptible lack fibrous roots and mycorrhizae and have much root dieback.

The first such progeny test with shortleaf pine indicated a definite inheritance of resistance to littleleaf. A high proportion, 45 to 80 percent of open-pollinated progeny of 5 of 6 parent trees tested showed resistance while, only 15 to 25 percent of open-pollinated progeny of 3 of 4 littleleaf trees appeared resistant. A much larger test, including both open-and control pollinated seedlings, has recently been dismantled and is now being evaluated.

The ultimate aim of this program is to eventually develop pine planting stock with a high inherent resistance to littleleaf and possessing good growth and form characteristics. Those strains, found by selection, which after thorough testing prove capable of yielding high percentages of resistant progeny will be made available to interested parties for the establishment of seed orchards. As new and better strains are developed by further selection and by intra- and even inter-specific hybridization they will be made available for inclusion in the orchards.

However, the development of new strains of pine resistant to the factors of littleleaf is not in itself a cureall for this important problem. In order to combat littleleaf successfully we must also improve the depleted sites which foster this widespread disease. Resistance to littleleaf will be a relative quality subject to considerable modification depending upon the character of the site. Hence resistance development must go hand in hand with silviculture designed for soil rehabilitation.

SLASH PINE PROGENY TESTS INDICATE GENETIC VARIATION IN RESISTANCE TO RUST

by

John C. Barber and Keith W. Dorman
Athens-Macon Research Center and
Eitel Bauer, Ida Cason Callaway Foundation

Southern fusiform rust caused by <u>Cronartium fusiforme</u> is one of the most serious diseases attacking slash pine. Each year, it kills many trees and the cankers make portions of the trunks unfit for lumber and other products. The nature of this disease is well known but little in the way of practical control measures is available for planted or natural stands.

One approach to the problem of control is to select resistant strains of slash pine, if they exist, or to develop resistant strains through planned breeding. A first step in this approach is to determine whether disease-free trees in infected stands produce seedlings having more than average resistance to the rust. Early results of 1-parent progeny tests at the tree improvement project of the Ida Cason Callaway Foundation near Chipley, Georgia, indicate that some degree of rust resistance is in fact passed on to the seedling progeny.

The test at Chipley are part of a broad program aimed at developing superior strains of souther pines. The mother trees, in a 15-year-old plantation of unknown seed source, were selected in 1950 on the basis of their growth rate, trunk and crown form, and freedom from rust cankers. At that time, about 75 percent of the surviving trees in the plantation were cankered. This stand had more trees with rust infections than the average, although fast-growing, old-field plantations generally have a high rate of infection.

The seedlings from the 1950 and 1951 seed crops were grown in the Foundation's nursery in 1951 and 1952 respectively. Seedlings were given standard spraying treatment to control rust in the seed beds and infection was low. Nothing is known of the culling practice for the control seedlings, which were purchased, but the usual practice is to cull diseased seedlings at the nursery. Seedlings lots designated control seed number 1 and 2 and Southern Mississippi were grown in the Foundation's nursery. Seed of control number 1 was purchased, that of control lot number 2 and Southern Mississippi were supplied by the Southern Forest Experiment Station.

Seedlings were outplanted as 1-0 stock in the spring of 1952 and 1953. The 1952 planting was in plots varying from 20 to 100 trees with 3 replications. The 1953 planting was in 25-tree plots with 4 replications and was adjacent to the 1952 planting. Stem and branch cankers were counted in the fall of 1955, when trees planted in 1952 averaged about 8

Table 1. Rust Infection in Slash Pine Progenies from open-pollination of Disease-Free Mother Trees and of unselected Mother Trees.

Seedling lot or numbers of parent	Planted Spring 1952				Planted Spring 1953			
	Trees:	Stem cankered	Branch cankered	Total trees with canker	Trees	Stem cankered	Branch cankered	Total trees with canker
	Number	Percent	Percent	Percent	Number	Percent	Percent	Percent
Control Seed (1)	114	37	55	64	66	18	15	30
Control Seedlings	104	28	58	64	42	25	33	48
Control Seed (2)	30	53	70	77	85	36	28	51
Southern Mississippi	56	52	71	77	92	50	26	58
Average	---	42	64	70	--	33	26	47
C-4	62	23	45	45	80	26	19	32
C-6	71	24	34	48	79	25	16	33
C-7	71	30	42	54	71	30	15	39
C-10	250	24	51	59	97	23	24	39
C-37	216	14	26	30	84	8	12	20
C-50	212	34	52	61	94	29	31	50
C-51	203	22	51	58	89	19	15	27
C-63	58	16	26	29	92	23	28	39
C-65	252	13	36	43	85	12	11	21
Average	---	22	40	47	--	22	19	33

feet in height and those planted a year later averaged about 5 feet.

Progeny groups of certain maternal parents had only about half as many infected trees as others (Table 1). Also, the average percent infection in progeny of 9 selected trees was 33 and 30 percent less in the 1952 and 1953 plantings respectively, than in 4 lots of control seedlings from unknown parent trees.

Infections were low in the progeny of C-37 in both plantings and were less than half that of the controls. Furthermore, the C-37 progeny are among the fastest growing in the plantations and the trees have characteristicly short branches. Progeny of C-50 are also very fast growing and extremely slender crowned, but they have the highest infection of any select group. Control seed number 2 and Southern Mississippi lots planted in 1952 and 1953 represent single lots of seed respectively. Part of each of the two lots of seed was planted in the nursery in 1951 and part in 1952. In the 1952 planting the percent of total trees with cankers was the same in both lots. In the 1953 planting there was only a 7 percent difference. However, for both seedling lots, there were fewer trees with stem cankers than branch cankers in the 1952 planting while the reverse was true in the 1953 planting. However, it should be pointed out that in these groups as well as in the progeny of plus trees it was difficult to tell if a large stem canker in a whorl of branches originated on the branches or on the stem. Stem cankers are the more damaging because they may deform the trunk, weaken it so that it breaks, or even kill the tree.

Although the results reported here are from few tests of short duration, they indicate there may be some inherent differences in susceptibility to rust among individual slash pine trees. More complete information will soon be available from periodic observations of these trees as they grow older and of trees in additional plantings made in 1954, 1955, and 1956 with seed from open-and controlled-pollinations.

DIFFERENTIAL GROWTH RATE OF YOUNG PROGENY OF INDIVIDUAL SLASH PINE TREES

by

James T. Greene, Keith W. Dorman, Eitel Bauer

Difference in the vigor of progeny of individual trees is of great interest to workers engaged in forest tree improvement and forest genetics research. Trees that produce fast-growing offspring may become the basis for a superior strain, which may produce superior seed in volume for large scale nursery planting. They would also be valuable breeding stock for intra- and inter-specific hybridization.

If it can be shown that progeny of individual trees vary in vigor, then source of seed becomes an important factor in racial variation studies, nursery selection studies and in investigations of the effect of seed size on seedling vigor. Observation at the Ida Cason Callaway Tree Improvement Project near Chipley, Georgia, of slash pine progenies through their 5th year indicate that such differences in vigor actually exist.

Description of Studies

By intensive scouting in plantations and natural stands of the 35,000 acre Callaway estate, individual trees that have twice the wood volume of the average tree in the same stand at the same age have been located. On a basis of diameter and height, crown form, limb size, and apparent resistance to disease, slash, loblolly, longleaf and short leaf pine have been selected. These trees are being used to answer several questions; will wind-pollinated seed from these fast-growing trees (that is to say, a superior mother and unknown father) produce fast-growing progeny; and when two superior trees are control-pollinated and crossed, will the off-spring be even more vigorous (superior mother plus superior father)?

In the studies by the Callaway Foundation, open-or wind-pollinated seedlings of about 40 selected slash pine trees have been planted since the spring of 1952. The progeny are out-planted in plots of 25 to 100 trees at 10 x 10 ft. spacing with 3 or 4 replications. These field test are designed to compare growth and other traits such as form, resistance to fusiform rust etc., of the progeny. For certain trees it was possible to make plantings from different seed crops for three successive years. It is this group consisting of the progeny of six different selected trees that will be discussed here and not results for all plantings of all species. The group contains two trees that produce what we will refer to as slow-growing progeny, C-6 and C-51. Four trees produce progeny which are somewhat faster growing, C-10, C-37, C-50, and C-63. Height data is available for two of the plantings in their fifth year from seed and for the remaining planting during its third year.

Table 1 - Relative seedling heights for several progeny groups at one through five years in relation to a slow growing group.

Progeny group	Total Trees	Thousand seed weight	Relative heights. Progeny of C-6 equals 100 at --					5-year height
			1 year	2 years	3 years	4 years	5 years	
	Number	Grams	---	---	Percent	---	---	Feet
Slow growing								
C-6	39	26	100	100	100	100	100	7.67
C-51	141	33	163	117	119	109	95	7.32
Fast growing								
C-10	180	40	122	129	140	124	116	8.79
C-37	149	39	129	116	122	114	102	7.80
C-50	142	40	120	118	125	119	116	8.88
C-63	40	40	115	120	138	127	114	8.78

Results

1st. slide: When seedling heights are compared for each year it can be seen that some progeny groups have maintained about the same degree of superiority, expressed on a percentage basis, each year throughout the 5-year period. (Table 1) The progeny of C-10, for example, were 22 percent taller than the progeny of C-6 in the nursery bed. At the end of the succeeding growing seasons they were 29, 40, 24 and 16 percent taller than C-6.

Progeny of C-51, which we consider to be slow growing were very fast growing in the 1951 nursery and were 63 percent taller than those of C-6. In the following years they were 117, 119, 109 and 95 percent of the height of C-6. The high vigor in the nursery of C-51 progeny was not observed in 1952 and 1953.

The superiority of the four fast-growing progeny groups was somewhat less in the fifth year than in the fourth. This is due, largely, to a slight increase in growth rate of the C-6 progeny rather than to a decrease in growth rate of the others.

2nd. slide: The relative vigor of seedlings from seed lots collected from the same tree in different years remains roughly the same for some trees but varied for others. At the end of the fifth year of growth for plantings made in the spring of 1952 and 1953 and the third year for plantings made in the spring of 1954, the progeny of C-51 were 95, 104 and 95 percent respectively of those of C-6.

For C-10 the relative heights were 116, 114, and 116. For C-63 they were 114, 116 and 111. These three groups were quite uniform. The others were more variable. C-37 was 102, 124 and 106 while C-50 was 116, 128 and 95.

For these six progeny groups, the seed weight was lower in slow-growing progeny which may have handicapped them iniatially but subsequent growth rate has not been rapid enough for them to catch up with other groups. In general, we do not find a strong relationship between seed size and seedling growth when seed is kept seperate by maternal parent.

We have both fast and slow progeny from maternal parents with low seed weight as well as from trees that have high seed weight. However, a complete discussion of this problem is beyond the scope of this paper as well as a discussion of differences in branch length and susceptibility to rust which have appeared in print or at earlier papers at this conference.

Conclusion

As a result of our observations on slash pine progeny groups to 5 years of age, we believe there are important differences in growth rate of the progeny of different trees. Just how much these differences will contribute to the selection of better strains or influence the detection of such strains through progeny tests with one-parent stock, we won't know until the plantings are older. We feel strongly, however, that serious error could result in many types of studies in tree improvement work if maternal parent is not considered as a possible source of variation.

Table 2 -- Height of progeny groups outplanted in 1952, 1953, measured in 5th year and 1954 measured in the 3rd year.

Progeny group	Average height at--			Relative heights. Progeny of C-6 equals 100 at--		
	5 years	5 years	3 years	5 years	5 years	3 years
	Feet	Feet	Feet	Percent	Percent	Percent
Slow growing						
C-6	7.67	7.46	2.11	100	100	100
C-51	7.32	7.73	2.00	95	104	95
Fast growing						
C-10	8.79	8.50	2.45	116	114	116
C-37	7.80	9.24	2.23	102	124	106
C-50	8.88	9.62	2.01	116	128	95
C-63	8.78	8.68	2.33	114	116	111

ROOTING AND AIR-LAYERING SOME SOUTHERN HARDWOODS

by

Thomas C. Nelson, Forester, Athens-Macon Research Center
Southeastern Forest Experiment Station, Forest Service, USDA

For the past several growing seasons, studies in the vegetative propagation of southern hardwoods have been under way at the Athens-Macon Research Center of the Southeastern Forest Experiment Station. These studies have had two principal objectives: (1) to increase the number of tree species which can be successfully out-planted from cuttings in the Georgia Piedmont; and (2) to develop methods of vegetative propagation necessary for intensive work in hardwood genetics and tree improvement.

Several methods of vegetation propagation have been or are being explored, such as propagation by rooting of cuttings, air-layering, trench layering, and vertical splitting of seedling stock.

Rootings of Cuttings

Completed Studies: Vegetative propagation through rooting of cuttings has been attempted for eastern cottonwood, American sycamore, yellow-poplar, sweetgum, and water oak. Hardwood cuttings of eastern cottonwood, American sycamore, and yellow-poplar have been successfully rooted in the nursery bed.

Hardwood cuttings of eastern cottonwood, obtained and handled according to the suggestions of Maisenhelder,[1] have been successfully outplanted in the Georgia Piedmont. A half-acre outplanting of eastern cottonwood in January, 1956, on a bottomland site near Athens, Georgia, had an 88-percent survival at the end of the first growing season. Average height of the stems was 7.0 feet. Ten percent of the stems were over 9 feet tall and maximum height growth was 10.8 feet.

Hardwood cuttings of American sycamore were also successfully rooted. The best trials gave 65 percent survival and maximum height growth of 8 feet during the first growing season.

Individual studies tested rooting and height growth in respect to the position of the cutting on the parent, size of cutting, and time of planting. The cuttings were 20 inches long made from 1-year-old sprouts of local origin in late October. Excluding the fall planting material, cuttings were packed in moist sphagnum moss and held in cold storage until the spring planting season. All plantings were made in beds in the nursery of the School of Forestry, University of Georgia, at Athens. Rooting was deter-

1/ Maisenhelder, L. C., Planting and growing cottonwood on bottomlands. Miss. Agric. Expt. Sta. Bull. 485. 23 pp., illus. 1951.

mined by survival at the end of the first growing season.

The resules of these studies on the rooting of American sycamore cuttings from first-year stump-sprout growth indicate that:

1. Butt cuttings have taller sprouts than cuttings taken from higher up the parent stem.

2. The best survival and height growth of butt cuttings were obtained from cuttings greater than 1/2 inch in diameter.

3. Sycamore cuttings were successfully rooted in fall plantings.

Yellow-poplar hardwood cuttings were rooted in fall plantings. Both stem and root cuttings of 1-year-old yellow-poplar nursery stock were tested in the spring of 1955. Out of 150 root cuttings, none survived. Out of 500 stem cuttings treated with Rootone, twelve rooted (2.4 percent) and have developed into excellent stems. In cooperation with Dr. Reines, of Georgia Forestry School, 170 cuttings from the same stock were placed in the greenhouse with 16 combinations of various hormones and concentrations and a control. Only five of the 170 rooted, with no apparent difference due to hormone treatment.

Softwood cuttings of yellow-poplar, sweetgum, and water oak planted in nursery beds were unsuccessful. Yellow-poplar cuttings 12 inches in length from sprout growth of the current year and the previous year's growth were treated with indolebutyric acid at 1,000, 3,000, and 8,000 p.p.m. in talc. The check was untreated. No rooting was obtained from this series of treatments made in June or in a series of cuttings made in early July and treated similarly.

Sweetgum cuttings 12 inches in length from the current year's sprout growth were made in early June and treated with indolebutyric acid at concentrations of 1,000, 3,000, and 8,000p.p.m. in talc plus an untreated check. None of the treatments produced roots. Exploratory tests with cuttings taken in early July from water oak sprout growth were also unsuccessful.

<u>Current Studies</u>: Several studies in the rooting of cuttings are now under way. Hardwood cuttings of American sycamore, yellow-poplar, sweetgum, and green ash were installed in the Forestry School nursery in November, 1956. These studies primarily involve tests of the value of several hormones in rooting.

In addition, approximately 500 hardwood cuttings of American sycamore have been outplanted on an old-field bottomland site near Athens in a test of the effect of site preparation upon initial survival and first year growth of cuttings. These cuttings are 1-year-old sprout cuttings 1/2 inch or larger at the small end and 20 inches long. Site treatments included no preparation, double furrow plowing, disc harrowing, disc harrowing plus two cultivations, and TCA applied at the rate of 100 pounds per acre. Each site treatment is being tested with and without fertilizer.

Air-Layering

The use of air layering as a method of vegetative propagation with southern hardwoods has been tested at Athens for American sycamore, green ash, sweetgum, eastern cottonwood, yellow-poplar, southern red oak, cherrybark oak, red maple, and flowering dogwood.

The techniques for American sycamore, green ash, and sweetgum have not been perfected to the point that a high percentage of success can be expected. However, successful air layers have been made with these species.

Although over 45 air-layers have been attempted on yellow-poplar, southern red oak, cherrybark oak, red maple and flowering dogwood, none has been successful.

Air-layers with eastern cottonwood showed a relatively high percentage of success with the first attempts. Subsequent refinements in technique have made it possible to approach 100-percent root formation from cottonwood air-layers. With cottonwood, the most satisfactory results were obtained by applying indolebutyric acid at a concentration of 3,000 p.p.m. in talc to a scraped girdle of the current year's growth on young stems.

It was also found that the amount of root formation in eastern cottonwood correlated with the amount of photosynthetic surface above the air-layer:

Number of leaves above girdle	Ovendry weight of roots in grams
0	0.18
2	Dead
4	0.65
6	1.29
8	1.49
10	2.91

Working plans have been completed to further test air layers on species upon which preliminary tests were unsuccessful. A basic study on the influence of physiological factors on air layering is also in the planning stage.

In addition to vegetative propagation by rooting of cuttings and air layering, two other methods have been tested in exploratory studies. Trench layering of yellow-poplar has been tried, and excellent callous formation was obtained although no root formation occurred. Vertical splitting of seedlings, followed with a coating of the exposed plant tissue with lanolin, is now being tested on yellow-poplar.

Summary

Exploratory studies on rooting and air layering of southern hardwoods have been in progress at the Athens-Macon Research Center for the past two

growing seasons. Although negative results were obtained on preliminary attempts at rooting cuttings and air layering of a number of species, they do not indicate that these species cannot be vegetatively propagated. Rather, they suggest that proper techniques have yet to be developed for those particular species.

Successful rooting of cuttings from eastern cottonwood, American sycamore, and yellow-poplar and successful air layering of American sycamore, green ash, sweetgum, and eastern cottonwood are reported in this paper.

PROPAGATION OF SOME DELTA HARDWOODS BY ROOTING

by

Louis C. Maisenhelder [1] Southern Forest Experiment Station, Forest Service, U.S.D.A.

Natural regeneration is now, and perhaps will always be, the most common means of reproducing the bottomland hardwood forests in the Mississippi River Delta. Planting in this territory is a minor problem, for it has been estimated that possibly only 5 to 10 percent of the land which should be in forest will require planting to restock it with acceptable species. Even this small percentage, however, represents several million acres. If we add the acreage on which it would be desirable to convert the existing stand to one of a better species composition, it is apparent that there is a valid reason for studying planting problems.

Good planting stock of species which can be easily and economically produced and planted is a vital part of any planting program. Recognizing that cuttings promised to be a satisfactory and economical means of propagating such species as would reproduce vegetatively, the Southern Forest Experiment Station in 1939 began to study the rooting ability of bottomland hardwoods, beginning with the native cottonwood (Populus deltoides). In recent years, as results with cottonwood showed the feasibility of using cuttings, the work was expanded to include small-scale investigations with black willow (Salix nigra), sycamore (Platanus occidentalis), green ash (Fraxinus pennsylvanica), sweetgum (Liguidambar styraciflua), and Nuttal oak (Quercus nuttallii). The findings will be reported briefly in this paper.

Cottonwood

Cottonwood was the first species chosen for study because its adaptability to vegetative reporduction was already well known and because it is a desirable species that grows rapidly and is suited to many of the sites in need of planting.

Cottonwood roots easily without special treatment. First-year survivals of 75 to 90 percent have been obtained by observing the following rules. Cottonwood cuttings should preferably be planted as soon as they are made, but cold storage is possible if late planting is necessary. Planting should be done before the buds swell or leaves appear. Cuttings should be taken from dormant one-to three-year-old seedlings or stump sprouts and should be 20 inches long and 3/8 to 3/4 of an inch in diameter at the small end. They should be set 15 inches into the ground to insure that at least a por-

1/ Stationed at the Delta Research Center, Stoneville, Mississippi. The Delta Research Center is maintained by the Southern Forest Experiment Station in cooperation with the Mississippi Agricultural Experiment Station and the Southern Hardwood Forest Research Group.

tion of the cutting will be in moist soil during the dry summer months. Roots are produced along the entire underground portion of the cutting, but only those in moist soil remain alive. Site preparation before planting and cultivation during the first growing season by disking are necessary to prevent the trees from being overtopped and killed by competing vegetation.

Cuttings taken from one-year-old wood in the tops of mature or near mature "plus" trees selected for their outstanding desirable characteristics do not root well. Five to twenty percent survival, varying with the individual parent tree, is the best that has been obtained with this type of material. Neither does the survival become materially better as cuttings from the resulting one-year-old sprouts are planted in ensuing years. For example, in 1954 cuttings from a mature tree gave 16 percent survival. In 1955 cuttings from this surviving one-year-old stock gave 22 percent survival and in 1956, 23 percent.

Treating the cuttings by soaking 24 hours in 60 and 100 parts per million solutions of the root-inducing hormones indoleacetic acid, indolebutric acid, and naphthaleneacetic acid still gave only 20 percent survival for the mature-tree clones as compared with 47 percent for clones originating from seedlings. These results do not offer much hope for the successful and economical propagation by cuttings of older "plus" trees that could provide better than average growing stock.

Cottonwood cuttings can be successfully kept in cold storage at temperatures ranging from 28° F. to 36° F. without losing their ability to root. The bundles of cuttings should be set in the storage room butt end down in a layer of moist sand several inches deep and sprinkled with water twice a week to maintain a humid atmosphere. After seven months of such storage, 75 percent of the cuttings rooted when planted in a greenhouse. Storage for 4 to 6 weeks followed by planting in the field has resulted in 90-percent rooting.

On suitable sites and with favorable weather and freedom from insect attacks, cuttings grow rapidly. First-year heights of 4 to 5 feet are common and under the most favorable conditions height of 12 feet and 1.1 inches in diameter at breast height has been attained.

Black Willow

Black willow roots even more readily than cottonwood and can be propagated by cuttings in the same way as outlined for cottonwood. Experience with this species at the Delta Research Center has been limited but survival has been high in all cases, usually 90 percent or better, and in one test the cuttings were planted in March after they were in full leaf. This ability of willow to root and survive after leafing out will make late plantings (after flood waters have receded) a more economical undertaking than with cottonwood, since the trouble and cost of cold storage can be eliminated. Height growth of willow averages about four feet the first year.

Sycamore

Tests of the rooting ability of sycamore have been carried on for three seasons. Hormone-treated and untreated cuttings of the same size as described for cottonwood were planted in the same way. The treatments were a 24-hour soaking in a solution of 20, 60, and 100 parts per million of indoleacetic acid, indolebutyric acid, and naphthaleneacetic acid. Using three-year-old sprouts for cutting stock produced a survival of 45 percent for untreated stock and 62 percent for the best treatment, which was indolebutyric acid at 20 p.p.m. All treated stock rooted better than the untreated but the difference was not statistically significant. A test using cuttings from one-year-old sprouts showed little difference in survival between the treated and untreated cuttings. The results were 83 percent survival for the untreated and 80 percent for treatment with indolebutyric acid at 60 p.p.m. Hormone treatment of this young stock therefore does not appear to be beneficial. The experience of some of our cooperators with field plantings of untreated stock indicates that 2/3 or more of the cuttings will root and survive.

Height growth for the first growing season varies with site and weather conditions but averages 3 to 5 feet.

Green Ash

Green ash cuttings from one-year-old stock also root rather easily when prepared, planted, and cared for in the same manner as described for cottonwood. Ash cuttings usually are smaller in diameter than cottonwood because one-year-old sprouts do not attain a size equal to that of cottonwoods. Cuttings 1/4 inch or less in diameter, taken from small one-year-old nursery-grown seedlings, have been observed to root and grow very well. All the cuttings were taken just above the root collar and this tissue may be better adapted to rooting than material further up the stem. Additional testing will be required to verify this observation.

Treatment with hormones as described for sycamore has given slightly higher percentages of survival than for untreated stock but the differences were not statistically significant. Untreated cuttings from one-yaar-old stock produced 70 percent survival and those treated with indolebutyric acid at 60 p.p.m. produced 88 percent survival. Two and three-year-old stock shows about 10 percent less rooting than do the younger cuttings.

For field planting the average survival ranges from 66 to 75 percent for untreated stock.

It is essential to plant green ash cuttings with the bud pointing up. All cuttings planted upside down failed to grow. This is a variation from the behavior of cottonwood and willow, which will grow either way but with some retardation in height growth when planted upside down.

First-year height growth for green ash is also somewhat variable but should average four feet on favorable sites. Unrooted cuttings and seedlings planted side by side made the same height growth in the first season.

Sweetgum

Sweetgum cuttings do not root easily, if indeed they can be made to do so at all. So far, we have not succeeded in getting even one cutting to root. All the previously mentioned hormone treatments have been tried on both young and old wood. Other hormones and perhaps softwood cuttings should be tried.

Nuttall Oak

From very meager data it appears that treatment with hormones, as described previously for other species, stimulates the rooting of Nuttall oak cuttings from one-year-old stock. Treated cuttings show approximately twice the survival of the untreated--30 percent as compared with 15 percent. There was little difference between the hormones, but the 100 p.p.m. concentration appeared to be the best. Judging by the results shown for red oaks in the publication "The use of Auxins in the Rooting of Woody Cuttings," by Thimann and Behnke-Rogers[2/], our solution concentrations were too low for best results. Further testing is indicated.

Conclusion

So far all of our work with the propagation of Delta hardwoods by rooting has been directed toward finding a simple, practical, and economical means of using dormant unrooted cuttings for field planting. In this we have already been partially successful with the species we have tried. Cottonwood and black willow have reproduced satisfactorily both in the nursery and in plantations. Sycamore and green ash have done very well in nursery tests, and pilot plantings of these two species are now being made. The oaks will require more intensive testing but there appears to be hope of finding a means to induce rooting. Sweetgum is the only species tested that has failed to produce some rooting.

As our program for the improvement of planting stock by selection progresses, we shall undoubtedly investigate the use of softwood cuttings, root cuttings, and grafting as means of obtaining vegetative propagation of the species whose dormant cuttings do not root readily.

2/ Thimann, Kenneth V., and Behnke-Rogers, Jane. The use of auxins in the rooting of woody cuttings. Maria Moors Cabot Foundation, Pub. No. 1, 344 pp. Harvard Forest, Petersham, Massachusetts. 1950.

AGE OF TREE AND ROOT DEVELOPMENT BY AIR-LAYERS IN LOBLOLLY PINE

by

Robert G. McAlpine, Candidate for Master of Forestry degree,
School of Forestry, University of Georgia.
Staff, Athens-Macon Research Center, U. S. Forest Service.

Activity in forest tree genetics and improvement has increased considerably during the past decade in the Southeast. Methods of vegetatively propagating tree species are deemed of prime importance as "tools" for needed studies. Among the pines, grafting techniques are sufficiently well developed to allow rather easy vegetative propagation of clonal stock from trees of all ages. This method is now being used extensively for the establishment of seed orchards.

Other forms of vegetative propagation, namely the rooting of cuttings and the air-layering of branches, are often more useful than grafting since both root system and top of the new "progeny" are genetically identical to the "parent" tree rather than the top alone as is generally true of grafted trees. Both cuttings and air-layers, however, suffer an important limitation not common to grafting. That is, as the age of the parent tree increases, the ability to develop roots on cuttings and branches decreases sharply.

Many instances of this phenomenon are found in the literature. Delisle (2), for example, found in working with white pine that rooting ability falls off in direct proportion with increasing age of the tree. He found that auxin treatment definitely increases the percentage and quality of rooting, but does not eliminate the effect of age of the tree on the rooting of cuttings taken from it. Cech (1), in working with loblolly pine cuttings, found that rooting falls off sharply after the trees reach five years of age. Zak (4), concluded that with shortleaf pine the age of the parent tree determines how easily material taken from it will strike roots. Shoots from trees beyond 10 years of age are rooted only with difficulty.

Although much work has been done in the rooting of pine cuttings, little has been done to establish the direct relationship between rooting ability and the age of the tree, through a series of age classes, from seedling to maturity. The present study was initiated to investigate the factor of age and specifically its relation to the successful rooting of loblolly pine. Because of the generally better results obtained by air-layering, this method rather than rooting, was decided upon to study this relationship.

Methods

During the summer of 1956, individual loblolly pines were selected in plantations of known age located on land of the School of Forestry, University of Georgia, and on property belonging to Bannon Jones at High Shoals, Georgia. From these plantings, 12 trees were chosen from each of 9 age classes: 2, 3, 5, 6, 7, 8, 10, 17 and 24 years. In each case, age refers to the total age from seed.

There is considerable variation in intensity of sunlight falling on different portions of the crown. For example, the south side of the tree is expected to receive more intense sunlight than the north side. To overcome this, the crown was arbitrarily divided into four quadrants corresponding to the cardinal directions, North, East, South and West. One air-layer was made in each of these quadrants. Dominant trees were selected to reduce the shading effect from surrounding trees and to assure as much as possible trees of equal vigor. In all a total of 432 air-layers were made.

Trees of the 2 year age class were not branched sufficiently to allow more than one layer per tree; therefore, the main stems of 48 potted seedlings in the nursery were treated. In all the other age classes only the branches were treated.

The air layer was prepared as outlined by Mergen and Rossoll (3), in Station Paper No. 46, S. E. Forest Experiment Station entitled "How to Root and Graft Slash Pine." The procedure was modified to include the use of a bamboo splint along the stem to prevent breakage by wind. Also, the air-layer was covered with aluminum foil to reflect the rays of the sun thereby reducing the build up of heat within. Indolebutyric acid in talc, at a concentration 8,000 p.p.m., was applied to the upper portion of the girdle. All layers were made on the current years growth, each was tagged, and the date, age and location of tree and position of crown noted.

The installation of air layers was a tedious and time consuming procedure especially on the larger trees. There was necessarily a time difference in layering of the first and last tree in the experiment. The treatments began on July 17, and the final layer was made on August 15. To overcome this difference as much as possible, treatments were scattered randomly throughout the age classes during the installation period.

A treatment time of 70 days was chosen and each layer was removed at the expiration of its time limit. Upon opening the following data was taken: number of roots, total and average length of roots, condition of callus, diameter above and below girdle in millimeters, and percent of bridgin by callus tissue. All roots were removed and oven-dry weights obtained.

Results

During the first few weeks of the air-layering period several of the trees in the 2 year age class died. This was presumably caused by girdling of the main stem during a period when food reserves in the roots were low. When the air layers were opened and examined most of the root stocks of this age class were dead, but in many cases the stem above the girdle had formed roots and was in good condition. Upon examination, it was found that death due to causes not directly related to rooting ability, was fairly uniform

Table 1: The Relation of Root Formation by Air Layering to the age of Tree in Loblolly Pine.

Age Class	Air-layers			
	Living 1/	Successfully rooted 2/		Average oven-dry weight of roots
	(number)	(Number)	(percent)	(grams)
2	39	39	100	0.540
3	40	36	90	0.170
5	42	15	36	0.016
6	40	7	18	0.004
7	40	8	20	0.004
8	40	2	5	0.002
10	46	3	7	0.002
17	44	0	0	0.000
24	43	0	0	0.000

1/ A total of 48 air layers were made per age class. The indicated discrepances represent losses of various kinds.

2/ Based upon living air layers.

throughout the age classes and these were deleted from future calculations.

Rooting in each age class was calculated as a percentage of the total 48 layers made less those which died, broke off, lost their foil covering or were whipped severely by adjacent branches. The percentage of rooted air-layers was highest in the youngest age class and decreased sharply with increasing age. In the 2-year age class 100 percent rooted while none rooted on trees 17 years of age and older. A similar pattern was found in the data on the oven-dry weight of the roots.

In the 2-year age class a considerable variation in size of the root systems was noted. The air-layers on seedlings, whose root stocks had died after beginning of root formation, produced such dense root systems that difficulty was experienced in extracting them from the moss. Those, in which the root stock remained alive, produced less well developed root systems and those, in which the girdle had been largely bridged over, developed a few small roots. In practically all cases where the root stock remained alive there was some degree of bridging of the girdle by callus tissue.

No differences could be found in rooting initiated in those air-layers located in the four quadrants of the crown. In the younger age classes, in which rooting was best, the crowns were so small that the amount of sunlight falling on each layer was fairly uniform. In the older age classes rooting was insufficient to allow any conclusions to be drawn.

An attempt was made to correlate the ratio of diameter of stem above girdle over diameter below girdle with the number of rooted air-layers in each age class. It was thought that this ratio might give some measure of food accumulation in the top. However, no correlation was found to exist.

Some evidence is present to indicate that there is a variation in rootability between individual trees. In the 3-year old age class the air layers not rooted were found to be localized on a few trees. In the 5-year class one tree had three rooted branches with the remainder scattered singly among the other 11 trees. In the 10-year class one tree had two rooted branches. Only one other branch had rooted in the remaining trees.

There is also an indication that other factors were involved, probably the most important being time of year. In the 5-year class the first six trees were air layered two weeks earilier than the remaining six. The root systems developed in the first six were much superior in number of roots and in root length. Also, at the nursery, some 2-year stock was air layered about five weeks after the 48 trees of this experiment. After 70 days all root stocks were living but few of the layers had rooted. Those rooted had much less well developed root systems than those previously layered.

Summary

The effect of age of tree upon root formation by air layering in loblolly pines was tested. A total of 432 air layers were applied on planted trees, employing age classes from 2 to 24 years. Rooting was best in the

youngest age classes and decreased sharply with increasing age of trees. All of the living air layers in the 2-year age class rooted while none rooted in trees 17 years of age or older.

Literature Cited

1. Cech, F. 1955. Third progress report, Texas Forest Serv. 51, 13 pp., illus.

2. Delisle, A. L. 1954. The relationship between the age of the tree and the rooting of cuttings of white pine. Univ. of Notre Dame, Indiana Academy Sci. Proceedings 64: 60-61.

3. Mergen, F. and Rossoll, H. 1954. How to root and graft slash pine. Southeastern Forest Expt. Station Paper 46, 22 pp., illus.

4. Zak, B., 1956. Experimental air layering of shortleaf pine. Southeastern Forest Expt. Station Paper 69, 12pp., illus.

CONTROL OF CONE INSECTS IN SOUTHERN PINE

by

J. F. Coyne, Entomologist, Forest Insect Laboratory
Gulfport, Mississippi

In years past, insect damage to tree seed in the South has been considered of relatively minor importance to the forester and entomologist alike. It was and still is largely taken for granted that there are good seed years and poor seed years, depending upon the whims of the individual tree species --dovetailed in with a variety of other ecological or climatalogical factors. The purpose of this brief paper is to illustrate that lacking the ability to do much about the cyclic habit of good seed years, we can, with the expense of some time, tender, and, no doubt, trouble make every seed year a better seed year than normally would be the case.

Under certain types of silvicultural management, insect damage to pine seed is of negligible importance. However, in some seasons insects destroy nearly all the seed of desirable pine species. With the arrival of accelerated planting programs such as may be experienced under the Soil Bank Act this loss of seed for nursery stock, especially seed from certain desired geographical areas, could prove very detrimental. Needless to say, companies engaged in the collecting, selling, or planting of seed from high quality trees are likewise adversely affected; finally, a tree genetics program of any type is capable of being retared immeasurably in increased costs and serious time loss by the feeding habits of the many species of insects found affecting the yield of pine seed.

At the Gulfport, Mississippi, Forest Insect Laboratory, 24 different species of destructive insects have been collected from the four major pines. There are perhaps more than this number in the collections of the Southeastern Laboratory at Asheville. No doubt, there are still other important species that have not yet been collected or identified.

The insects collected are of three main orders--the moths, beetles, and flies. Each order and sometimes each species within each order exhibits a variety of habits. For those in attendance at this meeting some familiarity with at least the more common types of injury may be well, in order that the time and dollars lost in caring for, collecting, and storing of infested seed or cones may be prevented.

In the South, perhaps the most troublesome are the larvae or caterpillars of certain species of moths which feed on the bracts or scales of the cones or on the seed itself. Such feeding deforms the young cones and often causes a great amount of cone mortality. Mining of the interior of mature cones by the caterpillars prevents the cones from opening and releasing their seed which, in many cases, is sound. This latter type of injury is distinguished usually by an opening on the surface of the cone from which protrudes a mixture of frass and resin.

The adults of this group are mostly inconspicuously colored moths and are usually less than one inch in wing spread. They begin their flight period in early spring and deposit their eggs on or near the first or second year cones. In the southern part of the United States there are usually at least two generations and occasionally as high as four generations each year. Most of the species of this group feed also on the terminal shoots of the tree crowns. A conspicuous example of this occurred the past summer, when boring of the terminals of the pitch moth Dioryctria amatella caused the appearanc of red needle flags on slash and longleaf pine. This type of damage accounts for the girdling or cone-bearing twigs and in some areas caused nearly complete mortality of first year cones.

Another moth, not often thought of as a cone insect, is the common pine tipmoth Rhyacionia frustrana. In a tree-breeding program the feeding habits of this moth in destorying the primordial tissues on which young female flowers are subsequently borne makes it necessary to wait for a longer time than necessary to make desirable pollinations. Protecting young loblolly or shortleaf or other susceptible species from attack by this moth will usually result in cone formation by the trees at 3 to 5 years of age.

Pine cones that drop to the ground before they are full grown or remain attached to the tree as withered forms are usually found to be killed by one or more species of cone beetles.

These beetles are leas than 1/4 inch in length and dark brown or black in color. They construct galleries in the pitch of the base or stalk of the cones during the first or second year the cones are on the tree. The female beetles lay their eggs in the central part of the cones, and the small, legless, grub-like larvae which hatch out begin to feed on the scales and seeds of the developing or ripening cones. Two or three generations of these beetles are possible each year in the southern states.

Possibly the insects most frequently encountered by pine seed collectors and nurserymen are the flies and midges. The young white or pink maggotlike larvae are often found emerging from spread cones in drying sheds. The mosquito-like adults lay their eggs on green cones. The eggs soon hatch, and the issuing larvae attack the cone scales, bracts, and seed--usually within the cones. Some species make a gall-like swelling on the outside of the cones. A number of generations of these flies can be produced annually. During some years considerable damage is done to cone crops in local areas--in other years the damage is negligible.

At the Southern Institute of Forest Genetics, since 1954 tests conducted on slash and longleaf pine have shown that seed crops can be protected from insects by the application of an insecticide. Beginning in March, one-half of one percent benzene hexachloride in a water emulsion applied four times on a bi-monthly schedule to selected parent trees has resulted in about a threefold increase in the yield of seed. With this formulation there is no phytotoxic effect on the foliage or cones of the treated seed or in the germination ability of seed from treated trees.

The spray application in this instance was made with a hydraulic sprayer maintaining a pressure of about 120 pounds. Higher pressures were found to break up the spray droplets so fine that they would be easily dispersed by the slightest breeze. A makeshift spray boom was devised by running a small-diameter hose up the inside of a 40 foot aluminum pruning pole and attaching a nozzle to the upper end. On days with little wind and with the boom being manipulated from a stand on the cab of a pickup truck, trees 65 feet in height can be treated. The average dosage per tree was about 3 gallons of the spray emulsion which allowed good coverage.

The effectiveness of this spraying can be summarized by saying that on unsprayed check trees the loss for the two years the cones are on the trees is about 74 percent. On sprayed trees the cone loss is about 30 percent. On a cost per tree basis, about $2.65 was spent in treating the trees in these tests four times each year. This cost is rather high, but in this instance, where high-value trees and high-value cones are involved, it is thought to be economical.

In inaccessible areas or on larger areas such as seed orchards, seed production areas, or where seed tree cuts have been made, it may be found economical to employ aerial application of the sprays. In California, preliminary tests have demonstrated that the aerial spraying of 2 pounds of DDT in diesel oil per acre was successful in getting a significantly higher seed yield from sugar pine seed trees. One aerial spraying gave good control for two or three years following treatment. This method may be found practical in southern forests as well. Some tests of this nature are now being proposed for areas in northern Florida.

At the Gulfport laboratory, only about 16 species of insects predatory or parasitic on destructive cone insects have been collected from caged cones. Less than ten percent of the cones yielded any predatory forms at all. Because of the many species of destructive cone insects involved, the cultivation or introduction of parasites into forest stands with the object of controlling the depredations of cone-feeding insects is not considered to be practical at the present time.

In all liklihood, even with the great amount of seed loss accountable to cone and seed insects, natural stands of timber could maintain themselves indifinitely. However, we are expecting these trees to produce great amounts of seed in excess of what it is naturally possible for them to do year after year. With the exception of occasional cone and seed destruction by climatic or pathological factors, insects are the main destructive agents. From our preliminary observations it appears that we can expect little assistance from natural control in keeping destructive cone and seed insects in check. As an alternative, serious consideration should be given to chemical control of these important insect pests if the harvest of pine seed of the quality and quantity desired is to be achieved.

INOCULATION TECHNIQUES IN STUDIES OF RUST RESISTANCE

by

F. F. Jewell, Pathologist
Southern Institute of Forest Genetics
Southern Forest Experiment Station, Gulfport, Mississippi

As the title listed in the program denotes, this subject is a rather broad one. To cover it thoroughly would take up far too much time here. Also, due to my rather limited experience in this field I don't feel qualified to discuss all the various aspects associated with it. Rather, the discussion will be limited to our work along this line which was started very recently.

In any research program in which disease resistance of plants is concerned, some means of testing for such resistance is required. There are, of course, depending on circumstances, several different methods which can be employed in resistance testing. However, in general, these can be divided into three broad groups. One group involves resistance testing under field conditions where dependance is placed on nature to provide proper inoculum and conditions suitable for infection of the experimental plants. In contrast to this is testing under artificial conditions where plants are subjected to concentrated amounts of inoculum under controlled conditions thought most suitable for infection. Usually, such testing is more severe than would occur under natural conditions. The third group would include methods combining in proper balance, both field and artificial resistance testing. There are, of course, disadvantages and advantages for all three groups. However, we believe that combining field and artificial testing best serves most purposes for the most accurate judging of results. This is the assumption under which the disease resistance program at the Southern Institute of Forest Genetics has been started. Here research has begun to develop resistance among species of Southern pine susceptible to <u>Cronartium</u> <u>fusiforme</u>, commonly known as fusiform rust. This is a heteroecious rust with its aecial and pycnial stages on pine and the unredial and telial stages on various species of oak.

Our initial efforts were aimed toward developing a method of inoculation by which large numbers of selected progenies could be tested simultaneously under controlled conditions. In April 1956 inoculation experiments were carried out on slash pine plants of two ages; 30 day old nursery seedlings and 1-year-old potted plants.

For the nursery seedlings, bulk slash seed was sown in six 4' x 4' nursery bed sections at 60 seed per square foot. Four of these sections were used for inoculation and two were set aside as checks, receiving no inoculum other than from natural sources. At 24-30 days of age the seedlings were inoculated under canvas tents of two types; a single frame tent and a double frame tent. High humidity was maintained with a water mist. Inoculum was in the form of small oak branches with telial-bearing leaves attached, inserted into the bed soil so the leaves formed a partial canopy over the seedlings.

Slides of Inoculation Tents

The seedlings were covered by each tent for about 72 hours. When the tents were removed after this period small water droplets were present on the needles of the seedlings and the bed soil was quite moist. This indicated that a high humidity had been maintained inside the tents as no water had been added to this space for 64 hours. At the end of 6 weeks small red spots and bands were noted on the cotyledons of a large number of the inoculated plants. Hand sections through these spots and microscopic examination showed typical Cronartium mycelium present in all sections. This was followed by a more thorough sampling of the spotted needles and rust mycelium was found in all cases. It was then concluded that these spots were probably the early symptoms of Cronartium infection.

Slides on Needle Spots

At this time the bed density was reduced to 30 seedlings per square foot. All seedlings were examined and the percentage with these spots were 69 and 98 in the beds inoculated under double tents, 85 and 89 in those inoculated under single tents, and 5 for both check lists. Still we were not sure the needle infections would result in the typical stem swelling associated with fusiform rust. In December, eight months after inoculation, 71 and 87% of the seedlings in double-tent beds, 74 and 86% of those in single-tent beds, and 2% in each check bed showed typical fusiform swellings on the stems. Thus the percentage of seedlings with stem infections corresponded closely with the percentage of seedlings showing spots at 6 weeks.

Slide - Infected Seedlings at 5 Months of Age

This indicates to us that these spots are rather good indicators of infection and possibly can be used in future work to judge early susceptibility or resistance. At least we know now what to look for.

Inoculation of potted 1-year-old slash pines was successful when the new flush of growth was wrapped in telial-bearing oak leaves and kept moist with or without a cotton covering for 48 or 72 hours. Thirty of 40 plants with the cotton and 21 of 40 without it became infected.

Slide - Inoculation methods used on Potted Plants

Another technique yielding limited success but troublesome to apply was the insertion of telial columns into the new growth stem tissue. Very few infections resulted from this method.

Slide - Single Stem Infection from Cotton and Leaf Wrap
Slide - Multiple Infection from Wrapping Method
Slide - Infection from Insertion and Failure

No needle spots were observed on the infected potted plants, but large purple blotches were noted on the stems in locations now occupied by the swellings. Whether these are indications or symptoms of stem infection is not certain at this time.

The overall results of this exploratory work are encouraging. With what we have learned in this past years' work and with what we hope to learn in the future, we believe we can develop a very satisfactory technique for testing for rust resistance in the southern pines. There are however, many factors that will require further study. What has been mentioned here are the results of one years'work only. We believe these can be repeated, but in doing so, several improvements in the methods will need to be worked out to refine the operation. For example, studies on the placement of inoculum in the seedbed are needed. We need to standardize the inoculum supplied, as to age, locality of collection, and most important, to use the right rust as inoculum. We have two rusts attacking the stems and branches of pine which have primarily the same oak hosts. These rusts must be separated for use in resistance testing. Another fact that required clarification is the time and the conditions of temperature and humidity required by the rust and the experimental plants for successful infection to occur. Also, the most suitable spacing of the plants to be tested is not known.

These are just a few of the problems ahead of us in this work. To work them out effectively will require time, but it is hoped this can be done in the very near future.

INITIATION AND DEVELOPMENT OF FLOWER PRIMORDIA IN SLASH PINE

by

Francois Mergen, Yale Forestry Research Center
John A. Hartford Foundation, Forest Biology Program
(Illustrated with Kodachrome slides)

The pollination and fertilization patterns have been carefully described for several species of the genus Pinus, but a systematic study of the time of flower primordia initiation, and a detailed morphological description of the rudimentary male and female flowers has not been made for pines. There has been a number of experiments which attempted to manipulate the flowering mechanism in pines by nutritional and other means. The timing of these treatments could only be guessed at for little precise information was available on the initiation of flower primordia. In applying the injury treatments and the fertilizer applications to the slash pine trees while I was at Lake City, I had little to rely on to decide on the time of application. It is of great importance that the flowering and fruiting cycles of our important forest tree species be known so that cultural methods can be developed to produce flowers in a more regular pattern in selected trees, and in trees growing in seed production areas and seed orchards.

The present paper presents the results of a study which was made to determine the time of male and female flower primordia initiation and the subsequent floral development of these structures on slash pine trees growing in the Lake City, Florida area. For the microsporangiate strobili, or the male catkings, the steps leading to the formation of the tetrad division of the microspore mother cells are described, and the description of the megasporangiate strobili or the female conelets, includes the various phases from flower primordia initiation to the formation of the ovule on the ovuliferous scale.

Materials and Methods

The buds for this study were collected at weekly intervals during the period from May 1953 to January 1954, from slash pine trees growing in an open old-field stand on the Olustee Experimental Forest in Baker County, Florida. The trees which were used had well-developed crowns and the collections were made from the distal branches in the upper part of the crown. Collections were restricted to trees which were flowering actively during the years prior to the study, and buds were collected only from branches which bore both male and female flowers in the previous two years. A weekly collection consisted of five buds each from five trees[1/]. Formalin-acetic acid-ethyl alcohol (FAA) was used

1/ The collection of the buds was started while the author was stationed at the Lake City (Fla.) Research Center of the Southeastern Forest Experiment Station. The author thanks P. E. Hoekstra and E. E. Miles for carrying out some of the field collections.

were larger in diameter, had a denser cytoplasm and accepted more stain than the surrounding cells.

The midrib or main axis was well marked by vascular bundles which connected the upper part of the rudimentary microsporophylls with the vascular system of the developing branch. Also, the outer layer of cells surrounding the microsporophylls, with the exception of those cells in the area of the sporogenous cell activity, had become suberized and accepted the safranin stain. This monocellular layer eventually forms the "epidermis" which surrounds the microsporophylls.

The sporogenous tissue enlarged considerably during the month of November. In some of the microsporophylls which had formed first, the microsporangia appeared to be fully developed by the early part of December. By December 14, the pollen sacs were filled with well-defined microspore mother cells which originated from the sporogenous tissue. They were surrounded by a tapetal layer consisting of three or four layers of cells. Also, at this stage a resin canal, complete with epithelial and sheath cells, had formed at right angles to the stalk close to the scalelike terminal appendage of the microsporphylls.

In the Lake City, Florida area the male strobili passed the "winter" in the microspore mother cell stage and the reduction division occurred during the middle of January. At the time the catkins were about 1.5 cm in length. Depending on weather conditions subsequent development from this stage on is very rapid. Catkins collected within three days from the same tree during the latter part of January, showed all stages from the microspore -mother-cell stage, through the tetrad stage, to the second vegetative division of the microspore.

B. Formation of the pistillate strobilus. The primordia for the female strobili are not laid down as early as those of the male catkins. The first evidence of pistillate flower primordia were observed during the latter part of August. They became first noticeable as slight protuberances in the axis of a developing cataphyll. This mass of cells was pointed, and vascular tissue in the central axis started to differentiate without any delay. Also, the protecting bud scales started to develop in a similar fashion as was described for the male flower. They continued to envelop the protuberance in a spiral manner until a tight hood had formed. By October 18, a hood of up to 12 layers of scales was observed around some of the primordia.

During this period of growth, there was pronounced differentiation into vascular tissue in the midrib area, and the apical part of the primordia assumed a more flattened appearance. The vegetative stalk also elongated considerably and formed xylem and phloem elements, and both longitudinal and horizontal resin canals were laid down.

The primordia of the bracts started to form during the latter part of October and were accompanied by active meristematic activity in the basal part of the rudimentary pistillate strobilus. They appeared as lateral outgrowths or papillae and progressed in an acropetal direction. They were as a killing and fixing agent. The buds were dehydrated in an alcohol-chloroform series and embedded in Tissuemat (56°C). Some of the longer bud scales were clipped off just before embedding to facilitate the sectioning. Serial sections were cut on a rotary microtome at thicknesses ranging from 10μ to 15μ. Four types of staining techniques were used: haematoxylin and safranin; safranin and fast green; tannic acid, iron chloride, safranin, fast green; and haematoxylin and aniline glue. Smears of the latter developmental stages were stained with acetocarmine. The sections were mounted in Permount for future reference.

Results

A. Formation of staminate cone. In the buds collected during May and early June no evidence of staminate strobili primordia was noticed and the apical point of the bud was somewhat rounded. In some of the collections the apical point had elongated considerably and by June 11 had assumed a more pointed shape. Cell division was very rapid at this stage as evidenced by the number of mitotic figures in the apical area. In one of the buds collected on June 25, a distinct swelling could be observed in a axil of a nearly formed cataphyll before the cataphyll had reached its full size. The tissue in these mounds of cells was undifferentiated during the early stages but by July 12 a row of vascular tissue was evident in the lower vegetative areas of the primordia. By July 19 differentiation of vascular tissue had progressed toward the apical portion of the rudimentary catkin. During the latter part of July the lower meristematic area started to differentiate hood scales which began to envelop the rudimentary strobilus and by September 13, up to eight layers of scales had formed. The innermost layer pushed between the primordia and the previously formed scales, curving inward near the apex, and formed a protective arch. These scales have a thick epidermis, especially in the outer surface, which becomes suberized early during the development. Several of the scales which formed last, the involucral scales, elongated only slightly. At this stage the strobili primordia had formed a protective cuticle and this hood should prevent excessive evaporation from this succulent structure. During this period of growth, the only change recognizable within the primordia proper was a broadening, and a lengthening of the axis of the rudimentary catkin. Additional meristematic activity became pronounced during the latter part of September. It resulted in a lengthening of the axis of the strobilus and the rudimentary microsporophylls started to differentiate at the base. During the early stages they are similar in appearance to the primordia of the hood scales and their axis is at a right angle to the main axis of the strobilus.

During the remainder of the month of October differentiation of microsporophylls progressed towards the apex and the first formed microsporophylls started to turn upwards. This was the result of a symmetrical growth, namely cell division, both periclinal and anticlinal, was more rapid in the abaxial area than in adaxial surface. In several of the buds collected on October 4, sporogenous initials had been laid down in the abaxial part of some of the early microsporophylls. In several of the sections, the sporogenous initials had already given rise to sporogenous tissue. These cells formed by both periclinal and anticlinal cell divisions. This development period continued for a period of about three weeks. After this time the developing strobili were covered with slight protuberances which were arranged in a spiral manner. Also, vascular tissue had formed in the rudimentary bracts of the lower region. This tissue was connected to the vascular elements of the midrib area. During the later stages of growth, cell elongation and cell division was more rapid in the lower region, causing these bracts to curve slightly upwards towards the apex of the strobilus. The ovuliferous scale arose in the axil of this bract and appeared at first as a conical mass of cells during the later part of December. Initiation of these primordia also progressed in an acropetal direction. Buds collected on January 6 showed well-defined mounds of cells which were subtended by the bracts. Vascularization in the midrib and as well as in the bracts had progressed rapidly. Also, the epidermal cells of the bract began to cutinize. There was distinct cell organization in the upper inward part of the ovuliferous scale. Rapid cell division, as evidenced by a large number of mitotic divisions resulted in the formation of a protuberance. This was the first indication of the organization of an ovule. In this ovular swelling were contained the sporogenous initials which will give rise to the sporogenous tissue. At this stage, which is about three weeks before pollination, the uncompleted strobilus proper was 4-4.5 mm in length, while the total length of the structure including the stalk and the hood was 12 mm. The strobilus is still completely enclosed by the interlocked hood scales and is whitish in color.

Discussion

The microsporangiate strobili were initiated during a period of about six weeks, while that of the female strobili was limited to about two weeks. In the samples studied there was only one distinct row of female strobili.

The period of initiation and development as given was applicable only for slash pine trees in the Lake City, Florida area for that particular year. The climatic and site conditions within the natural range of slash pine are varied and therefore affect their growth. As a result the period of initiation will fluctuate not only from year to year but will also vary over the range of the species. Therefore, the results of this study can only be applied with modification in another area.

The information obtained will be valuable not only in research work with this species but also should be helpful to the forest manager. The research forester can use these results to time the application of flower induction trials, to time the pruning of experimental trees in seed orchards so that he will have a large number of potential flower bearing branches, and to relate environmental and biotic conditions to the production of flowers. To the forest manager on the other hand these results will be of help during the timing of his cuts to convert a stand into a seed production area, or during intermediate fellings which are aimed at bringing about an increased seed crop.

STIMULATION OF FLOWER AND SEED PRODUCTION IN SLASH PINE

by

P. E. Hoekstra, Southeastern Forest Experiment Station
Forest Service U. S. Department of Agriculture

A greatly stepped-up reforestation program in the Southeast has emphasized the problems of obtaining an adequate seed supply, which in turn means sufficient annual quantities of the highest quality seed obtainable. To enhance the quality of slash pine seed, seed-production areas and seed orchards have been established, the former being thought of as a temporary measure until the seed orchards come into full production. Although release in itself usually increases seed crops, additional measures are considered necessary to stimulate premature and abundant flowering of slash pine in seed-producing areas. Work on other species of pine has indicated that stem-injury, root-pruning, and application of fertilizer are effective in this respect.

The results of two studies on flower stimulation of slash pine are presented here. In both studies the treatment effects were evaluated in terms of female flowers rather than cones so that any subsequent damage to cones by destructive agents would not complicate interpretation of the results.

Study I

In this study an attempt was made to stimulate 6-year-old planted slash pine to flower prematurely. The following treatments were applied in April 1954: partial girdling, strangling by wire, root-pruning, and fertilization in amounts of 5, 10, and 15 pounds per tree of a 3-12-6 mixture. During the latter part of February 1955, all the female flowers were counted on the upper three whorls of each tree.

Only 1 tree in the unfertilized plots produced flowers, versus 23, 26, and 31 flowering trees in the fertilized plots. Only 3 trees bore flowers in the plots which received no stem-injury, versus 22 and 56 flowering trees for the strangled and girdled plots, respectively. The differences were even greater in terms of flowers produced by treatment. The following conclusions were made from this experiment:

1. Application of fertilizer was effective. An increase in the amount of fertilizer beyond the initial 5-pound application, however, had no added effect.

2. Stem-injury also had a stimulating effect but the effect of partial girdling was much greater than that of strangling by wire.

3. Root-pruning substantially increased the number of flowering trees.

In September 1956, all mature cones were harvested in this experiment. Only 32 percent of the 755 flowers counted in 1955 had developed into mature cones.

Study II

The second study attempted to stimulate greater flower production on a 20-year-old seed production area already in production. Treatments included partial girdling and application of fertilizer. Two fertilizers were used, 7-7-7 and 3-18-6, at the rate of 20 and 40 pounds per tree. The treatments were applied in April, 1954. During the latter part of February, 1955, all buds and all female flowers were counted on a sample branch from each tree. The total number of flowers per branch was divided by the total number of buds to arrive at the number of flowers per bud.

The following conclusions were made from the study:

1. Applications of fertilizer resulted in an average flower production increase of 59 percent.

2. The 7-7-7 fertilizer with its high nitrogen content provided a greater stimulus for flower formation than did the 3-18-6 with its high phosphorus content.

3. Girdling the trees increased the flower crop significantly and the effect was independent of dosage and type of fertilizer.

A second flower-count, one year later, showed that these effects persisted, with the exception of those due to the type of fertilizer.

Summary

Root-pruning, partial girdling, and fertilization proved to be effective treatments in inducing 6-year-old saplings to flower prematurely. A combination of these three treatments caused 30 percent of the saplings to flower; less than 1 percent of the untreated saplings flowered. On 20-year-old, cone-bearing trees, application of 20 pounds of 7-7-7 fertilizer raised the flower crop 120 percent; girdling increased it 70 percent. A combination of these treatments resulted in 180 percent more female flowers. Similar differences in percent were noted a year later.

The poor harvest of mature cones in Study I led to an examination of breeding records at the Lake City (Florida) Research Center. These records showed that only 30 to 45 percent of the pollinated flowers yielded mature cones. Counts on the complete 1956 cone-crop of 13 trees, with an average of more than 1 bushel per tree, showed that only 55 percent of the cones were sound. These figures indicate that the full benefits of flower stimulation will become available only with adequate cone protection.

REASONS, PROBLEMS AND RESULTS OF GROWING A LARGE TREE IN A GREENHOUSE

by

Thomas E. Campbell, Forester
A. J. Hodges Industries, Inc.
Many, Louisiana

In the fall of 1953, when our greenhouse plant was still in the planning stage, it was decided that an addition was needed to house a seed-bearing size tree. Dr. Bruce Zobel suggested this addition and gave as his reason the following:

> "By having a tree growing under conditions which temperature and light can be controlled, we believe we can encourage flowering in the desired direction of the researcher. By means of grafting various and sundry scions, we can study numerous species and hybrids under the same conditions in the same room".

For this sound reason, the "tall house" was built. It measured 25 feet square by 22 feet high.

In the selection of a tree for this building, several factors had to be considered:

1. Size, quite obviously, was the most important. One must be chosen that would not outgrow its confines in two or three growing seasons.
2. It must be healthy, but preferable a slow grower.
3. Sonderegger pine (*Pinus sondereggeri*) was preferred due to its larger branches. This would make grafting simpler. Loblolly (*Pinus taeda*) was our second choice.
4. A prolific seed producer was desired.
5. It must be growing in a tight soil to make moving possible.

A loblolly pine was eventually selected, the cone bearing quality having to be sacrificed for size. Its measurements at the time of moving were 15.3 feet tall, 8.6 feet crown width and 4.2 inches dbh.

The tree was moved in March, 1954. The original shock of transplanting, plus terrific transpiration in the glass house, was almost too much. Feeder roots had not grown into the fill dirt and water would not penetrate the root ball in sufficient quantities, so it was dying from a lack of water. Even though several one gallon cans with holes in the bottoms were buried in the root ball to force watering, by August the tree seemed doomed.

At about this point, two of my former professors from L. S. U., with whom we are cooperating on other projects, came by on an inspection tour. Professor A. B. Crow suggested a haircut to cut down on transpiration, and a haircut it got. All the needles were cut back to the basal sheaths except a very small cluster on each twig tip. This haircut proved to be the turning point in its crisis.

Our next problem came in the form of a pine leaf scale. While playing with several recommended treatments, this pest almost got the upper hand. Eventually, a solution of three rounded tablespoons of Wettable Powder, 25% Malathion, in two gallons of water was used, adding an adhesive agent to make it stick. By spraying heavily once each week, the scale was finally brought under control.

The menial weekly task of pulling Bermuda grass out of the soil was overcome by a three inch layer of peat moss underneath.

The tree is sprinkled twice weekly and thoroughly watered once each week by means of overhead sprinklers during the summer months. In winter, it is sprinkled weekly and watered well twice per month.

Ammonium Nitrate is applied at the rate of five pounds per month, March through September.

In February, 1955, Bruce and I put 15 grafts of six different hybrids on the tree. All scions were from the Western Institute of Forest Genetics, or hybrids that Bruce had made of southern pines in East Texas. As of this writing, fourteen still survive.

More grafts were put on in February, 1956. Two hybrids and 23 separate species were used for a total of 37. At present, only 16 of the 1956 grafts survive, leaving a total of 30 successes now on the tree.

A list of those attempted, by year, and the survival is attached.

Two types of grafts were employed. Principally, side-bottle grafts were made, using test tubes to supply water until the union was complete. The other type was a side graft, but in using seedlings, the roots were left intact and enclosed in a polyethlene bag of wet spagnum moss.

The latter type worked very well, but in some instances formed a large swelling at the end of the scion after the roots were cut away. This seems to be caused by an excess of food material manufactured by the scion and not used by the stock, thus being more or less stored in the swelling.

One of the many interesting phenomena of this peculiar pinus is an individual graft. A Shortleaf (Pinus echinata) X Sonderegger pine (Pinus sondereggeri) hybrid was grafted in 1955 with the roots in moss. This seedling was perhaps 12 inches tall and the root collar diameter half the size of a cigarette at grafting. At present, the diameter of the scion

ATTACHMENT NUMBER 1
GRAFTS ON HODGES GREENHOUSE TREE

Applied February 17, 1955	12/12/56
Lot 3 (Pinus echinata X Pinus elliottii elliottii)	Living
Lot 4 (Pinus echinata X Pinus elliottii elliottii)	Living
Lot 7 (Pinus echinata X Pinus elliottii elliottii)	Living
Pinus echinata X Pinus elliottii elliottii	Living
Pinus echinata X Pinus sondereggeri	Living
Pinus taeda (1) X Pinus elliottii elliottii	Living
Pinus taeda (1) X Pinus elliottii elliottii	Living
Pinus taeda (2) X Pinus elliottii elliottii	Living
Pinus attenuradiata (P. attenuata X P. radiata)	Living
Pinus attenuradiata (P. attenuata X P. radiata)	Living
Pinus ponderosa X Pinus apacheca V7	Living
Pinus ponderosa X Pinus apacheca V7	Dead
Pinus ponderosa 1577 X Pinus apacheca	Living
Pinus ponderosa 1577 X Pinus montezumae	Living
Pinus ponderosa 1577 X Pinus montezumae	Living

Applied February 29, 1956		12/12/56
Pinus arizonica	(S.W. & Mexico)	Living
Pinus canariensis	(Canary Islands)	Dead
Pinus clausa	(Florida)	Living
Pinus clausa	(Florida)	Dead
Pinus coulteri	(California)	Doubtful
Pinus densiflora	(Japan)	Living
Pinus edulis	(SWUS)	Dead
Pinus elliottii densa	(Florida)	Dead
Pinus elliottii densa	(Florida)	Dead
Pinus flexilis	(N. Mexico)	
Pinus flexilis	(N. Mexico)	Dead
Pinus halepensis	(Mediterranean)	Dead
Pinus jeffreyi	(California)	Dead
Pinus laricio	(Mediterranean)	
Pinus laricio	(Mediterranean)	Dead
Pinus montezumae	(Mexico)	Dead
Pinus montezumae	(Mexico)	Dead
Pinus mugho	(S. E. Europe)	
Pinus mugho	(S. E. Europe)	Dead
Pinus muricata	(California)	
Pinus patula	(Mexico)	
Pinus pinaster	(Mediterranean)	
Pinus pinaster	(Mediterranean)	Dead
Pinus psuedostrobus	(Central America)	Dead
Pinus radiata	(California)	Dead
Pinus sabiniana	(California)	

February 29, 1956 (continued)

		12/12/56
Pinus sabiniana	(California)	Dead
Pinus serotina	(SEUS)	
Pinus serotina	(SEUS)	
Pinus thunbergii	(Japan)	
Pinus thunbergii	(Japan)	
Pinus virginiana	(Tennessee)	Dead
Pinus virginiana	(Tennessee)	Dead
Pinus ponderosa 4B59 X Wind		Dead
Pinus ponderosa 4BF9 X Wind		Dead
Pinus taeda (1) X Pinus elliottii elliottii (DAA)		Living
Pinus taeda (2) X Pinus elliottii elliottii (N)		Living

above the union is 1.1 inches, the length of the grafted branch is 5.5 feet and a breadth of five feet.

In September, seven months after grafting, five cone flowers put in their appearance. These lasted until just before opening for pollen, then all died. This has been the only graft to produce flowers up to this time.

The tree itself seems completely out of harmony with the seasons as far as flowering is concerned. Loblolly pine in our section normally flowers during the first half of February. In early August of 1956, apparent flower buds emerged, but were thought to be vegetative growth. Examination two weeks later proved them to be seven true cone flowers. Bags were put on these for controlled pollination and, for no apparent reason, they were all dead eight days later.

At this point, I might add that along with the cone flowers, nine pollen catkins appeared, but never reached maturity.

A close examination on December 12, 1956, for any new signs of flowering, produced a conelet in the very tip of the tree. Though this flower was not definitely marked in August, I strongly believe it to be one of the same group due to its location and appearance. Its location is very difficult to observe, and the conelet is much smaller and greener than normal loblolly cones outside the greenhouse. To strengthen my belief, the seven flowers which had been bagged, plus three other dead ones not previously seen, were still in evidence.

We had hoped to have a normal tree producing seed in a normal manner in our greenhouse, except for any forcing we may attempt at one time or another. Instead, with no attempt to change anything, we have something going on which we can't explain. Although we do realize it isn't normal for a pine tree to be enclosed in glass, protected from all the natural elements and growing under strange conditions, we hadn't expected such strange things as these to happen. However, we are eagerly looking forward to any future phenomenon that our pampered pinus will put forth.

HANDLING VALUABLE NURSERY STOCK

by

E. G. Wiesehuegel, T. G. Zarger and J. F. Hatmaker
Tennessee Valley Authority, Division of Forestry
Relations, Forestry Investigations Branch

The Norris Experimental Nursery, located below Norris Dam and operated by TVA since 1933 as part of its program in watershed protection and development, has provided significant information on the production of improved trees.

During the first twelve years a diversity of trees and shrubs of 100 species, totaling 1,035,000 trees, were produced. Stock was used in wildlife, reforestation and erosion control plantings. Between 1940 and 1943 methods were developed for production of straight-stem black locust stock by root propagation. Since 1939 emphasis has been on producing propagated selections of black walnut and other nut trees under sound nursery practices. Sixteen thousand Thomas black walnut were raised over an 11-year period for demonstration plantings. Promising varieties of black walnut, Chinese chestnut, and filbert averaging 500 grafted or budded trees per year have been grown for use in experimental plantings throughout the Valley. That these are valuable trees is attested to by the fact that commercial nurseries now charge $2.50 to $8.00 each for similar stock. Our first pine grafting studies were begun in 1950.

The nursery is situated on the Clinch River below Norris Dam on a colluvial bottomland soil most suitable for growing hardwoods. The cultural practices described are for out-of-door production, since there are no greenhouse facilities. A shaded cloth house was used for some of the pine propagation studies. A refrigerated cold storage room in the basement of the nursery building has proved a most effective and necessary adjunct to program needs.

Seed Collection and Treatment

Large seed are best for understock production because they produce more vigorous and larger seedlings than small seed. In selecting black walnuts for seed, kernel weight should be considered rather than nut size alone, for nuts with larger-than-average kernels result in seedlings of better caliper and height (2). Kernel weights below 3.0 grams should not be used for root stock production. Uniformity of seedlings is also desirable in nursery practice and can more readily be obtained from use of a single seed source than from mixed seedlots where a range in seed size is encountered. These relationships no doubt hold true for the other nut tree species.

Black walnuts should be collected in late September or early October, hulled immediately, and air-dried on wire trays for one week. The seed is stored dry in an unheated building in bulk lots until time of fall planting or stratification. Preference is given to fall planting in November. Seedlings from fall planted nuts emerge sooner and total germination is greater than for indoor stratification in a cold room. Nuts stratified outdoors in the fall for spring planting germinate as readily as fall planted nuts. Pecan, hickorynut, filbert and heartnut seed are handled the same as black walnut. Persian walnuts are stored dry for spring planting. The seed is soaked in water 10 days before planting in early April.

Chinese chestnut seed is collected in September, husked and partially air-dried on screens for one week. The chestnuts are treated for weevils, the larvae of which feed on the plant embryos. The nuts are placed in a five-gallon lard can and a jar lid half-filled (20 cc) with carbon disulphide is laid on top of the seed. A tight lid is placed on the can, which is kept closed for 24 hours. The seed must then be aired briefly before storing dry in either one- or five-gallon cans, depending on whether storage is in a refrigerator or cold room at about 34°F. In storage, the can lids are closed completely only after condensation on the inside of the lid stops accumulating. Fall planting is preferred to cold storage and spring planting. In either case seed must not be allowed to become dry or germination failures occur.

Oak acorns, like chestnut seed, must also be treated for weevils. Fumigation procedure is the same as for chestnut seed. Acorns of the white oak group must be planted immediately after collection, since the seed soon sprouts. Other oak species can be either stratified outdoors or in a cold room for spring planting or planted directly in the nursery in the fall.

Honeylocust seed matures in early September, although pods remain on the trees much longer. The seed are removed from the pods and stored dry. Stratification is from 60 to 90 days. Black locust seed is handled like honeylocust seed, except only a 30-day stratification period is needed.

Yellow-poplar seeds mature by middle October (10). The best seed can be obtained by shaking the tree limbs and collecting the seed on large sheets or a canvas spread beneath the tree. The heavier seeds shake out more readily and fall together to the sheets below. The best time for collection is on calm days, especially early morning. The seeds with wings are stored in a dry room at air temperature for almost immediate stratification (9).

Redcedar berries are immediately pulped after collection and the seed is cleaned with a strong soap or household lye solution to dissolve any remaining resin. After drying, the seed is stored in sealed containers in a cold room (9). November planting is simpler and as satisfactory as stratification, which requires storage in sand in a cold room, plus a 30-day period outdoors, to allow for alternate freezing and thawing.

Seeding and Planting Methods

Walnuts for understock production are planted in the nursery in 42-inch rows and six inches apart in the row. The seed is covered with 2-1/2 inches of soil to allow for a 2-inch soil cover after settling. Black walnuts planted at this depth give earlier germination and hence produce larger seedlings than nuts planted at a 3 or 4 inch depth (2). Germination percent for good seed (90 percent filled nuts) will average 75 percent. About one-fourth of the trees must be thinned to give a desired spacing of a tree to a foot of row.

Seedbeds are used to produce 1-0 oak, black locust, honeylocust, yellow-poplar and redcedar seedlings. Large seed like the oaks are planted in a six-by-six-inch spacing in the seedbed. A screen wire (16-mesh) may be placed on the floor of the seedbed to stop tap-root development and encourage secondary root growth.

The seedling rate for the other species is based on seed quality except for yellow-poplar, where weight of seed is taken into account (9). If stock for grafting purposes is needed, 1-0 trees are lined out in the nursery row the following year.

Black locust seed sown as late as June will still produce plantable stock in one year (9). Small lots are sown in cross rows six inches apart. Seed is covered with 1/4 to 3/8 inches of soil.

Honeylocust seed is removed from stratification and planted as soon as danger of frost is past. The seed is covered with 1/2 inch of soil and can either be broadcast or sown in rows.

Yellow-poplar seed is broadcast by hand in March or early April (9). The seeds are pressed into the soil with a roller and covered with one inch of sawdust or compost.

Redcedar seed is sown in 6-inch cross rows and covered with 1/8 inch of soil. The beds are covered with plastic sheets until germination begins in the spring.

Care During Growing Season

Cultural practices are generally the same for all hardwood species. Nursery rows are cultivated with power garden equipment. Spacing of trees in the row will allow for hoe cultivation. The trees are watered about four times during the growing season with a portable, 3-inch aluminum pipe sprinkler system. Seedbeds require some early weeding but tree growth soon shades out weed growth.

Few insect and disease problems are encountered with hardwood nursery stock but if once detected they should be controlled immediately. Look for leafhopper to attack the underside of chestnut leaves and midge to attack the upper surface of the leaves. DDT controls the leafhoppers and Malithon or nicotine sulfate, the midges. These sprays have been found effective for most of the problems that occur. Examples are the cottonwood leaf beetle and black walnut lacebug. Aphids are easily controlled with nicotine sulfate. Lead arsenate continues to be an effective control for leaf-chewing insects.

The common fungicide, Bordeaux mixture, is used effectively in control of leaf spot and other diseases. Phomopsis blight on redcedar seedlings can be controlled by constructing well-drained seedbeds and roguing out infested seedlings. Semesan sprays have not been too successful in controlling the blight at Norris Nursery.

In recent years many new insecticides and fungicides have entered the market. Some are proving very effective, while others must undoubtedly be tested further. Always follow the manufacturer's directions in mixing and applying chemicals.1/

Vegetative Propagation

Named varieties of black walnut and other nut trees are propagated by budding and grafting (1). Limited production by commercial nurseries and erratic survival of buds and grafts are reflected in the cost of stock. A grafted nut tree will cost several times the price of a budded peach or apple tree. The need for large numbers of improved nut trees for the cooperative test planting program led to development of economic practices in improved nut tree production. Main savings include the elimination of seedbeds and operations of lifting, grading, and lining-out seedlings. Growing time in the nursery was reduced by one full year.

Black walnut and most other nut tree seedlings reach sufficient caliper for propagation in the first growing season, provided attention is given to proper seeding and cultural practices. Understock should be at least 3/8" in caliper by August when they are budded. Much of the stock is usually 1/2-inch to 3/4-inches in caliper by then. A Jones patch-budding tool, used to remove a rectangular patch of bark from the understock and a similar patch with a bud from the scion, works exceptionally well. Width of the patch-bud is 1/2-inch but the tool can be modified to cut a 3/8-inch patch.

Three-eighths-inch strips of waxed muslin cloth are used to tie the buds in place. A dab of wax at the top of each wrap prevents them from loosening on the understock. Within three weeks the buds have grown

---

1/ Formulae for some of the common insecticidal sprays are: Malithon at 2 tablespoons per gallon of water; DDT wettable powder (50% DDT) at 2 teaspoons per gallon; and nicotine sulphate (40% nicotine) at 1 teaspoon per gallon with addition of soap for a spreader.

tight. The wraps are then removed to prevent girdling of the seedling.

During the dormant season, a U-shaped digger blade is run under the budded seedlings to check taproot development. When growth commences in the spring the stocks are cut back to the top of the patch bud. Sprouts that develop on the understock are kept removed. This forces all new growth into the patch bud. Buds are staked and tied to produce straight, well-formed trees. Budded trees average 20 to 30 inches in height at the end of the season.

Understock on which buds fail to "take" can still be utilized. They are grafted at the time budded trees are "cut back" in the spring. A modified-cleft-graft has been used most, although the whip-and-tongue graft can also be employed. The understocks are cut back to 3 inches above the groundline two weeks before the grafting is done to allow the sap flow, characteristic of black walnut, to cease. This profuse "bleeding" would "wash out" and sour the grafts. The grafts are tied with raffia and then waxed with a preparation made of beeswax (6 pounds), rosin (16 pounds) and linseed oil (1 pine). When the grafts begin growth all but the dominant shoot are removed from the scion.

The trees, both budded and grafted, are lifted in late fall. A digger blade pulled by a heavy duty farm tractor is run under the trees to facilitate lifting operations. Trees are root pruned of damaged and heeling-in bed. Stock to be held until spring is removed from the heeling-in bed to the cold room.

An example of propagations of Thomas black walnut made in a season were 1,165 cleft-grafts and 6,470 patch-buds. Survival record for 12 seasons on cleft-grafting of Thomas was 58 percent and for 10 seasons on patch-budding Thomas was 50 percent (14). A better quality tree can be produced at lower cost by patch-budding than by grafting. Propagation trials (1) with chip, shield and patch-budding in the spring, bench-grafting, and modifications in cleft-grafting did not improve on the practice of patch-budding in summer and cleft-grafting in the spring. The U.S. Department of Agriculture Farmers' Bulletin 1501 constitutes a most useful reference for anyone interested in propagating nut trees (8).

A source of scionwood of promising nut tree selections and varieties has been developed at nearby locations by establishing orchards, arboretums and topworking wild trees. Scionwood for spring grafting is collected during the dormant season from vigorous shoots of the previous year's growth and stored in damp sphagnum moss at 34° F.

For summer budding, bud sticks are collected at the beginning of the day and again after lunch on the day that budding operations are performed. Budwood is obtained from the current year's growth. Leaf petioles are removed with a sharp knife and care is used so as not to injure the bud at the leaf axil. Buds from the base of the budsticks are easier to work and fit on the understocks.

Extreme care is taken to keep scionwood of the numerous selections and varieties from becoming mixed. Trees from which scionwood is collected are mapped as well as permanently labelled in the field. Scionwood is tied in bundles and labelled with wooden wire tags. Labelling in the nursery row is done with redcedar stakes and stamped aluminum labels.

Propagation of some of the nut trees requires procedures differing slightly from those in use with black walnut.

Pecan seedlings can be either budded or grafted, but it takes two years in the nursery row for trees to reach buddable size.

Hickories take 3 to 5 years in the nursery row to reach buddable size. The hickories are generally grafted in the spring, since in patch-budding it is difficult to get the patch with bud free from the budwood without damage to the bud. Bitternut, C. cordiformis, and shagbark, C. ovata, hickory seedlings are more satisfactory for understock than either the shell bark, C. laciniosa, or mockernut, C. tomentosa, seedlings.

Persian walnuts are more easily grafted than budded since the patch buds are hard to remove from the budstick. Understocks used are black walnut and heartnut, J. sieboldiana cordiformis.

All chestnut varieties are propagated by grafting. For speed, the whip-and-tongue graft is best; the saddle graft (inverted cleft-graft) also gives good results. Survival of chestnut grafts has run as high as 95 percent.

Filberts are multiplied by root suckers. Selections on their own roots are planted two feet apart in nursery rows. Trees are left to grow for two years during which time suckers are produced from the roots. Then the entire block of trees is lifted and the new trees of plantable size are separated from the parent clones. Four to six trees with adequate root systems can be obtained from a single parent. Trees may also be produced by root-grafting.

Propagation of straight-stem black locust is by root cuttings. During the winter months roots from trees grown in the nursery row are cut into 4-inch cuttings, bundled in lots of 50 and stored in sand boxes at 34° F. In early spring the cuttings are planted vertically in nursery beds on a 6 x 6-inch spacing or in nursery rows with 3 six-inch rows planted every 42 inches across the nursery block. The cuttings ranging from 1/4 to 3/8 inches in diameter are planted 3-1/2 inches deep with not more than the upper half-inch of the cuttings remaining above the ground line. Boards with pegs are used to mark the position of cuttings while planting. Hand dibbles help to deepen the planting hole to the proper depth and to tamp around the cuttings. Before lifting in the fall a digger blade is run under the trees to sever the roots at an 18-inch depth. The 6 x 6-inch spacing is more satisfactory than either a 4 x 4-inch or 3 x 3-inch spacing with regard to survival, yield of plantable trees and yield of root cuttings.

Honeylocust, Gleditsia triacanthos, is easily budded and grafted. Selection of buds from thornless shoots of thorny trees results in the development of trees free from dangerous and undesirable thorns (3). The technique has application in producing thornless trees bearing pods high in sugar content for pasture tree planting. Commercial nurseries have patented varieties that are thornless and staminate, resulting in a tree much in demand for ornamental plantings. Selections of yellow-poplar for figured wood studies are whip-grafted in the spring after understock has grown in the nursery row one year. Root-grafting is also a very satisfactory method. Potted grafts may be kept in a shade house to develop or the grafts may be planted directly in the nursery. One-year wood is used for scions.

Cottonwood planting stock is produced from stem-cuttings. In the nursery 12-inch cuttings are planted flush with the ground in 42-inch rows and 6 inches apart in the row. The cuttings are made in late winter, stored in boxes in sphagnum moss in a cool cellar until March planting time. During the growing season the trees are watered frequently, especially during dry spells. Cultivation is required during the first two months of growth. Heights of 10 to 15 feet in one season are not uncommon. Stems from the new production are cut off in late winter to make additional stem cuttings for both nursery and field needs. The root stubs, which are also plantable, are lifted following removal of the stems from the trees.

American holly can be successfully rooted under a polyethylene covered frame, using a mixture of sand and peat moss. One-inch softwood cuttings made August to October with a single leaf and bud are plunged into the rooting medium so that one-half to two-thirds of the leaf is exposed. Only occasional watering with a sprinkling can is required to maintain needed moisture. Hormone powder hastens rooting. Holly can also be dormant grafted by the side graft method. A four-inch scion with a few leaves attached works well when the graft union is waxed and the entire graft is covered with a polyethylene bag.

The pines are not as easily propagated as some of the hardwoods. Experimental studies have been conducted for developing techniques for the production of pine clonal material by numerous investigators (5), (7), (11), (12). The report by Mergen and Russell (6) illustrates methods for air-layering, grafting succulent tissue, dormant grafting and in-arching of slash pine. Since the methods described have application in the propagation of other pine species, it is recommended as a reference for anyone beginning work in this field. Zak (13), in a continuation of studies begun in 1947, has attempted to find more practical methods for multiplying shortleaf and loblolly pine.

Investigations by TVA have been concerned mostly with loblolly, shortleaf and white pine (4). Modifications and trials of procedures found successful by other workers have been tested at Norris both in the nursery row and under a shaded cloth house.

Handling of pine seedlings for understocks is the same for all species. One-year-old seedlings, except white pine, which is 2-0, are potted in 3-1/2-inch clay pots with "woods" soil and plunged in sawdust under partial shade. The seedlings are allowed to grow another year for dormant grafting but may be succulent grafted the same spring. In the shade house, watering is required only 2 to 3 times a year, depending on rainfall. Stock that is not potted is lined out in the nursery row.

We find the side-graft very successful for dormant grafting onto potted stocks under partial shade. Dormant grafting may be carried out from mid-January until early April. Success in grafting of shortleaf, loblolly and white pine is dependent on the use of polyethylene film as a cover for the grafts.

Cleft-grafting when the stock and scion are in a succulent condition proves a very satisfactory method with shortleaf and loblolly pine. Grafted trees can be obtained the same year the seedlings are potted. The methods work well in the nursery row if the polyethylene bag is covered with a kraft paper bag to provide shade for the graft. Holes are cut in the paper bag to provide ventilation. May is the best month for succulent grafting at Norris, Tennessee.

Air-layering attempts have not proved too successful. Only a 30 percent survival was obtained with loblolly pine in 1955 tests. Shortleaf and white pine air layers failed to produce roots. In 1956, roots were induced on shortleaf pine in trials of the needle-cluster method of rooting. Failure of air-layered branches to root on trees growing in the nursery may be caused by unduly high temperatures within the rooting medium. Use of reflective insulation around the polyethylene cover may result in better success with air layering.

Loblolly pine and shortleaf pine have been successfully grafted on understock of the following species: loblolly, Jack, Virginia, Scotch, shortleaf, and mugo pines. Graft survival was highest for loblolly and shortleaf pine when they were grafted on understocks of their own species.

Shipping Plant Materials

The proper packaging of trees or scionwood for shipment is important to assure that plant materials will arrive at their destination in good condition. The bulk of the propagated nut trees for use in the variety test program are shipped by parcel post. Stamped aluminum labels are wired to each tree to identify varieties. (In planting, the label is removed from each tree and nailed to a stake placed near the tree.) Trees are tied in lots of 4 to 6 trees by variety with as many as 5 varieties being packaged in a bundle. Damp sphagnum is packed around the roots and this portion of the package is covered with heavy kraft paper. Then the entire package is covered with burlap followed by an outside wrap of kraft paper. The bundles are tied with heavy twine to prevent loosening of trees and loss or damage in transit. Consignees have always reported favorably on the condition of stock on arrival.

For larger express shipments, sisal kraft paper is wrapped around the tree roots and then the entire package is covered with burlap. The burlap is tied and then sewed with cotton cord.

Savings in shipping costs can now be made with the use of nursery wraps made of kraft paper coated with polyethylene plastic. It is important in shipping large trees that the weight of the wrapping material be strong enough to prevent tearing.

In the dormant season, pines are packed root to root with a layer of moist sphagnum placed around the roots. The tops of the trees are left open in wrapping with sisal kraft paper. During the early growing season pine trees can be shipped successfully by packaging the roots in damp moss and covering the tops with polyethylene film.

Shipment of scionwood has been made easy with the use of polyethylene film. However, if plastic film is not available, wrapping the budsticks in a layer of damp newspapers and then covering the package with waxed paper before finally wrapping with kraft paper proves very satisfactory.

Summary

The Norris Nursery was established in 1933 to produce stock for experimental and developmental purposes in TVA's watershed protection program. Early production was mostly seedling trees for wildlife and erosion control projects. Then, as the improved nut and forest tree phase of the program developed, vegetative propagation of clonal plant material became important. Many of the trees propagated were not generally available from commercial nurseries. Methods found successful for producing improved trees of black walnut, black locust, Chinese chestnut, filbert and honey-locust and findings based on lesser experience with cottonwood, hybrid poplar, yellow-poplar and shortleaf and loblolly pine are reported, since they may have application in forest tree improvement programs.

LITERATURE CITED

1. Chase, S. B. 1947. Budding and Grafting Eastern Black Walnuts. Proc. Soc. Hort. Sci. 49: 175-180.

2. ____________ 1947. Eastern Black Walnut Germination and Seedbed Studies. Jour. Forestry 45:661-668.

3. ____________ 1947. Propagation of Thornless Honeylocust. Jour. Forestry. 45:715-722.

4. ____________ and Galle, F. C. 1954. Pine Grafting, A Preliminary Report. TVA Div. of Forestry Relations. Tech. Note 18.

5. Mergen F. 1955. Vegetative Propagation of Slash Pine. Southeastern Forest Experiment Station Paper 54.

6. _________ and Russell, H. 1954. How to Root and Graft Slash Pine. Southeastern Forest Experiment Station Paper 46.

7. Perry, T. O. 1955. A Grafting Technique for Forest Genetics Research. Jour. Forestry 53:33.

8. Reed, C. A. 1926. Nut-Tree Propagation. U. S. Dept. of Agr. Farmers Bul. 1501.

9. Tennessee Valley Authority. 1954. Operations Manual for TVA Nurseries. TVA Div. of Forestry Relations.

10. ___________________________ 1940. Yellow-poplar Seed Collection, Storage and Seeding Practices. TVA Div. of Forestry Relations, Tech. Note 1.

11. Texas Forest Service. 1953. First Progress Report, Forest Tree Improvement Program of the Texas Forest Service. Texas Forest Service Cir. 35.

12. Zak, B. 1955. The Grafting of Shortleaf and Other Pine Species. Southeastern Forest Experiment Station Paper 47.

13. ______ 1956. Experimental Air-layering of Shortleaf and Loblolly Pine. Southeastern Forest Experiment Station Paper 69.

14. Zarger, T. G. 1945. Nut-Testing, Propagation and Planting Experience on 90 Black Walnut Selections. Proc. Northern Nut Growers Assoc. 36: 23-30.

"EVERY SEEDLING FROM SELECTED SEED"

by

D. A. Harkin

In progress now is the largest planting of trees from selected seed ever made in this country. By the end of this planting season West Virginia Pulp and Paper Company will have planted 13,000,000 loblolly and slash pine seedlings - all produced from seed from selected trees. Most of the seed was collected from seed collection areas in plus stands. However, because we expected a poor cone crop this year, it was necessary to collect a two year seed supply last fall. Seed collection areas scheduled for cutting could not supply all of this so some cones were collected from seed trees in reproduction stands - but still from selected trees. The seedlings have been grown for us by the South Carolina State Nursery. Collection of slash and loblolly seed only from selected trees is now established policy. The principle has also been extended to Atlantic white cedar where seed collection areas produce the same benefits as in pine: desirable parentage, abundant and large cones, and large seed of high viability.

We consider seed selection a big step forward in forest management. However, we know that there are all degrees of "selection" of trees and seed. Much more rigid selection than that applied in seed collection areas is possible, so we have really only taken the first step in tree improvement. The next step is to produce seedlings from orchards of rigidly selected clones. To this end the process of selecting and testing superior trees has begun and we have been keeping abreast of the techniques of vegetative propagation. In May, Mr. Easley reported to the tree improvement committee that the results of our first serious attempt at grafting indicated about 40% success. Subsequent losses reduced this to 10%, so we still have much to learn about grafting. With the assistance and guidance of the North Carolina State College Tree Improvement Project, we plan to get started on a grafted loblolly pine seed orchard this year.

Even seed orchards of rigidly selected clones are only considered an intermediate application of genetics to forestry. A further application, perhaps the ultimate, is breeding for specific characteristics. This objective has been pursued in a limited program of controlled pollination since February, 1954. Several hybrids within species and between species are now one year old. The characteristics of one cross are distinct enough to report. Slash pollen on longleaf strobili produced 24 seedlings of which 15 have stems from 1" to 4" long. The other 9 are still in grass stage. Most needles are as long as longleaf but are more delicate than either slash or longleaf. The most successful interspecies hybrid in terms of number of cones successfully pollinated and seedlings produced was loblolly pollen on pond pine. We hope to combine the site adaptability of the pond pine and the form and growth of loblolly for planting in the Pocosin country of Eastern North Carolina. Of course the evaluation of the useful properties of these hybrids will take many years. This is all the more reason for beginning now.

The first major step in the evolution of forest genetics has been accomplished by collecting seed only from selected trees. It would be wasteful to lose the potential in this seed through mediocre nursery practice. The higher value of seed from orchards in years to come will make it even more imperative to get as many plantable seedlings as possible from every bushel of cones. This need to make the best use of seed was an important factor in West Virginia's decision to build its own nursery. Beginning with the sowing this spring we will be able to give select seed the care it deserves.

It has been demonstrated that the harvesting of well ripened cones and careful extraction can produce twice the yield of seed per bushel as is commonly obtained, and at no extra cost. Viability of seed from collection areas has been found to be in the neighborhood of 50% above average. Thus, application of present knowledge can yield three times the number of plantable seedlings per bushel of cones obtained under common practice. Probably lighter sowing in the nursery would result in fewer culls. The seed resource can probably be stretched even further by dividing the seed into several sizes. Small seeds produce seedlings which cannot compete with the larger seedlings in the nursery bed, but in all other respects they are just as good. By sorting seed into several sizes and planting each separately a larger proportion of the seed should produce plantable seedlings.

Recently one lot of seed was divided into three sizes on a crippen, 3 screen, seed cleaner. The small seed contained 23,600 per pound, medium seed 19,300 per pound, large seed 16,300 per pound. Of the total number of seeds, 29% were small, medium 55% and large 16%. The optimum breakdown is not known and will have to be determined by experiment. The number of seeds per pound and the screen sizes used to get this breakdown will probably vary from year to year with the quality of the seed crop. These figures are cited only as an example of the type of size breakdown that can be obtained.

How much genetic improvement can we expect from selected seed? It is impossible to know, of course, but one guide is suggested. We are all familiar with the deterioration of a stand after a high-grading cut. The standards of selection used in our seed collection areas are such that the practice should be considerably more eugenic than high-grading is disgenic. The pendulum of genetic quality is probably swinging back more than halfway. As one who only a few years ago scoffed at the idea of applying genetic principles to forestry, to me this seems like great progress.

GRAFTED SEED ORCHARDS IN THE SOUTH

by

Wang Chi-Wu and T. O. Perry
School of Forestry, University of Florida,
Gainesville, Florida

INTRODUCTION

At the last meeting of the Southern Forest Tree Improvement Conference in New Orleans two years ago, we reported to you the activities of the forest genetics program at the University of Florida. At that time, we were busily engaged in the selection of superior trees. During the two years since then, hundreds of superior trees were selected, ten thousand grafted plants were made with materials from the selected trees, and 15 seed orchards were established in Florida, Georgia, South Carolina and Alabama (fig. 1.).

The credit of this accomplishment is largely due to hundreds of enthusiastic foresters of the eleven pulp and paper companies[1/] that participated in this program. It was through their effort that the superior trees were selected. It was through their effort that the seed orchards were established and maintained. Seed orchards have also been started by other institutions in the Southern states (Hargreaves et al. 1955). We will limit this discussion to our own experiences.

THE SUPPLY AND DEMAND OF SEED.

There had been an increasing demand for pine seeds during the last decade, in which large scale planting was carried out on an extensive scale in the Southern states. In round figures, Florida planted approximately 100 million pine seedlings last year, and Georgia planted about 120 million. Nearly all of them are slash pine (*Pinus elliottii*) and loblolly pine (*P. taeda*). The figure for the eleven Southern states as

---

1/ Brunswick Pulp & Paper Company, Brunswick, Ga.
The Buckeye Cellulose Corporation, Foley Fla.
Container Corp. of America, Fernandina Beach, Fla.
Gair Woodlands Corporation, Savannah, Ga.
Hollingsworth & Whitney Division, Scott Paper Company, Mobile, Ala.
Hudson Pulp & Paper Corporation, Palatka, Fla.
International Paper Company, Southern Kraft Division, Mobile, Ala.
Rayonier, Inc., Fernandina Beach, Fla.
St. Marys Kraft Corporation, St. Marys, Ga.
St. Regis Paper Company, Jacksonville, Fla.
Union Bag & Paper Corporation, Savannah, Ga.

a whole is close to 700 million (Cossitt).

In the thirties and the early forties, a large portion of pine seeds used in the South was supplied by Brownie Wilder. His seeds were collected from a relatively restricted area around Lake City in Northern Florida and adjacent Southern Georgia. The shortage in the seed supply was most keenly felt in the past two or three years. There was an almost total failure in pine seed crops over most of Florida and Georgia at a time when the demand for pine seed was the greatest. To meet the enormous demand of seedlings for plantations, state and private nurseries were forced to procure whatever seeds were available. Conditions did not usually permit them to make selections with regard to the geographic origin of the seeds and the qualification of the seed trees. A considerable portion of the slash pine seeds were collected from a relatively restricted area in Southern Georgia around Homerville. This was one of the few areas in which slash seeds were available in commercial quantities. Genetically this practice is exceedingly significant. Probably never before in human history has the genetic constitution of a tree population been changed by artificial means on so large a scale in so short a time by plantations over extensive areas throughout the Southern states with seedlings from restricted geographic origins. The serious consequences will be evident in years to come.

The capacity of seed production in a seed orchard of grafted superior trees is not known. From the experiences of the 13- to 16-year-old plantations of slash and loblolly pines in Australia planted at 30 by 30 feet spacing (Florence et al. 1956), we can reasonably expect an average of approximately 24 pounds of seeds per acre for slash pine and 33 pounds per acre for loblolly.

If we figure 14,000 seeds per pound for slash and 18,000 seeds per pound for loblolly (U.S. Forest Service 1948) and the viability is assumed to be 75 percent, then we need approximately 300 acres of seed orchard for slash pine or approximately 200 acres for loblolly pine for every 100 million viable seeds.

The 14 seed orchards established in the last year vary in size from two to seven acres. This initial attempt will yield valuable information for the establishment and management of seed orchards on an extensive scale. The 14 seed orchards are scattered in four states. Besides the model seed orchard of the University, there are eight seed orchards in Florida, four in Georgia, one in South Carolina and one in Alabama in the vicinities of the following localities:

Florida: Perry (Buckeye), Yulee (Container, Rayonier), East Palatka (Hudson), Mariana, Bronson and Madison (International), Cantonment (St. Regis).

Georgia:	Brunswick (Brunswick), Statesboro (Gair), Denton (International), Egypt (Union Bag).
South Carolina:	Georgetown (International).
Alabama:	Alabama border west of Cantonment (International).

With the exception of the seed orchard in Gainesville which for experimental purposes was planted at four different spacings from 25 by 25 to 40 by 40 feet, most of the other seed orchards were planted at 30 by 30 feet spacing. This is approximately 50 trees to an acre. For a seed orchard to produce 100 million seeds, according to the above calculations, 15,000 grafted plants are required for slash pine or 10,000 grafted plants for loblolly. We have not solved all the problems related to the grafting or other means of vegetative propagation of selected pines. However, so far as propagation of slash and loblolly pines by grafting is concerned, we are confident that a simple technique and schedule could be developed that would make the propagation by the tens of thousands just a routine matter. We will discuss briefly what we learned by experience in the past years.

THE PROPAGATION OF SUPERIOR PINES.

We made a little over 10,000 grafts in the past three seasons: 437 in the first year (1954-55), 4172 in the last season (1955-56) and 5491 in this season (1956-57). The majority of the grafts were slash pine grafted on slash stock, with a small percentage of loblolly on loblolly or slash stock. The overall percentage of successful grafts for the last season is 64 percent; and the figure for this season is 85 percent. In order to find out the best method and the best time for this operation, several methods had been tried in the first year from December to June. We are glad indeed to report this increase in success over the 1954-55 season when the percentage of successful grafts varied from 21 percent to less than 1 percent.

On more than one occasion, we were approached by interested parties inquiring about the "secret" of our humble success. A detailed record for all the steps of our operation had been meticulously kept from the time the cuttings were collected from the selected trees until the grafted plants were ready to be shipped out for outplanting in the seed orchards. We tried not to make the same mistake twice.

The most important single factor affecting the successful grafting union is beyond doubt the condition of the scion and the stock. A major improvement could be made in the survival ratio by not insistently using dead twigs on dying stocks.

However, all the cuttings used in the past years with only rare exceptions were in apparently good condition. Nevertheless, the percentage of successes varies considerably. Obviously, a successful graft union depends upon a number of factors. Among the factors examined are the age of the tree, the geographic origin, the date of grafting, the grafter, the cold storage of the scion, the type of bags used, the duration of shade, the presence of male or female flowers or conelet, the age and condition of the stock, plant hormones, insecticide, fungicide, pruning and fertilizer.

Even without the help of statistical analysis, we know for sure that among the factors examined, one factor was most significant, in our case at least (Fig. 2). The lack of it, nearly ruined our whole operation. This was the regular spraying of insecticide. The overall percentage of successful grafts for the last season was 64 percent. However, of the 101 clones (1738 grafts) that had not been sprayed with insecticide at an early stage, only forty-two percent were successful. The 169 clones (2434 grafts) that were under regular spraying schedule had a survival percentage of a little over 79 percent, which is close to this season's result.

We found the best result was obtained with fresh material, but cold storage of the cuttings, at above freezing temperature for a short duration of time, which is almost inevitable in large scale operation did not seem to have a serious deteriorating effect on the scions. We have conducted an experiment on the cold storage of cuttings. Successful grafts have been obtained from dormant cuttings that have been in cold storage for more than three months.

One additional factor is so obvious that it is too often overlooked, namely, the man who did the grafting. The bulk of our propagation work was carried out by two men. Each of them used materials of approximately equal number of randomized clones from each of eleven groups of selected trees. The performance of Man A (111 clones, 1687 grafts) was consistently superior to Man B (107 clones, 1632 grafts.) (Fig. 3).

The grafting of superior pines on seedlings in the nursery and in the field, a practice which we carried out only on a limited scale, had yield comparable results as the grafting on potted seedlings. In our program the shipment of thousands of grafted plants to seed orchards in four states, and the free exchange of materials between the eleven participating pulp and paper companies necessitate the use of potted stocks for easy handling.

According to our working schedule, the polyethelene bags are gradually released at the end of the sixth to the eighth week after the grafting. Most of the mortality occurs before this critical period. Two to four weeks after the removal of the bags, the plants are moved from the lath house to the open field under regular irrigation; and they are now ready for out planting in the seed orchard.

THE DESIGN AND ESTABLISHMENT OF SEED ORCHARD

Under conditions generally prevailing in the southeastern states, grafted plants of superior slash or loblolly pines are ready for out-planting at the end of the tenth to the twelfth week after the grafting. The heavy spring work schedule usually delays the out-planting of grafted plants to a time not ordinarily considered as optimum for transplanting. The time for out-planting has been a matter of controversy. However, we are fully convinced that there is everything to gain by setting out the grafted plants in the seed orchard as early as possible. In the season just past grafted plants were shipped out from late July through August. Due to the good ground preparation and the great personal care exercised by the foresters in charge of the seed orchards, good results were obtained, even in transplanting during the summer. With the exception of two seed orchards which lost close to 20 percent, the mortality in transplanting in all the other seed orchards were from 5 percent to 10 percent. Better results are expected for the current season. All the plants will be shipped out and transplanted at regular weekly intervals from March to the early part of May.

A few major decisions are essential prior to the planting of the seed orchard. The decisions include (1) the width of the pollen barrier, (2) the design of the plantation, and (3) the number of clones to be included in each orchard. These matters involve information on pollen dispersal for the southern pines and theoretical consideration regarding the establishment of a seed orchard.

To get the pollen dispersal information, we collected series of pollen slide at various known distances from the pollen source. Preliminary examination revealed that even at a distance of one mile from the nearest pollen source, a few pollen grains could still occassionally be found. However the number of pollen grain fell off so drastically within 400 feet of the source that pollen barrier of this distance was recommended for the seed orchards.

Nearly all the selected trees used in the seed orchards are represented in the plantations of the University. They serve not only as a study on the establishment and management of seed orchards but also as a repository of selected trees for genetics research. The number of clones included in the other seed orchards vary from 15 to 30. At the end of this season (1956-57) each seed orchard will have materials from a total of 30 to 50 clones. The number of grafted plants for each clone vary considerably. On the average, each clone is represented by approximately 8 to 10 grafted plants.

The simplest design for the arrangement of the clonal materials in the seed orchard is usually the best for general purposes. A completely randomized design was used when the plants were few in number and the area of planting limited. A randomized block design is very desirable when more plants are available and all the clones are nearly equally represented by grafted plants. In this case, the plants are divided into blocks, each of which includes a complete set of the clones randomly arranged. The chance of inbreeding is minimized and the even dispersal of pollens from all the clones throughout the seed orchard if facilitated.

The number of clones to be included in a seed orchard is a matter of basic consideration. It has been definitely shown from the result of our controlled pollination that selfing is detrimental in the southern pines. Gustafsson (1949) in his discussion on the genetic principles of seed orchards to avoid the dangers of inbreeding, considered 20 to 30 clones as a minimum.

On the other hand, the need for uniform pollen distribution in the seed orchard places a maximum limit on the number of clones in a given seed orchard. This is not a problem in a good pollen year. Plantations in Australia (Florence et al. 1956) show, however, that in a poor pollen year the cone yield of trees in a plantation was influenced by the availability of pollen. In a large seed orchard with many clones this means that free access of pollen of all the clones throughout the seed orchard will be very much restricted in a poor pollen year. In Sweden a system of seed orchards for the production of Pinus sylvestris seed has been established for each geographic region. The number of selected trees available is obviously not the limiting factor. However, 25 to 50 clones are recommended to be represented in each seed orchard. (Arnborg 1956).

The number of clones used in our seed orchards was unfortunately not wholly decided on a theoretical basis, but was rather dictated by the materials available which include only the very best of the selected trees. Clonal materials of these seed orchards could be substantially enriched through liberal exchange of cuttings and grafted plants between companies that have forest holdings within the same geographic area.

CONTROLLED POLLINATION OF THE GRAFTED PLANTS AND PROGENY TEST

The selected trees used in the seed orchard are definitely superior phenotypically. The real merit of the tree, however, can be determined only through the progeny test. It is true that the grafted plants in the seed orchard probably will not begin to bear seed in quantity until the 10th year or later. But controlled pollination for the purpose of the progeny test can be made on the grafted plants in the seed orchard within 12 months following the out-planting.

The seed orchards were established in the summer of 1956 with grafted plants made in the winter of 1955 and spring of 1956. A considerable number of the plants produced male and female catkins in the spring of 1957 in nearly all the seed orchards. In one seed orchard, where the plants were very well taken care of and were fertilized with commercial fertilizer, 50 out of a total of 168 plants bore female catkins. All the clones were represented by the flowering plants of this seed orchard. These plants were used for controlled pollination this spring.

No special attention was given to the catkin bearing cuttings for grafting in the 1955-56 season. We did emphasize the collection of cuttings whenever possible from above the lower third of the crown. The thin, short and usually crooked shoots of the lower branches are generally not very successful in grafting. Furthermore, on the assumption that both the male and female "flower buds" which were occasionally found on the cuttings, were unnecessary burdens to the scion, and hence, so the reasoning went, detrimental to the grafting union, the use of catkin bearing cuttings was discouraged. But for experimental purposes and also out of necessity, when not enough non-catkin bearing cuttings were available, a portion of the propagation was made with catkin bearing materials. Out of a total of 4172 plants about 250 plants bore female catkins and 400 plants bore male catkins.

Emboldened by last season's experience, we decided to make as many catkin bearing grafts as possible in this season. Special attention was paid to the female catkins both in the collecting and in the selective use of scion materials. Out of a total of 5491 grafts made, over 400 successful grafts bore female catkins and over 600 bore male catkins. They were used in controlled pollination. A crop of seed can be expected for the progeny test from the grafted plants 15 to 18 months after they are out-planted in the seed orchards according to this season's working schedule.

This season's propagation work started in the first week of November. For most of the selected trees, the season was too early to detect even the earliest sign of female flower bud. Far more cone producing grafts could be made by the exclusive use of female catkin bearing scions which are detectable in spring by small swellings on the side of the terminal bud.

There are distinct advantages in conducting controlled pollination on grafted plants. In this season, materials from over 300 selected trees were all assembled in one lath house. Pollen production could be forced by the manipulation of temperature. Most important of all, the female catkins of the hundreds of selected trees could be inspected with ease at regular intervals and pollinated as soon as they were receptive. It is next to impossible with even the best of facilities for us to hunt out the 300 standing trees scattered in the remote corner of four states, to examine them at frequent intervals, to collect the pollen, and to pollinate them exactly at the time when their female catkins are receptive; and above all to accomplish all these operations within the short breeding season which is variable from year to year, from place to place, and from tree to tree.

For the present stage of our work which involves a large number of clones as a result of the mass selection, utilization of the grafted plants is the only practical way to conduct controlled pollination on this large scale.

Secondly, it was always a painful experience at harvesting time to see that a high proportion of the hand pollinated cones high up on the tree were destroyed by insect, fungi, or rodents (Hoekstra 1956). It is difficult for the hundreds of selected trees in their natural stands to get as much protection and daily care as the grafted plants in the seed orchard under regular irrigation and spraying schedules.

Furthermore, the selected trees, once they were grafted, could be multiplied by vegetative means almost indefinitely. Within a matter of years, more flowering materials could be found in the grafted plants through repeated propagation than on the selected tree itself. The effect of frequent crop failure and inevitable intervening poor crop years of the trees in the natural stand could be minimized by good seed orchard management.

The Swedish ladder and tree climbing equipment are still useful tools in forest genetics. But more and more cuttings are being collected by high powered rifles which can bring down the desired branch high up in the crown almost at will. It is also true that probably with only some rare exceptions, the cuttings of slash and loblolly pine in the southeastern states can be propagated by grafting with considerable degree of confidence. From the calculation in the section on the supply and demand of seed, 15,000 grafted plants of slash pine on 300 acres of seed orchard or 10,000 grafted plants of loblolly on 200 acres are enough to produce 100 million viable seeds. The production of seed from superior trees in seed orchards to supply the total annual planting in the southeastern states is actually within easy reach.

With our present facilities, 10,000 grafted plants can be made in one season without too much difficulty. However, the superiority of the selected trees has to be proven by the progeny test. At the present, we are hesitant in making more grafts than are necessary for experimental purposes. By the use of controlled pollination on the grafted plants in the seed orchards, enough seeds from the hundreds of selected trees could be obtained for the progeny test in the next two to three years. The first crop of seed from the superior clones which were grafted and pollinated in the season of 1955-56 will be harvested this coming autumn. We hope the preliminary result can be obtained in time for the next meeting.

LITERATURE CITED

Arnborg, Tore (1956). Pine Seed Orchards of SCA (Svenska Cellulosa Artiebolaget, Sweden). Medd. nr. 82 Sällskapet f. praktisk skögsförädling, 1956.

Cossitt, Floyd M. (Forester in charge of planting, Southern Region, U. S. Forest Service, Atlanta, Ga.). Private communication. The eleven southern states include: Ala., Ark., Fla., Ga., La., Miss., N. C., Okla., S. C., Tenn., and Tex.

Florence, R. G. and McWilliam, J. R. (1956). The Influence of Spacing on Seed Production. Zeitsch. f. Forstgenetik Bd. 5:97-102.

Gustafsson, A. (1949). Seed Plantations -- Their Structure and Genetic Principles. Abst. in Bull. World For. Cong. No. 4, 1949.

Hargreaves, L. A. and Dorman, Keith W. (1955). Georgia Starts Pine Seed Orchards. Southern Lumberman, Dec. 15, 1955.

Hoekstra, R. E. (1956). Pre-harvesting Loss of Cones in Slash Pine. Southern Lumberman, Dec. 15, 1956.

U. S. Forest Service (1948). Woody Plant Seed Manual. USDA Misc. Publ. 654.

THE GEORGIA SEED CERTIFICATION PROGRAM

by

S. P. Darby
Chief of Reforestation
Georgia Forestry Commission

HISTORY

During the January 1956 session of the Georgia Legislature, two bills were introduced regarding seed. One bill (H.B. 195) dealt with the licensing of seed dealers, while the second bill (H.B. 104) provided a method for the guarantee of high quality seed and for protection of the public against false claims. Officials of the College of Agriculture, University of Georgia, were authorized to provide for seed certification and the Georgia Crop Improvement Association were designated as certifying agents.

As a result of the two bills, the Georgia Chapter, Society of American Foresters, during February 1956, appointed a committee to investigate the possibilities of obtaining certified forest tree seed and to draw up preliminary standards, provided same appeared to be feasible.

Officials of the Crop Improvement Association were contacted and made aware of our needs for higher quality seed. Our program was received by them in a most cordial manner and we were advised to prepare specific ways of accomplishing our objective, plus individual crop standards for material to be certified. Last March and April the committee held several meetings and as a result preliminary standards were drafted. These standards were presented to the Georgia Chapter during its annual meeting and members present voted to adopt same and to proceed to put this program into effect as recommended in the committee report.

The first task in obtaining certification was to develop firm standards and adequate machinery for putting the program into effect. The preliminary standards had to be expanded and things such as, charges to be made, how applications are to be processed, forms to be used, etc., had to be dealt with. The committee felt these should be kept as simple as possible and that as the program grows, refinements will be made.

The second item to be dealt with before our program will be an actuality, is acceptance by the legal certifying agency. Since State law specifies who shall have this responsibility, acceptance by them is a must.

PURPOSE OF PROGRAM

Perhaps there are those present that question the need for this program. I, for one, feel that it will be one of the greatest aids to forestry that has been developed in recent years. Anyone that has been connected with the procurement of seed knows what I am talking about. Those of you who have not had the pleasure of cone collection work will have to take my word for it but, at times, it is like buying "a pig in a poke". A method is needed whereby the forester has some guarantee of seed quality, or at least knows the type material he is purchasing.

At the time the certification standards were being written, the committee felt that this program had a two-fold purpose. The immediate objective is to raise the quality of seed currently being used, thus improving stands now being established. The ultimate objective is to make available and maintain sources of high quality seed and propagation material of genetic superiority.

MECHANICS OF CERTIFICATION

Let us now briefly look at how certification is to be accomplished. As previously stated, the G.C.I.A. will be the legal agency for placing the Blue tag on the seed sacks. All administrative details will be handled by them. A permanent forest tree seed certification committee has been appointed by the Georgia Chapter, S.A.F. This committee is composed of five members and is to serve in an advisory capacity to the Crop Improvement Association. Only those races, strains or varities that are approved by the Seed Certification Committee and accepted by the Certifying Agency will be eligible. The Executive Secretary of the G.C.I.A., plus the Certification Committee, will review and either approve or disapprove all applications. Field work, such as inspections, will be done by Crop Improvement Association personnel.

Four classes of material will be eligible to receive the Association tag. These are material from:

(a) Seed Producing Areas
(b) Seed Orchards.
(c) Superior Trees or Strains.
(d) Open Pollinated Select Trees.

Each class of material previously mentioned must meet definite prescribed crop standards. Procedure for obtaining certification will vary depending on the class of material, however, each has several things in common. The individual contemplating having material certified must become a member of the G.C.I.A., and a formal application for certification must be filed with the Association. At the time of application, necessary fees must be paid.

Seed Producing Areas and Seed Orchards must meet minimum crop standards at the time of application. The Association, or its authorized representative, will inspect the area and report their findings to the Certification Committee. The Committee and Secretary of the Crop Improvement Association, at a properly convened meeting, will determine if the area meets the prescribed standards and either approve or disapprove the application. In order for the area to remain certified, periodical inspections will be made. Yearly certification certificates will be issued so long as an area meets the minimum standards. In event an area fails to meet the prescribed standards the individual will be advised in writing and given a definite time to correct the sub-standard practices.

Individuals desiring to have specific races or strains certified must present acceptable proof of such superiority to the G.C.I.A., and Seed Certification Committee at the time of application. The Committee will evaluate any and all proof of superiority and refer same to the proper forest Experiment Station for testing or verification, if same warrants. Once tested or approved by the Experiment Station, the application will be processed as previously outlined.

Landowner or individual making application to have material from open pollinated select trees certified, will specify the location, species, and size of stand where the collection is to be made. The area will be inspected by a qualified graduate or registered forester, who is approved by the Crop Improvement Association, to determine if collection is feasible. If an area or stand is approved for collection, then the select trees will be marked in a prescribed manner by the approved forester. At the time the selected trees are marked, an estimate or cruise will be made to determine the approximate number of bushels of cones which will be produced. This data, anticipated yield, is to be confidential and available only to the Association.

Immediately prior to the collection of cones, the Association is to be notified so that field inspections can be made as needed.

None of the above four categories will qualify for certification unless the seed are processed in a manner approved by the Certifying Agency.

This is only a brief resume of the proposed tree seed certification program in Georgia. Regretfully time will not allow a detailed report on individual crop standards for each particular type of material. Today I have tried to explain how we went about organizing our seed certification program. I hope it will prove helpful to many of you interested in this work.

We're happy that the seed certification program here in Georgia is about to become a reality. I am most confident that on February 1st, when our standards are presented to the Board of Directors of the G.C.I.A. at their annual meeting, Georgia will have the machinery for obtaining certified forest tree seed.

FOREST GENETICS AT THE INSTITUTE OF PAPER CHEMISTRY

by

Philip N. Joranson, Malcolm N. May, and
Robert C. McKee
The Institute of Paper Chemistry
Appleton, Wisconsin

Research and Education in Genetics

Research and education at The Institute of Paper Chemistry in the forest genetics field have received their direction and character largely from the nature of the Institute itself. Perhaps a few remarks about the Institute are therefore in order.

Located in Appleton, Wisconsin, the Institute is a national organization of about 260 persons, supported by the membership of three-fourths of the pulp and paper companies of the United States. It comprises a graduate school with enrollment of about 50 students, all of whom are registered in a four-year Ph.D. curriculum designed to prepare men as scientific generalists for responsibilities primarily in the production, technological control, and research functions of the pulp and paper industry.

Current research and technical activities include more than 100 simultaneous projects. These include basic research--both institutional and on contract--as well as problems in the applied areas and technological services. In addition and entirely independent, is the basic research of the fourth-year students on their thesis problems. A very complete library and extensive abstracting and bibliographical services are also maintained.

Research activities are divided among a number of sections. These include pulping and papermaking technology, cellulose chemistry, organic chemistry, colloid chemistry, lignin chemistry, biology, physics, plastics, graphic arts, container, and physical testing.

The program in genetics is intended to develop, first, as a fundamentally oriented curiosity, within a particular province, regarding phenomena which underlie the genetic conditioning of pulpwood, and second as a concern about how new basic facts revealed by fundamental studies may be put to work in tree improvement applications.

The research province selected is rather sharply delimited. It is focused upon an understanding of the genetic conditioning of particular characteristics in the pulpwood raw material which register important effects during the pulping, bleaching, and papermaking operations, as well as in the properties which the product exhibits as it leaves the paper machine.

Simultaneous with these studies is a continuing effort to identify with maximum assurance certain of those frequently elusive factors in the realms of wood and fiber structure, of chemical makeup, and of chemical constituent variability across the cell wall which are of most significance in manufacturing the major types of paper and paperboard, and which would therefore--if they were known--serve as targets for more intensive tree improvement efforts.

The current lack of precision in this respect has been of increasing concern of forest geneticists, and this not only in the South. What is perhaps not so generally appreciated, however, is that even before the geneticist became conscious of the inadequacy of our knowledge in this area, it was already recognized that needed improvements in the technology of pulping, bleaching and papermaking also depend upon exactly the same kind of fundamental insight. In order to proceed intelligently with improvements in processing, the pulp and paper researcher must be in a position to guide his efforts in consideration of the same kind of cause-and-effect intelligence that the geneticist would like to have.

The Institute has participated in this particular quest for a long time, and has an especially active project at present. It has become evident from recent experiences that when there is a fusing of the curiosities of the geneticst with those of the man who probes the fundamental behaviors which underlie the technology of the industry, not only does the geneticist benefit from insight into the nature of the problems encountered in defining objectives, but the pulp and paper researcher is then also in a position to receive from the geneticist, for use in critical experiments, certain especially useful sample materials which simplify the analytical task by reducing and/or better defining some of the variables involved. In Part II of this report, we have presented a portion of a recent discussion regarding genetic improvement objectives in the southern paperboard field.

The full time Institute genetics staff of doctoral level consists of two geneticists, with backgrounds in forestry, physiology, cytology, and ecology, and a man trained in forest soils and silviculture. In addition, there is a combination greenhouseman-fieldman full time, and co-operative arrangements are in effect with the Lake States Forest Experiment Station, the University of Michigan, and Iowa State College for the early phases of pathological and entomological study, respectively, and for statistical counsel.

Working facilities include a genetics building with greenhouse attached, a clear 38-acre tract nearby for nursery, arboretum and testing, and additional test areas elsewhere in the woodlands of co-operating paper companies. All of the other facilities of the Institute are at the disposal of the genetics program.

During the past several years, many of these facilities have been employed for a related group of studies with aspen materials. These are polyploids, hybrids, selections, and introductions. In one current investigation which will soon be completed, an intensive comparison is being made between two groups of mature trees which differ genetically in a sharply defined and demonstrable way. The tests upon the two groups of trees involve pulping, bleaching and papermaking performance, fiber dimensions, and a chemical characterization. This and other studies are now approaching the reporting stage, and will soon be available in the journals.

Recently, some of the southern mills have prompted the Institute to consider how it might invest the specialized kind of research capital which it has accumulated over the years, in genetic studies of some of the qualitative aspects of southern tree improvement. In response to this suggestion, and also motivated by its own growing convictions on the subject, the Institute has spent roughly the past 18 months in studying the background, content, and feasibility of a genetics program addressed to southern species.

Out of these preparations, a plan has been developed which will be discussed soon with a group of companies which participate as members in the Institute. We have given special attention from the outset to the avoidance of unnecessary duplication of effort with existing activities, and have also become aware of some of the needs which are felt by colleagues working in existing tree improvement programs.

We would like to believe that Institute participation in the overall program of genetics and tree improvement in the South would contribute to the feeling and the substance of mutual encouragement in the many-sided task which lies ahead.

The Institute's educational program in genetics includes a course, elected by regular and special students, in basic genetics and its applications in tree improvement for the pulp and paper industry, participation in the guidance of thesis research and in a special program for orientation in research which occupies the third year, and presentations made at conferences and at the new industrial summer seminar.

Consideration is also being given to the possibility that arrangements will be made for qualified graduate students in forest genetics in other institutions to pursue thesis research at the Institute, making use of facilities and of the guidance of the staff.

A Preliminary Discussion of Wood Quality Objectives for Genetic Improvement in the Southern Paperboard Field

Several months ago, members of the pulping and papermaking, biology, and container sections of the Institute co-operated in the preparation of a panel discussion of fundamental research in relation to the needs of the paper-board industry of the South as they might be met (1) by the application of genetics and (2) by advances in pulping technology. Part of the background for the discussion which was developed was agreement that prominent consideration should be given to increased employment of hardwoods.

The discussion was recorded in full in the proceedings of the semiannual meeting of the Fourdrinier Kraft Board Institute, October 18 and 19, 1956, and the portion which related particularly to the discernment of qualitative objectives for tree improvement is reproduced in the following.

The Southern pines which are commonly pulped are so closely related that, for the most part, it is often difficult to distinguish between them on the basis of the characteristics of the wood or of the pulp alone. These pines contain approximately 30% lignin, 50% alpha-cellulose, and 20% hemicelluloses and extraneous components.

In all of these southern pines there are two distinctly different types of fibers within an annual ring. These are summerwood fibers and springwood fibers. The springwood fibers are larger in diameter and are much thinner walled than are the summerwood fibers. With conventional pulping methods, the summerwood fibers are individually much stiffer than the springwood fibers, and they do not fibrillate as readily as do the springwood fibers. The average fiber length varies from approximately 2.1 mm. for Virginia pine to 4.9 mm. for Longleaf pine. In contrast to the pines, the fibers found in the hardwoods are shorter and narrower, in general, than the softwood fibers.

Along with the fibers in hardwoods are vessel segments which are relatively short and broad compared to the fibers. In general, these vessel segments do not contribute much to the strength characteristics of a sheet of paper.

The chemical composition of most of the hardwoods will run about 20 to 25% lignin, 45 to 50% alpha-cellulose, with 25 to 30% hemicelluloses and extraneous components.

Desirable properties in paperboard might be listed as follows:

(1) Strength
(2) Runability on machines
(3) Scoreability (the quality in a board which permits it to be creased and subsequently folded uniformly along a predetermined line without rupture of the surface fibers), and
(4) Printability

With these properties as targets, what chance do we have of achieving them with the kinds of woods which are available in the South?

The pulps from the southern pines are well known for their strength, and these good strength characteristics seem to stem from good inherent fiber strength, good capacity for fiber-to-fiber bonding, and relatively long fibers. There are, of course, variations in strength properties of the pulps, depending on the properties of the fibers in the original wood and upon how these properties have been changed on pulping. Springwood fibers develop very good fiber-to-fiber bonding in general, and this is particularly advantageous in bursting strength, tensile strength, and compressive strength. The summerwood fibers do not bond together well, in general, but tend to contribute to fair tear resistance.

Runability, which simply means the ability to maintain steady operations at a competitive speed on the board machine, is related in many respects to the strength properties of the sheet and has a very pronounced influence on the economics of the operation. Here again the combination of fiber properties found in the southern pines generally seems advantageous.

Scoreability is rather difficult to relate to basic fiber properties at our present stage of knowledge, but we feel that long fibers, certain types of fiber bonding and good fiber flexibility are important.

Printability is, unfortunately, adversely affected by many of the factors that contribute to good strength characteristics and scoreability. The combination of fiber properties found in the southern pine does not seem particularly good from a printability standpoint. This is probably related to the size of the fibers, the stiffness of the fibers, and the influence of these characteristics on the continuity of the surface to be printed. In contrast to this situation in pine, the pulps from the hardwoods--when used in board--do not in general give as good strength, scoreability, or runability. This is probably related--at least in a large measure--to the relatively short fiber lengths. However, these strength deficiencies should not categorically be laid to the differences in fiber length. Other factors related to fiber-to-fiber bonding and inherent fiber strength are also involved.

In contrast to strength, scoreability, and runability, the printing characteristics of boards made with the hardwood pulps are generally better than those made from southern pine pulps. These good printing characteristics are probably related to fiber length to some extent, and the ability of these shorter fibers to form a more closely knitted surface with good resiliency and ink absorption.

We might now ask whether, out of these remarks relating fiber properties and the properties desired in board, we are able to set certain tentative targets toward which we may point the hypodermic pollinating needles of the geneticist. While this is a concern which will require far more study than it has received in the past, we might at least start with the following suggestions. It should be emphasized that, as given here, they apply only to genetic improvement of pulpwood for <u>board</u> manufacture.

1. To reduce the lignin content of the wood, since this would permit higher pulp yields.

2. For most board pulps, perhaps to attempt to increase--in the case of conifers, at least--the hemicellulose content of the wood.

3. Also, in the case of conifers, for most purposes, to minimize the summerwood content and increase the springwood content, or, conceivably, to try to make summerwood fibers more similar to springwood fibers.

4. For the hardwoods and for some of the shorter-fibered pine species, such as pond pine and Virginia pine, possibly to attempt to increase average fiber length.

5. For most purposes, perhaps to increase the wet flexibility of the delignified fibers.

6. In the case of hardwoods, to decrease the number of vessel segments, if possible, or, as a problem for a really ingenious geneticist, to make the vessels more fiberlike in nature.

7. Finally, since strength is so important in the desired properties of board, to set the general target of trying to increase the inherent strength of the fibers and their capacity for fiber-to-fiber bonding. This, of course, relates to some of the individual items already mentioned, as well as to others about which very little is known.

The strongest emphasis should be placed upon recognizing that this is a very tentative list, and that perspectives likely will be changed by future fundamental insight in ways we cannot predict. But, on the other hand, we should not depreciate the fact that there is now at hand at least enough basic information to orient further efforts and also to point with some confidence in certain directions.

The paperboard field, which was the subject of this attempt to move toward defining tree improvement objectives, is but one of several major areas of paper manufacture in which similar efforts need to be initiated. These additional areas would include bag and wrapping paper, dissolving pulp, glassine, tissue, book, and perhaps others.

POLLEN HANDLING

by

E. B. Snyder, Southern Institute of Forest Genetics,
Southern Forest Experiment Station, Forest Service
U. S. Department of Agriculture.

I have divided the subject into hastening of pollen shedding, pollen extraction, and pollen storage. All experiments mentioned, other than by cited authors, were conducted at the Southern Institute of Forest Genetics during 1956.

Hastening Pollen Shedding

First, how can pollen be obtained days or weeks ahead of natural shedding? Mergen (3) grafted longleaf catkin-bearing scions on slash stock in late December and obtained pollen in time for use on slash flowers. Placing severed branches in jars of nutrient solutions is a complementary method which may be used later in the season and requires less labor and space. The following data were obtained chiefly from severed cuttings. The technique was to:

1. Collect catkin-bearing stems about 12 inches in length.
2. Make a slanting cut on the base of the stems with a very sharp grafting knife.
3. Plunge the basal end into a surface-sterilized container filled with water.
4. Place in greenhouse and keep containers filled with water.

Results from collecting catkin-bearing stems of slash pine up to five weeks before natural shedding are shown in Table 1. Nuclear stages were determined by the simple acetocarmine smear technique (4,5). When catkin-bearing branches were taken before the tetrad stage, no pollen was recovered. At the tetrad stage partially viable pollen was recovered. The next slide illustrates the earliest stage of microsporogenesis which matured any viable pollen. The next slide shows the four immature pollen grains escaping from their microspore cases. Viable pollen matured when catkins were collected at this stage.

Treatments, in addition to those just outlined, might permit earlier collections. Unfortunately, it was not possible to test various treatments at most of the stages, but a battery of treatments was applied 4 to 6 weeks before natural shedding. This was done to avoid conflicting with the pollination program. Although no viable pollen was produced, it is thought that treatments were effectively screened as measured by catkin elongation. Catkin elongation is an essential process

Table 1.-Catkin lengths, date of shedding, germination percentage at 10 months, and stage of pollen from slash pine catkins collected at intervals beginning 5 weeks before natural shedding.

Date of Cutting	Catkin length: Initial	Catkin length: Final	Shed before natural shedding	Pollen: Germination	Pollen: Stage at cutting
	mm.	mm.	days	%	
12/22	11	11	No pollen	-	premeiotic
12/26	12	12	do	-	do
12/29	14	14	do	-	do
12/31	14	14	do	-	do
1/2	20	20	do	-	1st division
1/4	18	18	do	-	do meiosis
1/6	18	18	do	-	do
1/9	17	17	do	-	2nd division
1/13	17	27	11	-	do meiosis
1/16	19	40	11	50	tetrads
1/18	18	20	8	-	do
1/20	20	25	8	-	do
1/24	22	36	6	-	immature pollen
1/30	23	38	2	-	do
2/1	25	40	3	-	do visible
2/5	27	45	2	-	prothallial (?)
2/9	46	46	0	-	do

in pollen shedding. Therefore catkin elongation is the basis for the following recommendations from four factorial experiments. Part of the experiments are shown in the next slide. The recommendations are:

1. Boil cut bases of stems one minute before placing them in final solutions. We made the transfer from the boiling water by tongs and a vial of water so that the cut ends were not exposed to air after boiling.

2. Use a cutflower preservative, or a sugar plus fungicide, especially if high temperatures are to be encountered.

3. Strip needles from stems.

4. Incubate at 25°C.

5. Supplement daylight with continuous artificial light. The beneficial effect of this is attributed to extra heat rather than to a light effect. The next slide shows the apparatus used for testing interrupted darkness and supplemental light.

In the next slide only the stems in the first jar were boiled; no treatment was applied to the second; and the third is a bottle graft. Boiling was the best treatment out of the many tried and in most cases resulted in the shedding of non-viable pollen. The benefit of this treatment is attributed to improved water absorbtion. It had no effect when applied four days before natural shedding probably because water absorption was not a limiting factor within so short a time. Effectiveness of special treatments such as boiling is limited to applications at intermediate nuclear stages. They can't be applied too early or too late.

As an illustration of the possibilities of forcing, longleaf catkin-bearing branches were cut four days before natural shedding. They were placed in water and received no special treatment. Outside conditions were warm and windy, yet we beat mother nature at her best by getting catkins to shed pollen a day or two sooner than those on the outside.

Pollen Storage

Assume that we have extracted pollen and now want to store it for a year. What are some of the conditions affecting its viability? What makes pollen so hard to keep? Table 2 gives some of the answers. Here, pollens with three different initial moisture contents were stored in different amounts per same sized bottle for 10 months. If pollen had a low initial moisture content, viability was maintained, if it had a high one its germination percentage deteriorated. However, if a small amount of wet pollen was stored, the moisture escaped before fungi or other deleterious agents could ruin the pollen. Other tests have shown that

Table 2.--Germination percentages of different amounts of pollen with different initial moisture contents stored unsealed at 5° - 10°C.

Amount per 24 ml. Shell vial	Initial moisture content percentage		
	12	29	51
ml.	%	%	%
4	94	78	73
8	95	76	58
12	90	77	54
16	89	80	49
20	91	79	47
Mean germination Percentage	92	78	56

pollens exposed to a dry atmosphere will attain the same equilibrium moisture content regardless of their initial moisture contents. The speed of drying to a safe moisture content is dependent on the mass of the pollen stored.

What is the correct moisture content and relative humidity for storage? Duffield (2) suggested storage at 25% relative humidity (R.H.). We stored pollen over a saturated solution of potassium acetate to give this R. H. The viability of this pollen was identical to that stored unsealed in a refrigerator and its moisture content after 10 months of storage was 14%. By coincidence, this moisture content is the approximate threshold for fungal activity in organic substrates. Thus there is considerable evidence that a pollen moisture content near 14% is desirable.

What makes pollen spoil when sealed in stored vials? Our results after 8 to 10 months show that pollen with an initial moisture content of 44% was a total loss whereas pollen at a 14% moisture content remained fully viable.

Pollen Extraction

The last column of Table 2 shows that wet pollen may be saved if it is dried. This can be done in many ways. For instance, vacuum desiccation has been used by us with limited success. However, an alternative is to extract under conditions such taht the pollen is already at its correct moisture content. Extraction of dry pollen resulted in better viability after storage, double the yield, freedom from sawfly larvae, and elimination of the extra desiccation operation. The lower humidity probably inhibited the hatching of the insects' eggs.

How can dry pollen be produced? The next slide shows how dry pollen was obtained experimentally. This set up is too elaborate to be used extensively but does illustrate factors in extraction. Here we have a sealed cabinet containing five sealed compartments. The next slide is a close up showing that each compartment has a Placerville-type extractor, chemical solution for controlling humidity, and a fan for circulating air. The cloth is a thin cotton batiste easily penetrated by the circulating air. Minute quantities of pollen escaping through it are not a contamination problem because of the sealed compartment. However, when pollen-proof canvas was used, as at Placerville, wet pollen was produced because the dry air could not penetrate it sufficiently. I think the best procedure is to force air at controlled humidity through the funnel and canvas bag as is done at Placerville.

Pollen with a 14% moisture content was produced in 36 hours at 25°C. and R.H.'s of 37 and 53%, respectively, for longleaf and slash pine. Duffield (1) suggested extraction at 15 to 30% R.H. These figures will vary according to the sample size, treatment time, temperature, velocity of circulating air, and the size and the moisture content of individual catkins.

LITERATURE CITED

1. Duffield, J. W. 1953. Pine collection dates - annual and geographic variation. Calif. For. and Range Expt. Sta. Note 85. 9 pp.

2. ______________ 1953. Studies of extraction, storage, and testing of pine pollen. Zeitsch. Forstgen. u. Forstpfl. 3: 39-45.

3. Mergen, Francois. 1954. Improving the early growth of longleaf pine. Forest Farmer 13: 8-9, 16, 17, 19.

4. Smith, L. 1947. The acetocarmine smear technique. Stain Tech. 22: 17-31.

5. Swaminathan, M. S. et al. 1954. A simple proprionocarmine PMC smear method of plants with small chromosomes. Ind. Jour. Genet. 14: 87-88.

ROOTING OF SOUTHERN PINES

by

M. Reines
Associate Professor of Forestry Genetics
School of Forestry, University of Georgia

Rooting of cuttings and air layering methods of shoots of forest trees are the important techniques necessary for the growth of forest tree improvement programs. By these techniques countless numbers of "progeny" with above ground parts and root systems genetically identical to those of their parents can be propagated. Not only is this important in correlated tree improvement and genetic studies but the methods are essential to seed orchard establishment, physiological studies, site relationship studies, and even in restocking.

The availability of great quantities of identical clonal stock provides more precise means for evaluating or testing the validity of tree selections as to their superiority, relative to specific traits, as well as their ability to produce better progeny. It also makes possible an expanded breeding program which will enable us to more readily determine the transmissability of characteristics from heterozygous parents to equally heterozygous progeny by the application of population genetic methods.

Seed orchards planted with many like individuals produced vegetatively from many superior parents, would insure the cross pollination of superior strains to produce many better progeny. Grafting has been attempted to accomplish this. Not only has this method been of limited success in its application to seed orchard establishment, but the question of stock-scion compatibility presents a problem.

A request for 1200 seedlings for plantation management studies was made recently. Seedlings from a single open pollinated selected parent are being supplied. At best these seedlings are variable. Were they the progeny of a controlled pollinated parent, they would still be a heterogenous lot. This study vividly emphasizes the need for great numbers of identical seedlings gotten only by rooting or air layering. Information derived from cultural methods, studies of site influences, and physiological investigations using such clonal material could be more accurately evaluated. The confounding factor of genetic variation characterized by the usual lot of seedlings could be ignored.

Past experience with species more readily rooted than our own native southern pines has given us some leads in the search for practical means of rooting pine cuttings. It is now recognized, that success or failure in rooting is dependent upon the age of the tree from which the cuttings are taken or upon which air layers are made. Deuber, Fields, Jacobs, Snow, Kammissarov, and Thimann and Delisle have shown that in many coniferous species, cuttings taken from young trees up to five years of age root more readily than those taken from older trees. This has also been indicated by the work of Mitchell, Schopmeyer, and Dorman with slash pine and by Cech of Texas with loblolly pine cuttings. McAlpine recently observed that the same holds true for the air-layering of loblolly pine. Studies here at Athens, though not specifically designed to show age differences, have demonstrated the successful rooting of cuttings taken from one-year-old seedlings and consistent failure of those from older trees to root.

A second principle emphasizes the effect of position on the tree from which cuttings are removed on their rooting capacity. The generality conveys the conception that rooting capacity of cuttings is greater when taken from the lower portions than from the upper portions of a tree. Some workers have suggested that this may be correlated with the differential distribution of natural root inducing hormones as a consequence of proximity to the roots of the parent tree.

Variation in rooting capacity between trees of the same species has been recognized. How much of our success or failure with rooting cuttings of slash, loblolly, longleaf and shortleaf pines depends upon variation in rooting capacity is difficult to say, but the possibility of its existence cannot be ignored. Equally apparent are the differences in rooting capacity between species and the different requirements necessary to propagate them.

Time of collection and the condition of cuttings affect survival and rooting capacity. Dorman and Mergen agree on October and early November collections for slash pine. Cech finds December and January the best time for the collection of loblolly pine cuttings. Cuttings should be healthy. They should be taken from the current year's branch growth.

Mechanical or chemical treatments before or after collection apparently influence both the survival and rooting. Length of cuttings as it affects survival and rooting has been a matter of controversy. In general a reduction of above ground needle or leaf area is accompanied by diminished survival and rooting. Cuttings with a heel of old wood generally intereferes with rooting. Dorman reports that bases cut in a number of ways have little effect on percent rooting. A long slicing basal wound with the object of stimulating the production of a large area of callous tissue from which profuse rooting can originate is being used here. Slash pine cuttings have responded well to basal wounding before chemical treatment according to Mergen. Pre-callousing as a consequence of storage in sphagnum has been found unsatisfactory and unnecessary in the handling of slash pine cuttings. Dorman however reports 25% rooting of slash pine cuttings stored for two weeks in wet sphagnum at 85° F. Strangulation and phloem blocks in order to increase food reserves in distal portions of branches prior to the collection of cuttings has failed to stimulate rooting according to Cech.

The use of growth substances has been looked upon with favor in the rooting of cuttings. It has become standard procedure. Failures resulting from its use have been ascribed to time of treatment, concentration of the growth substance, method of application, or propagating conditions. It has been said that in general the more difficult a species is to root, the higher will be the concentration that is required. The application of this premise should be tempered with caution. High concentrations may prove toxic, where low and medium concentrations may be effective. Optimum rooting varies with the substance and carrier used; with the species, age and condition of the cutting; with the time of year; and with the method of treatment. Not only does treatment with growth substances increase the number of cuttings that are rooted successfully but it also increases numbers of roots, root length, and survival. While some measures of success has been acheived in the use of growth substances we cannot anticipate results since certain treatments have not been consistently productive from trial to trial and with different species. Concentrations used in the propagation of other pines have been found unsatisfactory for slash pine.

Treatments with additives other than growth substances have been found beneficial. Mirov has recommended the use of warm water to remove oleoresin and improve water absorption by the cutting. Cech observed no benefits resulting from water soaks used to remove possible inhibitors. Evanari, and Thimann and Delisle have suggested that the use of sugar may be of value in improving the rooting capacity of cuttings. The applications of honey, vitamin B1, potassium permanganate and other substances have been recommended. Mergen observed no benefit from applications of pyrodine, thiamine, pentachlorophenate, or nicotinic acid. Exposure to ethylene has been ineffective in the stimulation of rooting according to Cech.

In general, rooting media giving optimum propagation conditions will vary with the species and its requirements in respect to aeration, heat, pH, moisture, and available nutrients. Sand, sand and peat with varying proportions of each, vermiculite, perlite, styrofoam, redwood bark, pea gravel, forest duff, charcoal-sand mixtures and other media have been used. Dorman has favored the use of a sand medium over sand-moss medium and has rooted slash pine cuttings in pure and mixed media of redwood bark. Mergen found sand and vermiculite promising. McAlpine and Zak have been using a sand-peat medium. Washed sand of unspecified grade and local origin is being used at the University of Georgia. For no other reason than to avoid confounding an already confused situation. A mixture of sand and charcoal is also being tried. However, survival of cuttings in this medium has been no better than in pure sand. Of course there are other modifying factors which may be responsible for this poor initial performance. Grigsby has had excellent results with perlite, alone or in mixtures with coarse sand. He attributes this success to good aeration and drainage. Cech's trials with sawdust, vermiculite, forest duff, sandy loam soil, sand, sand vermiculite, panaloam, pea gravel, and redwood bark as rooting media have been inconclusive. While sawdust was superior at one place he found sand better in another for the same species.

According to most workers light intensity should be reduced. It is not clearly stated whether this recommendation is based upon the deleterious effects of full sunlight itself or the heat which the light produces. Shading of propagation benches here seems to improve survival during all seasons. The tolerance of slash pine cuttings to full sunlight seems greater than that of loblolly pine. Grigsby has gotten good rooting results with loblolly pine cuttings in full sunlight. The increase of day length by artificial light has shown some promise and should be investigated further. Rooting of cuttings is unaffected when removed from plants exposed to supplementary red, and far red light according to Cech.

Emphasis has been placed on the retention of high humidity over propagation benches. However there is some controversy. Dorman concludes that high humidity does not compensate for water sprays or mists. Grigsby has used intermittent misting with a readily drained medium to good advantage. McAlpine has found that mist is disappointing and he has simply used daily watering with a hose in the propagation of shortleaf and loblolly pine. Results of Mergen's studies on the use of a sweat box or propagation frame demonstrated its unsuitability for rooting slash pine cuttings. Nor did the sub-irrigation of the bases of cuttings show promise. At the University of Georgia misting improved the survival of both slash and loblolly pine cuttings in propagation benches under shade in the greenhouse. Mist applications will be continued. Tentatively a schedule of intermittent misting will be used during the heat of the day in the summer. During the cooler seasons when it is necessary to heat the greenhouse an intermittent misting schedule will be used over a 24-hour cycle. Our currently poor survival of cuttings in the greenhouse may be attributed at least in part, to the insufficiency of the current misting schedule and possibly inadequate drainage from the medium in the bench.

Slash, loblolly, shortleaf and longleaf pine cuttings can be and have been rooted. Twelve percent of 420 loblolly pine and 28% of equal number of slash pine cuttings taken from one-year-old seedlings have been rooted here. Grigsby of Mississippi via personal communication reports the rooting of 18% untreated and 46.8% treated loblolly pine cuttings. For another group of 22 cuttings from a single tree he reports 68% successfully rooted cuttings. The trees from which these cuttings were taken were 25 years old. These are the best results reported to date. Cuttings rooted by Dorman have grown into sizeable trees. Nevertheless we cannot repeat what has been done before nor have we been able to improve upon it. The majority of successes have been with cuttings of young trees. Unfortunately the characteristics we seek have not been recognized in seedlings or in young trees.

Needle bundles have been rooted by Thimann and Delisle with white pine, Toda with Japanese red pine, Jeckalejs with red pine and more recently by Zak with shortleaf pine. Needle bundles have also produced buds. Potentially here is the method whereby hundreds of small plants could be produced from a single branch of a parent tree.

A recent communication from the experiment station at Lake City reports that air layering is much more successful than rooting of cuttings on slash pine. Consequently their vegetative propagation work during the last two years has been done using air layers and some grafting. Air layering though successful does not hold the promise of plenty that rooting of cuttings does. However, as employed by McAlpine in determining the effect of age on rooting it can be used to gather information which is applicable to other rooting methods.

Using a modified air layering technique Zak is able to root needle bundles. The root originates from the small slab of stem tissue to which the needle bundle is attached.

In conclusion, empirical studies undertaken thus far have netted one major contribution, namely that difficult to root pines can be propagate vegetatively. But, the successes have been few and large numbers of rooted cuttings still cannot be produced upon demand. Consequently the emphasis must shift to more basic investigation devised to give information which can be used in the precise manipulation of cuttings so that they can be made to root.

Root initiation and development, and the physiology involed are the primary considerations in this approach. The predisposition of living parenchyma cells in stem tissue to divide and to differentiate into roots needs further investigation. The agent or agents of stimulation should be identified. Their activity in relation to other metabolic processes which are ultimately expressed in growth and form must be understood. Seasonal fluctuations in food reserves probably exert their profound effects on rooting and must be examined.

Water relationships inside and outside the cutting influence survival and rooting. Cuttings are so much less successfully rooted than air layers, presumably air layers differ only in that they have a water bridge of xylem which connects it to the remainder of the tree. This is lacking in cuttings. Is it the water alone or is the water a vehicle for some necessary constituent, such as nutrients or food or food derivatives If water alone is the critical factor what then is the water balance inside the tissue necessary to insure survival and growth? How may this inbalance be remedied? Does misting or other means of maintaining a high relative humidity reproduce this balance or is transpiration and an adequate water supply in the medium sufficient to promote root growth.

Photoperiod, light intensity, and light quality inasmuch as they profoundly influence the growth and reproduction of whole plants may likewise affect cuttings.

Species and even different individuals within a species may vary as to their capacity to root. What are the differences between cuttings from those which will root and those which will not root?

Rooting capacity also apparently differs between cuttings or air layers from young and old trees and even when taken from different positions in the same tree. Are there differences in age? If the reproductive capacity of living tissues is different in younger and older trees or different in tops and bottoms of individual trees, what are the intrinsic differences in these tissues? What then is aging in plant tissues?

Environmental factors, temperature, media etc., which influence not only survival but also growth warrant examination.

Until the solutions to some of these problems are uncovered the rooting of southern pines may remain unpredictable and unreliable as a tool, in its application to forestry research and practice.

WHAT WE KNOW ABOUT GRAFTING

by

Hoy C. Grigsby[1/]
Mississippi Forestry Commission

More forest tree species are currently being propagated by grafting than by any other vegetative means. This is true probably because grafting is the most successful method in use. The inconsistency of results, however, indicates that more research is needed in working out the problems that still exist in the grafting of both pines and hardwoods.

Grafting differs from rooting--the other principle method of asexual propagation--in that the resultant product consists of a portion of two trees, the root of one joined with a scion of another.

Several methods of grafting are made use of in testing superior tree phenotypes, setting up seed orchards, inducing early flowering and other tree improvement work. Among these are budding, cleft, saddle, side, and approach grafts. Basically the principal is the same for all--the fusing together of the cambium, phloem and xylem tissues of the stock and scion to the extent that the two parts become one.

Grafting can be done almost any place where the transpiration of water from the scion stem can be controlled while union is being made, whether in the greenhouse or outside. Of course this can be easily regulated in greenhouses where humidifiers are used. Without humidifiers, use must be made of grafting cases, plastic bags or other containers to keep transpiration down in the scion.

Lathhouse and open field grafting may be done when the scions are enclosed in bags and shaded to retard transpiration or when transpiration loss is replaced in the scion by the absorption of water from a container such as a bottle.

Patch budding has been used successfully on hardwoods by Zarger(8). Patch bark grafts have been made on shortleaf pine by Jackson and Zak (3). In this process a specially made tool is used in removing the material from one stem and placing it on another.

1/ Since this paper was prepared the author has accepted employment with the Southern Forest Experiment Station, Crossett, Arkansas.

Only moderate success has been achieved in cleft-grafting hard tissue in the pines. In using this method, the main stem of the stock plant is severed and the scion is placed in a slit in the stump. There is one notable exception, however. Perry and Wang (6) have had 80 to 90 percent success with this method on potted stock in a lathhouse. The graft is made in the hard tissue near the top of the stock. After being waxed, it is covered with a ventilated plastic bag. Mergen (5) developed a method of cleft-grafting the soft tissue of slash pine buds which proved highly successful. A plastic bag was used to cover the grafted tip to slow up transpiration in the scion. This method can be used throughout the growing season with good results in the field as well as in the greenhouse. An additional bag made of paper is used to shade open field grafts while union is being made. More recently soft-tissue grafts have been used successfully on loblolly and shortleaf pines and other species (7).

Side grafts, including veneer grafts have been widely used in slash, loblolly and shortleaf pines (1,5). Good success has been attained on potted stock in the greenhouse where the humidity is kept high. In using this method, the wedge-shaped scion is placed in a slit on the side of the stock and the graft is wrapped with a rubber budding strip. After union is made the stock plant is pruned back to the graft over a period of several weeks. Zobel and Cech (9) have used this type of graft in a lathhouse with good results. The scion and entire grafted portion of the stock was enclosed in a plastic bag.

Moderate success has been attained by Grigsby (2) in side-grafting bare-root loblolly pine stock under controlled greenhouse conditions. The advantage of this method is that the space normally taken up by pots is eliminated.

Wedge and saddle grafts have found little use for grafting hard or dormant scions.

A method that has proven very successful for grafting under field conditions is an approach-type known as the bottle graft. The scion is joined to the stock leaving a protruding base which is placed in a bottle of water. This water is absorbed into the scion, replacing that which is lost in transpiration. After union takes place, the bottle is removed and the end of the scion is clipped at the graft. A principle similiar to this, known as inarching, has been used to graft seedlings into mature trees by Mergen (5), Zobel (9) and others. The roots of the seedling are enclosed in a plastic bag filled with moist peat moss and the seedling is tied to a branch of the tree and grafted in the same manner as a bottle graft. Cech (9) is using this method in reverse (i.e., severing from the tree after union is made and planting) to multiply hard-to-graft clones in seed orchards. After obtaining a potted seedling upon which the desired wood has been grafted, inarching can be done repeatedly on seedling stock already established in the seed orchard.

A novel type of graft known as heteroplastic micrografting has been used by Mergen (4) and others in an effort to induce early flowering in the pines. The stock and scion are young succulent seedlings in or just past the cotyledon stage.

General Observations

Success or failure of plant grafting is largely a matter of water relationships in the scion stem and later in the scion-stock combination. Transpiration of water from the scion stem is dependent on environmental conditions and on the character of the shoot itself. Full sunlight, high air temperature, and low relative humidity in the air s surrounding the scion all contribute to a high rate of transpiration. Succulent material, as used in soft-tissue grafting, is far more sensitive to conditions of high transpiration than is mature and hardened tissue.

The extent and rapidity of union between stock and scion are also important factors in successful grafting. The greater the area of contact between the two parts, the better the chance of success. Grafting skill has much to do with the outcome of any grafting project.

Grafting to stock established in the field is more desirable than grafting potted material. A root system that has been cramped within a pot doesn't function efficiently immediately after planting in the field.

The age of a tree is of little consequence in grafting provided the tissue is healthy and vigorous. Good results have been attained in grafting scions from trees that are 50 years old and older. Treatments such as fertilizing, watering and pruning may be used to obtain vigorous shoots (7).

It is known that some trees graft more readily than others of the same species.

Careful consideration should be given to the matter of gradually pruning the stock tree after grafting in order to force the scion shoot into dominance.

A strong disadvantage to grafting is that it does not reproduce the genotype of the parent tree in the root system.

It is highly probable that incompatibilities may become evident between stock and scion in some of the grafting we are doing today. This has been experienced in the grafting of fruit trees and ornamentals in the field of horticulture.

In general, most forest tree species can be grafted readily by one method or another when stock and scion are both of the same species. Grafting within a genus appears to be practical as evidenced by recent work (4). However, inter-generic grafting is extremely difficult and only of limited use.

LITERATURE CITED

1. Chase, Spencer B. and F. C. Galle. 1954. Pine grafting--a preliminary report. Division of Forestry Relations, Technical Note No. 18. Tennessee Valley Authority.

2. Grigsby, Hoy C. 1955. The tree improvement program of the Mississippi Forestry Commission. Proceedings third Southwide conference. Southern Forest Tree Improvement Committee. Published by Southern Forest Experiment Station.

3. Jackson, L. W. R., and Bratislav Zak. 1949. Grafting methods used in studies of the littleleaf disease of shortleaf pine. Journal of Forestry 47: 904-908.

4. Mergen, Francois. 1954. Heteroplastic micrografting of slash pine. Southeastern Forest Experiment Station. Paper No. 47. U. S. Forest Service.

5. ______________ and Harry Rossoll. 1954. How to root and graft slash pine. Southeastern Forest Experiment Station. Paper No. 46. U. S. Forest Service.

6. Perry, Thomas O. and Chi Wu Wang. 1957. Personal communication. University of Florida.

7. Zak, Bratislav. 1955. The grafting of shortleaf and other pine species. Southeastern Forest Experiment Station. Paper No. 59. U. S. Forest Service.

8. Zarger, Thomas G. 1948. Planting improved black walnut. Forestry Investigations Branch. Circular.

9. Zobel, Bruce J. and Frank Cech. 1957. Personal communication. Texas Forest Service.

WHAT WE KNOW ABOUT AIR LAYERING

by

R. W. Johanson
Southeastern Forest Experiment Station
Forest Service, U. S. Department of Agriculture

Air layering is one important method used to obtain vegetative propagules from desired stock. The desirability of using this method over others depends to some extent on the use to be made of the propagules. If they are to be used as clonal stock in a seed orchard, the method that gives the greatest number of "takes," or one that gives the earliest flowering would be selected. Where clonal stock is to be used as a means of testing certain characters of a parent tree, such as gum yield or growth, and the influence of the rootstock might cause complications, grafts cannot be used--only air layers or rooted cuttings are suitable. In trials thus far on older southern pines, air layering has been more successful than the rooting of cuttings.

Layering, or the growth of roots on a plant branch, occurs naturally on many plants, including many of the conifers. Layering in nature occurs when branches come in contact with the ground and are covered by soil, moist litter, or moss.

According to Cooper (1911), Mayr noted that members of the genera Abies, Picea, Pinus, Larix, Pseudotsuga, Chamaecyparis, and Cryptomeria had all been observed to reproduce by layering. In Scotland a specimen of Picea excelsa had many natural layers from the trunk and others from the primary substems so as to form a double series of young trees in two concentric circles around the parent trunk. Cooper also refers to Vogtherr, who speaks of the layering habit occurring frequently, though often overlooked, in moist habitats in northern latitudes and in mountain regions.

A method of layering whereby roots are induced to form on a part of the tree not in contact with the ground has been in use by the Chinese for some 20 centuries. It is known to the horticulturists as air layering, Chinese layering, marcottage, mossing off, or vegetative propagation from gootes. In air layering, a handful of moist sphagnum moss or other moisture-holding material is placed around the stem where a wound or girdle has been made, and this in turn is covered by moisture proof wrappings. The branch or stem is usually completely girdled to inhibit the translocation of photosynthate material through the phloem tissue. The phloem and cambium should be removed, but all xylem tissue should be left intact.

During 1940-1941 Lasschuitt (1950) induced root formation on branches of Pinus merkusii by air layering. This species of pine grows in the jungles of Indonesia. Lasschuitt had noticed adventitious roots growing along the wounds of a split in a forked tree. This observation prompted him to attempt to induce rooting on branches with wound stimulation. He rubbed mechanical wounds with a mixture of leaf mold and soil from a pine site containing mycorrhiza. The wounds were packed with 5 to 10 kilograms of this mixture which was held in place with mats. During the dry season this rooting medium was watered. After 8 months, 7 of the 75 air layered branches had roots.

Wyman (1952) compiled a large list of plants according to their rooting ability from cuttings and their ability to root when air layered. None of the plants listed were of the genus Pinus, but it was interesting to note that some of the plants that rooted with difficulty as cuttings were easily rooted when air layered.

A primary prerequisite to successful air layering is keeping the medium around the wound moist at all times. As a wrapping material, polyethylene plastic functions well in areas of fairly high relative humidity, as at the Lake City Research Center, and without the necessity of additional waterings.

Root stimulation with such growth regulators as indolebutyric acid and naphthalene acetic acid has been successfully carried out on many members of several coniferous genera by Kirkpatrick (1940). Although a few genera, including Cedrus and Pinus, failed to give very positive responses to this type of stimulation, other genera gave good rooting response within 2 to 3 months.

Singh (1953) found that as he increased concentrations of B-indoleactic and a-naphthalene acetic acid from 0.25 to 1.0 percent he got progressively better rooting responses in air layering mango trees, while untreated controls did not root at all.

Mergen (1955) initiated an air layer study at Lake City in 1952-1953 on slash pine trees ranging in age from 5 to 17 years. The study was designed to determine whether or not 0.8 percent indolebutyric acid in talc (Hormodin No. 3) aided root formation in air layers, and what effect time of air layering had on rooting. By making 2 air layers in each of 26 trees, a treated and untreated layer per tree, and by doing the air layering at 3 different times during the year (October 22, May 15, and August 6), he found that not only did he get more rooted branches (84 versus 50 percent) using the indolebutyric acid stimulant, but he also had over twice as many roots per branch when rooting did occur. Date of air layering had its greatest effect on time elapsed before first root development: for those air layers that were made in October, 23 weeks passed before the first roots appeared; when air layering was done in May, roots appeared within 6 weeks; and air layering done in early August showed the first roots in 8 weeks.

Hoekstra ran an air layer study on slash pine (publication pending) at Lake City to determine the relationship of tree age, concentration of indolebutyric acid, and time of year of air layering. The study was set up statistically with a split plot design to test the following variables; tree ages 6 and 23 years; 3 indolebutyric acid concentrations, 0.4 percent, 0.8 percent, and 1.2 percent; and 2 times of air layering, July 1 and September 1. After the air layers had been in the trees 12 weeks they were cut down and rooting determinations were made.

Highly significant differences were found between concentrations of indolebutyric acid and between dates of application as they affected the occurrence of roots. The highest acid concentration, 1.2 percent, gave the highest rooting percent for both age classes--93 percent in the 6-year-old ortets and 78 percent in the 23-year-old ortets--when layering was done on July 1. The range in rooting success varied from 16.7 to 93.7 percent, thus emphasizing the effectiveness of the treatment combination.

When number of roots per successful air layer was computed, it was found that the average per treatment ranged from 3 to 33.8. It appears that the acid treatment was most effective on 6-year-old trees in July.

From the results of this experiment it appeared likely that the optimum concentration of indolebutyric acid had not been reached for either age class. Hoekstra set up a supplementary study using 1.2 and 1.6 percent indolebutyric acid and 1.2 percent naphthalene acetic acid. On the 6-year-old ortet 150 air layers were made, 50 for each treatment. The 1.2 percent concentration of naphthalene acetic acid killed all of the air layers, and the 1.6 percent concentration of indolebutyric acid had a depressing effect on rooting, indicating that the 1.2 percent concentration of indolebutyric acid was at the top of the response curve for young slash pines. Ninety air layers were made in the 23-year-old trees, using the same growth regulators and concentrations. It appears the air layers were taken down a bit too early, since only 6 branches had rooted at the end of 12 weeks. However, of these 6 rooted air layers 5 had been treated with 1.6 percent indolebutyric acid. The inferences to be made from these data are weak, but it is not at all unlikely that older trees need more stimulation to produce roots than do young trees.

Zak (1956), working with shortleaf and loblolly pine seedlings, layered 10 of each species using 0.8 percent indolebutyric acid as a growth regulator. After 53 days the greatest rooting response difference between the two species was in number of roots formed per successful layer. Whereas shortleaf produced an average of 15.5 roots, the loblolly produced only 6.6 roots. The knowledge of species differences in response to variou stimuli should be of value to those who plan extensive projects involving air layers on several species.

A unique use of air layering to root needle fascicles has been attempted by Zak with some success. His best results were obtained by loosening a slab with an upward cut about 1/2 inch long and 1/16 to 1/32 inch deep beginning below the needle fascicle, the cut slab being held away from the stem with a piece of toothpick. Hormodin No. 3 dust was sprinkled into the wound. Sphagnum moss was applied and the treated area wrapped with polyethylene plastic. The method should be useful if it can be made to work on older trees, and if the propagules can be induced to put on height growth.

When Zak air layered 8- and 9-year-old shortleaf pine grafts using 0.8 percent indolebutyric acid, he was able to get only 1 of 33 branches to root after a 65-day time lapse. The one successful air layer formed only one short root. Since the original scion parents were 35 to 40 years old at the time of grafting, it appears that young grafts react to vegetative propagation in the same way as adult trees from which the scions were taken. This senescent response is not the kind hoped for in clonal plantations, but perhaps all is not as bad as it appears.

At Lake City this past summer some 1500 air layers were made in the course of 3 different studies on several ages of slash pine. The entire program was conducted using 1.2 percent indolebutyric acid as a growth regulator, as recommended by Hoekstra.

An irrigated seed orchard of high-gum yielders will be outplanted with air layers and grafts of proven high-gum yielding genotypes in the spring of 1957. Two hundred and fifty air layers were made on 10-year-old rooted cuttings and 3-year-old grafts. The cuttings were taken from two 27-year-old trees and one 18-year-old tree in 1944. Thus far, 34 air layer propagules have been cut down and potted from these cuttings, while 113 still remain alive in the trees. The air layering was done in June and July of this year and the first ones were potted in the middle of October. Since the primary interest is to get plantable propagules, the air layers are not cut down until at least four roots are visible along the inside edge of the plastic. At this writing, many remain in the trees without visible roots, but they are otherwise vigorous in appearance. Plans are to leave them a full year so that we can find out whether they will root or die.

An interesting growth phenomenon was noted at Lake City in 1955. Fifteen 6-year-old air layer propagules and ten 23-year-old air layer propagules were outplanted in the station nursery to observe how well the propagules could stand outplanting. Thirteen months later only one of the propagules had died. The surprising thing to note, however, was that the propagules from 6-year-old trees had averaged 3.0 feet o growth, while the propagules from the older trees averaged less than 1 foot of growth.

As a result of the afore-mentioned observation, an experiment is being conducted to test the outplanted growth response of air layers from trees 5, 10, 20, and 40-years of age. Included also will be air layers from 10-year-old rooted cuttings. At least 5 trees per age class have been air layered with 10 air layers each for a proposed outplanting. Air layering was done during the first 2 weeks in July using 1.2 percent indolebutyric acid.

Over 20 percent of the air layers from each age class, except the 40-year-age class, have been cut down and potted thus far. If roots form on the air layers of the 40-year-old trees, the propagule plantation will be established. Succulent scion material from trees within all of of the age classes will also be grafted and established in the plantation to determine what differences in growth might be expected within an age class from air layers or grafts.

Air layer success for 1956 cannot be fully evaluated yet, as all the returns have not come in. In the rooted cutting plantation, where 214 air layers were made, 30 percent of the layers died within 3 months and another 15 percent died within the next 3 months. Air layer mortality on 5-, 10-, 20-, and 40-year-old trees has ranged by age groups from 30 to 65 percent thus far. All air layers that have not died on the 5-year-old trees are now rooted (36 percent success from 70 made). Thirty percent of the air layers have rooted on the 10-year-old trees with a possibility of another 12 percent coming in (50 air layers installed). Twenty percent of the air layers on 20-year-old trees have already rooted and 48 percent are still in the trees (88 air layers made in this age group). Not one of the 42 air layers placed in five 40-year-old trees has rooted yet. However, 42 percent are still alive and may root by next spring.

An interesting thing to note is that air layers made in late June and early July began showing roots the last week in September and continue to root even now. Some individual trees have already had air layers rooting over 2 months apart, with more to come. This development causes researchers to wonder whether it is wise to rate the rooting respon of a species or age group to various treatments over a relatively short period of time--say 50 or 70 days--as we have been so prone to do.

In conclusion it would probably be appropriate to mention several problems that confront the worker who wishes to air layer:

1. The reduction of mechanical breakage of air layer branches in the tree.

2. Greater rooting success of air layers, especially in older trees.

3. The reduction of the rooting time between the first and last rooted air layer in a given tree.

Basically, we need a better understanding of the nature of the stimulus that causes rooting.

LITERATURE CITED

Cooper, W. S. 1911. Reproduction by layering among conifers. Bot. Gaz. 52: 369-379.

Kirkpatrick, Henry, Jr. 1940. Effect of indolebutyric acid on rooting response of evergreens. Prof. Paper No. 30, Boyce Thompson Institute for Plant Research, Inc. Yonkers, N. Y.

Lasschuitt, J. A. 1950. Het vormen van adventiefwortels bij Pinus merkusii. Tectona 40: 319-322.

Mergen, Francois. 1955. Air layering of slash pine. Jour. Forestry 53: 265-270, illus.

Singh, L. B. 1953. Vegetative propagation of mango (Magnifera indica L.) by air layering (gootes). Sci. 117(3033): 158-159.

Wyman, Donald. 1952. Air layering with polyethylene films. Jour. Royal Hort. Soc. 77(4): 135-140.

Zak, Bratislav. 1956. Experimental air layering of shortleaf and loblolly pine. Southeast. Forest Expt. Station Paper 69. 12 pp., illus.

PROGRESS IN NURSERY SELECTION OF LOBLOLLY, SHORTLEAF AND WHITE PINE SUPER-SEEDLINGS

by

Birger W. Ellertsen, Chief, Forest Management Section
Forestry Investigations Branch, Division of Forestry Relations
Tennessee Valley Authority, Norris, Tennessee

The selection of exceptionally tall individual pine seedlings from uniform seedbeds in the TVA Forest Nursery at Clinton, Tennessee, is now in its sixth year. The purpose of this project is to determine whether nursery selection is a feasible method of discovering genetically superior strains of forest trees. All "super-seedlings" are outplanted and kept under observation. Those continuing to show superiority will be preserved for propagation, breeding and seed production purposes. Since the last report on this study,[1] additional loblolly, shortleaf and white pine super-seedlings have been selected and annual remeasurements of older trees in the arboretum have been made. Some of the original super-seedlings of each species have continued to outgrow the controls. So far, comparisons have been made primarily on the basis of height growth, but ultimately other criteria such as form, branching habits, wood quality and resistance to disease and insect attack must also be taken into account.

Methods

Selection of 1-0 loblolly and shortleaf pine and 2-0 white pine seedlings was continued on the same basis as originally planned.[2] Exceptionally tall seedlings were first tagged and their heights measured along with the heights of the 25 seedlings nearest each of the marked trees in the seedbeds. The average of each 25-seedling sample was computed and subtracted from the height of the corresponding tall seedling. Those with the greatest differences were chosen at a maximum rate of one out of every 200,000 seedlings in the seedbed and transplanted to the arboretum. At the same time, control seedlings were selected--one from each 25-seedling sample and of approximately the same height as the computed average.

The study provides for selecting super-seedlings of each species over a five-year period. The last loblolly pine selections were made a year ago; the shortleaf pine will be completed next year; and the white pine, in 1958. So far, roughly 70,000,000 seedlings have been examined and 285 selections have been made (Table 1).

1/ Ellertsen, Birger W. 1955. Selection of Pine Super-seedlings--an Exploratory Study. Forest Science 1 (2): 111-114.

2/ Wiesehuegel, E. G. 1952. Testing Tree Progeny and Appendix to Testing Tree Progeny. TVA Div. Forestry Relations, Technical Note 14.

The super-seedling arboretum is located at the TVA Forest Nursery in Clinton, Tennessee. The control- and super-seedlings are planted alternately in each row and are spaced eight feet apart. Height measurements are recorded at yearly intervals and special ovservations whenever unusual developments occur. For example, snow storms in late 1954 and early 1956 caused considerable damage in the plantation. Individual tree observations were recorded concerning the extent of damage and subsequent recovery. More recently, tip moth has become prevalent and appropriate records are being made.

No control or corrective measures have been taken to minimize the injury caused by various natural agents. For example, some of the tip moth damage could have been prevented by spraying or corrected by early pruning of multiple leaders. Snow damage could have been lessened by knocking heavy snow accumulations off the bent-over trees and propping up those which did not straighten up at once. The trees are permitted to develop without special attention on the premise that individuals subjected to a multiple selection process will be best suited for early propagation of seed orchard planting stock. At the same time, these trees along with others that have excelled only in certain respects will be available for cross-breeding purposes.

Last year a start was made in propagating additional stock of individual trees which have exhibited one or a combination of desirable characteristics.

Results and Discussion

Eighty-six percent of the super-seedlings planted during 1951 to 1955 are still alive (Table 1). Of this number, roughly five out of every eight have continued to outgrow the controls (Tables 2 and 3).

There are now ten groups of loblolly, shortleaf and white pine super-seedlings which have been in the arboretum for one or more years. In only two instances did the tallest super-seedling of a group immediately after planting maintain its relative height superiority in succeeding years. On the other hand, super-seedlings that outgrew the rest and became the tallest of their respective groups during the first growing season after outplanting generally maintained this relative height position in succeeding years. For example, loblolly pine super-seedling No. 11 selected in fall 1951 was surpassed by several others at the start. Yet it grew to be the tallest of the group the following year. It was still the tallest four years later in fall 1956 even though its terminal bud had been killed by tip moth in the intervening period and it now has a forked top.

Among the loblolly pine, tree No. 11 selected in 1951 so far has exhibited the fastest growth rate--16.6 feet in six years. Shortleaf pine No. 7 which grew 8.4 feet in four years and white pine No. 8 which grew 3.9 feet in three years are the outstanding selections of these species. These trees not only surpassed the heights of the control seedlings, but also the average heights of trees measured in plantations throughout the Tennessee Valley.[1/]

However, height is not the only criterion that can be used in evaluating the seedlings. Differences in branching habits are showing up. Some trees, particularly among the loblolly pine, have exhibited pronounced differences in their ability to withstand snow damage. Recently an increasing number of loblolly and shortleaf pine have been damaged by tip moth and some of the fastest growing trees have been attacked. Although it is too early to tell, a special watch is being kept for individual trees that may prove resistant or able to maintain a satisfactory growth habit and rapid rate of growth.

Loblolly pine is a southern species with a natural range that excludes most of the Tennessee Valley. However, experience has shown it is adapted to a wide range of sites and for the most part, grows faster than other species being planted in the Valley. On the other hand, loblolly pine is susceptible to snow and ice damage. In the super-seedling plantation, individual trees which sustained the heaviest damage were often rapid growing trees with relatively large limbs. Some trees appeared to be stiffer than others but in general, trees with shorter, smaller branches fared best. Trees that succumbed were weighted down and bent over by the snow. In one instance, the snow melted within a day and little permanent damage occurred. In the other storm, the snow froze and held some of the trees prone for several days. Of these, 15 percent have never recovered fully and are malformed to some degree.

It is felt that snow hardiness is a particularly important criterion in making selections for use within the Tennessee Valley. While the winters are not severe, occasional heavy snowfalls occur when the snow is wet and freezes on the trees. Loblolly pine super-seedling No. 10 is an example of a tree exhibiting snow hardiness and a relatively rapid rate of growth.

Some of the shortleaf pine seedlings were also bent over by the snow, but without lasting after effects. Actually the shortleaf pine seedlings were younger and smaller than some of the loblolly pine when the storms occurred. It also appears reasonable to assume that shortleaf pine is more hardy than loblolly pine in this respect. Individual shortleaf pine trees are showing tip moth damage just as the loblolly pine, but as yet an attempt to pick out resistant trees appears premature.

1/ Allen, John C. 1953. A Half Century of Reforestation in the Tennessee Valley. Jour. Forestry 51 (2): 106-113.

There are indications that at least a portion of the shortleaf pine super-seedlings--more so than in the case of the other two species--are hybrid stock. These trees do not exhibit a typical shortleaf pine nor loblolly pine appearance but rather something in between.

The white pine has been the hardest species to select in the seedbeds. The seedlings were variable in size and many of the tallest trees tended to be spindly. The final selection was made on a dual basis where the tallest trees with the stoutest caliper were chosen. This resulted in fewer white pine super-seedlings being selected than either loblolly or shortleaf pine. To date, white pine super-seedlings have been picked at the rate of one out of every 357,000 as compared with a rate of 1:242,000 for shortleaf pine and 1:228,000 for loblolly pine. The principal comments regarding the white pine in the arboretum at this time are that the trees are thrifty and in a healthy condition and that the "supers" stand out out from the controls.

Summary

Since the last report on this study, 101 super-seedling selections of loblolly, shortleaf and white pine have been made bringing the total up to 285. The survival of super-seedlings planted through fall 1955 was 86 percent. Of this number, roughly five out of every eight have continued to outgrow the controls. The most rapid growing loblolly pine is tree No. 11 which grew 16.6 feet in six years. The shortleaf and white pine counterparts were tree No. 7 growing 8.4 feet in four years and tree No. 8 which grew 3.9 feet in three years, respectively.

Criteria in addition to height used in judging the trees include form and branching habits, resistance to snow damage and insect injury.

The study has yet to prove whether mass selection in the nursery seedbed is a feasible method of discovering genetically superior strains of forest trees. On the other hand, the method has not been disproved. At least a portion of the super-seedlings are continuing to outgrow their controls and to exhibit other desirable characteristics.

Table 1. Number of Seedlings Examined and Super-seedlings Selected from Nursery Seedbeds

Species	Year	Number seedlings examined in seedbeds	Number Super-seedlings	
			Selected and planted	Surviving Fall 1956
Loblolly Pine	1951	6,412,000	33	27
	1952	3,595,000	18	9
	1953	6,289,000	30	28
	1954	16,265,000	78	70
	1955	15,314,000	51	45
	Total	47,875,000	210	179
Shortleaf Pine	1953	2,300,000	10	10
	1954	1,735,000	6	6
	1955	2,942,000	13	12
	1956	3,672,000	15	15
	Total	10,649,000	44	43
White Pine	1954	3,758,000	9	7
	1955	4,003,000	10	10
	1956	3,316,000	12	12
	Total	11,077,000	31	29
All Species	1951-56	69,601,000	285	251

Table 2. Survival and Growth of Loblolly Pine Super and Control Seedling Selections

Year Selected	Year Measured	Number of Super-seedlings: All	Number of Super-seedlings: Outgrew Controls	Average height of seedlings, feet — All: Super	All: Control	Outgrew controls: Super	Outgrew controls: Control	Tallest seedling: Tree Number	Tallest seedling — Height, feet: Super	Height, feet: Control
1951	1951	33	-	1.3	0.6	-	-	17	1.7	0.7
	1952	27	10	1.7	1.2	2.0	1.0	11	2.5	.9
	1953	27	12	3.5	2.9	4.0	2.6	15	4.9	2.5
	1954	27	12	6.2	5.3	7.0	5.0	11	8.8	4.7
	1955	27	11	9.3	8.6	10.2	7.9	11	12.3	7.9
	1956	27	10	13.0	12.3	14.3	11.4	11	16.6	11.9
1952	1952	18	-	1.4	.7	-	-	44	1.6	.8
	1953	9	6	2.1	1.2	2.2	1.2	39	2.7	1.3[a]
	1954	9	5	3.6	2.7	3.9	2.8	45	4.5	2.8[a]
	1955	9	5	6.2	5.2	6.7	5.3	45	7.6	5.3[a]
	1956	9	6	9.8	8.2	10.2	8.1	45	11.0	8.1[a]
1953	1953	30	-	1.3	.5	-	-	70	1.7	.7
	1954	29	20	2.6	1.5	2.7	1.4	72	3.6	1.4
	1955	28	23	5.3	3.9	5.3	3.7	71	6.8	5.4
	1956	28	24	8.5	6.8	8.7	6.6	72	10.5	6.7
1954	1954	78	-	1.3	.5	-	-	111	1.6	.6
	1955	70	43	2.5	1.5	2.6	1.5	113	3.7	1.6
	1956	70	50	5.0	3.8	5.2	3.6	113	7.4	4.3
1955	1955	51	-	1.2	.5	-	-	197	1.7	.7
	1956	45	18	1.9	1.2	2.2	1.1	206	2.6	1.7

[a] Estimated values based on all living controls of similar seed source and age since paired controls of super-seedlings 39, 41, 43 and 45 died during the first year.

Table 3. Survival and Growth of Shortleaf Pine and White Pine Super and Control Seedling Selections

Year Selected	Year Measured	Number of Super-seedlings: All	Number of Super-seedlings: Outgrew Controls	Average height of seedlings, feet: All: Super	Average height of seedlings, feet: All: Control	Average height of seedlings, feet: Outgrew controls: Super	Average height of seedlings, feet: Outgrew controls: Control	Tallest seedling: Tree Number	Tallest seedling: Height, feet: Super	Tallest seedling: Height, feet: Control
				Shortleaf Pine						
1953	1953	10	-	1.0	0.4	-	-	7	1.2	0.6
	1954	10	8	2.2	1.2	2.3	1.2	7	3.0	1.5
	1955	10	9	4.1	2.6	4.2	2.6	7	6.1	3.4
	1956	10	9	6.1	4.0	6.4	4.0	7	8.4	5.3
1954	1954	6	-	1.2	.5	-	-	14	1.5	.6
	1955	6	5	2.1	1.1	2.1	1.0	11	2.4	1.3
	1956	6	5	2.8	1.8	2.8	1.6	11	3.6	2.3
1955	1955	13	-	1.2	.5	-	-	28	1.4	.6
	1956	12	6	2.0	1.1	2.2	1.0	25	2.8	.9
				White Pine						
1954	1954	9	-	1.3	.6	-	-	8	1.5	.7
	1955	7	7	2.0	.7	2.0	.7	8	2.7	.9
	1956	7	7	2.8	1.1	2.8	1.1	8	3.9	1.6
1955	1955	10	-	1.1	.4	-	-	15	1.3	.5
	1956	10	4	1.6	.8	1.7	.7	a/	1.7	.8

a/ Super-seedlings 11, 13, 14 and 18 were all 1.7 feet tall. The average height of their paired controls was 0.8 feet.

CONTRIBUTIONS OF SILVICULTURAL PRACTICES OTHER THAN GENETICS TO FOREST TREES

by

T. O. Perry and Wang Chi-Wu
School of Forestry, University of Florida,
Gainesville, Florida

The genetic improvement from past work with agricultural crops can be classified into three types. One type of improvement is that in which the crop is bred for resistance to some type of disease or insect damage. The ability to or the ability not to raise a given crop may depend upon the success of this type of breeding program. A second type of improvement is through the selection and breeding to increase the proportion of some particular chemical constituent of the plant. Selection and breeding with sugar beet varieties has increased the sugar content from six to more than twenty percent for a 3.3 fold increase. Similar increases have been obtained by selecting strains of rubber trees with high latex yielding capacities. Where the photosynthetic productivity is not altered but rather the relative proportion of some constituent of the plant is increased, selection and breeding has usually resulted in increases in productivity in the range of 300 to 400 percent. The third type of improvement through selection and breeding is in the increase in general productivity of the plant with regard to gross volume production, say in bushels per acre in corn or wheat or tons of hay, or quanitty of cellulose fiber per acre. This third type of improvement is the one that has gained the widest reputation among laymen and is the one about which there is the greatest misunderstanding. Past experience of selection and breeding programs with corn, wheat, sorgham, peanuts and so forth indicates that selection and breeding programs have increased the growth productivity of these plant crops in the order of 25 to 30 percent. These three types of genetic improvement might be succinctly designated as the all or none, the qualitative, and the quantitative. All three types of genetic improvement have been the result of many generations of selection and breeding.

Trees, unlike agricultural crops, have not been cultivated for thousands or ten thousands of years and have not undergone a previous history of selection and breeding. Even the old open-pollinated varieties of agricultural crops represent the best of selections that have had their origins in the pre-Egyptian times of 3,000 B. C. Therefore, it is reasonable to expect that we will have considerably greater increases in productivity from our early genetics work with trees. It is not reasonable, however, to expect, as some publications do, that increases of 50 to 300 percent will be realized from the first generations of selection and breeding with forest trees. While it is not possible to predict precisely the increases to be made in our early selection and breeding work, increases of magnitudes much larger than 15 to 30 percent seem unreasonable.

Faced with our expanding population which has already made the timber resource review report out-of-date, and our diminishing supplies of fossil fuels and raw materials, one must expect that the demands upon the plant growth of trees will increase considerably over the next 15 to 200 years. If forestry is to meet these demands, we must find some means of increasing forest production other than the method of tree improvement through selection and breeding. Fertilization and cultivation are two obvious methods of increasing the productivity of forest lands. Heretofore, such practices were not economically feasible because of the low price of wood as a raw material. However, there has been a tremendous increase in the price of this product from almost nothing before World War II to $5.00 to $7.00 per cord on the current market. Soil site index studies by Barnes and Ralston[1/] and others have indicated that plantations in the southeast coastal plain are growing at very rapid rates. The general evidence is that five to ten percent of our lands in the southeast coastal plain are capable of growing better than two and a half cords of wood per acre under current management and planting practices. General evidence from the literature and studies in this country and abroad indicates that cultivation can increase the annual volume growth per acre by about 85 percent. Similarly past experience has indicated that we can expect a 65 percent increase in productivity through the use of fertilizers on our better sites.

Let us examine the production to be realized from fertilization, cultivation, and genetics improvement when combined on a hypothetical land management case.

On the best five to ten percent of our land in the southeast coastal plain a potential yield of two and a half cords per acre is obtainable with our current planting and management practices. Suppose a program of land management that calls for clearing and cultivation of the land with modern heavy machinery at a cost of twenty dollars per acre, and suppose this land is cultivated twice a year after planting for three subsequent years, with a cost of $15 per acre for cultivation. The total cost of such a cultivation program including compound interest at five percent semi-annually would be $214.60. If this cultivation increased productivity of the land 85 percent, the increase would be from two and a half cords per acre per year to 4.62 cords per acre per year for a total production increase of 2.12 cords per year for twenty-five years. This increase would amount to 53 cords and at $7.00 per cord would yield a $370.10 gross return. The net return on the investment of cultivation would therefore be $165.60; a net profit of 77 percent after deducting the annual costs of cultivation and an interest of five percent compounded semi-annually for 25 years.

[1/] Barnes, R. L. and C. W. Ralston. 1955. Soil factors related to growth and yield of Slash pine plantations, Bulletin 559, Agricultural Experiment Station, Gainesville, Fla.

Three hundred pounds of the typical commercial fertilizer costs about $6.00 and the cost of application would be about $4.00. Therefore, if we fertilize an acre of land with 300 pounds of 4-7-5 every third year with a cost of $10.00 per year, the total cost of fertilization at the end of the twenty-five year period including five percent interest compounded semi-annually would be $147.17. If this fertilization increased productivity 65 percent from the base of two and a half cords per acre per year, the increase in production would be 1.62 cords per acre per year or an increase of 40.6 cords for a twenty-five year period, which if valued at $7.00 per cord, would be a gross return of $284.00. The net return of the investment of fertilization is $136.87, a profit of 93 percent over and above the cost of application and the usual interest costs of five percent compounded semi-annually. A 2.1 cord per acre increase from cultivation and a 1.62 cord per acre per year increase from fertilization brings the cord production of our base acre of land to 6.24 cords per acre per year as a potential growth. When high quality selected trees are available as seed sources in orchards we can expect the production of seed to be cheaper than it is at present. Therefore, for practically no cost for a hypothetical genetic improvement of 30 percent (30th of 6.24 cords) we will increase the productivity another 1.87 cords per acre per year to put the total per acre production to 8.11 cords per acre per year with the combined intensive management practices of the use of cultivation, fertilization, and genetics.

Those who find difficulty in imagining this picture of a threefold increase over the base level of production as we have it today with current management practices should realize that this discussion pertains only to the best acre in 10 or 20, and that undoubtedly these increases will not be economically obtained from all of our land.

NEW DEVELOPMENTS IN FOREST GENETICS RESEARCH PROGRAMS AROUND THE COUNTRY

by

Stephen N. Wyckoff
Forest Genetics Research Foundation

To the best of my knowledge, no other newly developed field of forest research has been as enthusiastically received as forest genetics. Widespread interest and support have provided working facilities and financial aid at a rapid rate. This enthusiastic acceptance brings both opportunity for expansion of the work and responsibility to organize the research effort so as to proceed toward the desired goals in an orderly manner. Orderly progress is secured when every study contributes to the attainment of some broad objective, when there is no duplication but sufficient replication of research, when each research worker knows what others are doing and when the results of research are made available as rapidly as possible. It may therefore be worthwhile to survey briefly the research in forest genetics now under way in the several major forest regions of the country, to discover any nation-wide tendencies that may be developing and their significance.

The following survey is necessarily general because records for a more detailed study are not available. I have merely attempted to determine the genera and species being studied in each region and the kinds of studies being conducted. The studies have been placed in a few very broad subject matter categories which could be revised and made more specific if the necessary information were available. The categories here used are:

1. Racial studies. This category includes all seed source or provenance studies and all studies of geographic variation of species, and the testing, with clones or seed progeny, of forms recognized through such studies.

2. Selections. The search for and selection of superior phenotypes and the testing of their progeny under a range of environmental conditions. The purpose is to obtain genotypes superior in growth rate, form, resistance to parasites or superior in other respects, for use as parent stock in breeding, or as a source of seed for large scale plantings.

3. Species hybridization. This may be for the general purpose of study of a genus, to determine species relationships and crossability and where heterosis may occur. Or it can be more specific in purpose, for the development of hybrids of practical value.

4. Racial hybridization. This is to develop superior forms within a species.

5. Studies of vegetative propagation. Forest geneticists recognize the value of vegetative propagation as a tool in research and in the development of seed orchards.

6. Studies of flower induction. The value of frequent and abundant seed crops is universally recognized by forest geneticists.

7. Fundamental studies. This includes studies of physiology, cytology, polyploidy, taxonomy and other subjects which provide basic knowledge for research in forest genetics or which may bring results of direct practical value.

Much information for this survey was obtained from Jonathan Wright's very valuable "Directory of Forest Genetics Education and Research in the United States and Canada." This was supplemented with later information which workers in the several forest regions were kind enough to send me. Altogether, these various sources give a general summary of current research throughout the country.

As we should expect, we find that in each forest region most of the forest genetics research is concentrated on the timber species of greatest local value. Thus in the Far West (the Rocky Mountain and Pacific Coast states) Douglas-fir and several species of pines are receiving the most attention. In the pines, ponderosa pine and its closely related species, the white pines and lodgepole pine are the principal subjects of study with some special work on Monterey pine and its closely related species. The white pine investigation is part of a national and international project for development of forms resistant to the white pine blister rust and possessing desirable growth characteristics, in which three of our forest regions and many workers in Canada are cooperating by exchange of information and experimental materials. The Far West's special interest in this study is the protection of western white pine and sugar pine. One pine study in the West, the general study of pine hybridization by the Institute of Forest Genetics at Placerville, California, applies to the entire genus and is not limited to the species of the region.

Studies of geographical variation of ponderosa pine and Douglas-fir which should yield valuable results are also under way in the West. It is believed that the tremendous variety of environmental conditions under which these species occur has given rise to numerous forms, variously called races or ecotypes, and that knowledge of these forms will be indispensable to the improvement of these species. Several studies of individual tree selection of Douglas-fir and of vegetative propagation and flower induction in pines and Douglas-fir are also being conducted in this region.

When we direct our attention to the North Central region we find that three genera, the poplars, pines and spruces, are winning the race for attention by forest geneticists. In the pines, the three most important species, the red, white and jack pines, are receiving the most attention. As for the spruces, the indigenous black and white and the exotic Norway spruce are the subjects of research with several other exotic species being used in experimental species hybridization. In the poplars, the aspens seem to get the most attention, with practically every institution in the region that is conducting forest genetics research working on them. In this region, racial studies, species hybridization, individual tree selections and studies of vegetative propagation and flower induction are the most numerous. A number of studies under several of these categories are directed toward the development of forms resistant to diseases and insects. This region is participating in the study of white pine resistance to blister rust which I have mentioned, with the particular interest here in eastern white pine. Other studies pertain to resistance of poplars to canker diseases.

The Northeast region shows a somewhat different pattern in regard to the species being studied. As in the North Central region, pines and poplars are getting the most attention, but they are evidently followed by chestnut and maple. However, most of the work on chestnut consists of selections and testing of hybrids for resistance to chestnut blight, and much of it on maple pertains to sugar yield. Spruce, hemlock, ash, larch and birch are also being studied. Racial studies seem to be most numerous in the Northeast, followed by species hybridization, studies of vegetative propagation, flower induction and cytology.

I hesitate to make many comments concerning forest genetics research in the South before this audience. So I shall merely say that the records show that a very great proportion of your work is on your native species of pines, with some effort being expended on maple, chestnut and bald cypress. As to the types of studies you are conducting, racial studies seem to be most numerous, followed by individual tree selections, species hybridization and flower induction studies. A number of your studies pertain to disease resistance.

When we merge these regional summaries into national totals we find that work on the pines is in the lead throughout the nation. The poplars are second, followed by spruce, if we disregard the special work on chestnut and maple. The high rating of the poplars is due to their importance in the North Central and Northeast regions. They may, however, assume some future importance in the Pacific Northwest.

When we consider the number of commercially valuable pine species in the country, the numerous uses to which they are put and the fact that they constitute nearly one-fourth of the nation's forest growing stock, we will doubtless agree that our forest geneticists have done well to make them the principal subject of study.

There are two points concerning this national pattern of research which I think merit comment. When we consider the wide distribution of the spruces, true firs and hemlocks, their many uses and the fact that they constitute one-fifth of the nation's growing stock, I feel that they merit more attention than they are getting. Both by volume and area they represent a large and permanent part of our forest resources. Their improvement should pay big dividends.

My second comment is that in our national pattern of forest genetics research the hardwoods, of which walnut, oak and cherry are examples, that have been in constant use by the American people throughout our history, and which we value so highly and use so much in our daily lives, simply do not appear to any appreciable extent in our present effort. Surely they merit it. I am not so rash as to propose that the softwood research program be curtailed to permit work on the hardwoods, but I do suggest and hope that an adequate portion of the future expansion of our national research effort be devoted to the hardwood species. For some time the Foundation has been hoping to receive a comprehensive and thoughtful plan for a program of forest genetics research on these species.

The nation-wide summary shows that racial studies head the list in every region. The others which are evidently considered of major importance are species hybridization, individual selections, vegetative propagation studies, racial hybridization, and flower induction studies. These are followed by such fundamental studies as cytology, taxonomy, physiology, polyploidy and wood technology, as they apply to forest genetics.

It seems logical to expect that our research in forest genetics will follow the two traditional avenuse of plant genetics: first, the improvement of natural forms through selection and second, the development of new ones by hybridization, both intra- and interspecific. To this we should add the testing of natural polyploids and the formation of new ones, in a few forest tree genera. If our development is to follow these avenues we seem to be on safe ground with the principal lines of work which we have under way. The emphasis on racial studies and selection seems particularly fortunate in these early years of our work in forest genetics research. They will bring results of practical value and will provide the materials for breeding. Studies in vegetative propagation and flower induction seem necessary for the development of two powerful tools needed for research and seed orchard management, and it is well to start them early. Exploratory programs of species hybridization are invaluable in helping to determine species relationships within a genus, and in seeking hybrid vigor. But I suspect that the most fruitful work in this field will be done when we have accumulated much more knowledge of the species with which we are working than we now possess. Racial hybridization will doubtless increase as racial studies provide more requisite information.

Fundamental studies in taxonomy, cytology, physiology, polyploidy and wood technology as related to forest genetics are fewer in number than those discussed above, but their importance should not be overlooked. The fundamental knowledge that they provide is the basis upon which many of the other studies must stand. Failure to provide for their continuation and expansion will ultimately stunt the research in the fields generally considered to be of more practicability. We hope that workers in forest genetics a decade or more hence will not reproach us for not having prosecuted these basic studies more vigorously.

This summary of the present research program leads me to a brief discussion of the activities which the Forest Genetics Research Foundation proposes to conduct. Our program is set up under two general subject headings: grants for research and education, and what we are calling general assistance to research. The first heading is self-explanatory, and all that needs to be added is that we propose to make grants to research projects which will contribute significantly to the development of forest genetics. For educational purposes, we propose to make grants to carefully selected individuals possessing special qualifications for research who are in need of financial help to complete their advanced training. Much of this will be in preparation for the Ph.D. degree, but we may have occasion to assist in post-doctoral studies.

Our plans for general assistance to research are not yet final because we propose to be guided to a considerable degree in this activity by the suggestions of research workers throughout the country. There is, however, one initial undertaking which we propose to conduct in the near future. I stated earlier in this discussion that my summary of current research in forest genetics is of limited value because it is based upon partial information. To provide a more accurate and complete basis for planning our work and for the benefit of others who may need the information, we plan to conduct a survey which we hope will constitute a project inventory of forest genetics research in the United States. We shall ask every institution conducting such research for a brief statement on each study, including project title, a brief description of the study (probably 200 words) and the names of the individuals working on it. When this information is brought together it will be classified by subject matter categories established with the advice of forest geneticists, and by forest regions. We then plan to discuss the work in each region with a representative regional group which we hope in each case will be the regional forest tree improvement committee. Such a discussion should consider carefully the nature and scope of the research currently under way in the region and arrive at a mutually acceptable conclusion as to what new projects should be started, or what current projects strengthened, to round out most effectively the pattern of regional research. By this procedure we hope that the Foundation can establish guide lines for future activities based on accurate and detailed information, and developed cooperatively with, and to the satisfaction of the technical workers in each region.

This survey will necessarily be made by mail, and we shall ask for the support and assistance of each regional forest tree improvement committee in the undertaking. As soon as possible we also want to have a representative of the Foundation visit each institution conducting research in forest genetics.

My personal contact with forest genetics research workers in various parts of the country leads me to believe that in the course of this survey we shall receive enough practicable suggestions for the Foundation's general activities to keep us more than busy. Some suggestions that have thus far come to us are that we might assist in the publication of research results of general interest, and that we might assist in the publication of research results of general interest, and that we might sponsor meetings on special research topics, bringing together for several days a number of individuals having one primary interest for exchange of information and ideas. We invite comment on these proposals and your suggestions for other activities.

PUBLICATIONS AND REPORTS PREPARED IN COOPERATION WITH THE COMMITTEE ON SOUTHERN FOREST TREE IMPROVEMENT:

Report of the first southern conference on forest tree improvement. Atlanta, Georgia, January 9-10, 1951. U. S. Forest Serv., Atlanta, Ga. (Mimeo.)

Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1951. (Mimeo.)

Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1951. (Mimeo.)

Hereditary variation as the basis for selecting superior forest trees. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Expt. Sta. Paper 15. 1952.

Directory of forest genetic activities in the South. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Expt. Sta. Paper 17. 1952.

Working plan for cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Sources of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1952.

Suggested projects in genetic improvement of southern forest trees. Committee on Southern Forest Tree Improvement. Southeastern Forest Expt. Sta. Paper 20. 1952.

Testing tree progeny. A guide prepared by the Subcommittee on Progeny Testing, E. G. Wiesehuegel, Chairman. Tennessee Valley Authority, Technical Note No. 14. 1952.

Report of the second southern conference on forest tree improvement. U.S. Forest Serv., Atlanta, Ga. 1953. (Mimeo.)

Progress in study of pine races. Philip C. Wakeley. Southern Lumberman 187(2345): 137-140. December 15, 1953.

The role of genetics in southern forest management. Special subcommittee of the Committee on Southern Forest Tree Improvement, Bruce Zobel, Chairman. Pt. 1, Forest Farmer 14(1): 4-6, 14-15. Pt. 2, Forest Farmer 14(2): 8, 14-19. Pt. 3, Forest Farmer 14(3): 8-9, 14-15. (Reprint, 11 pp. 1954.

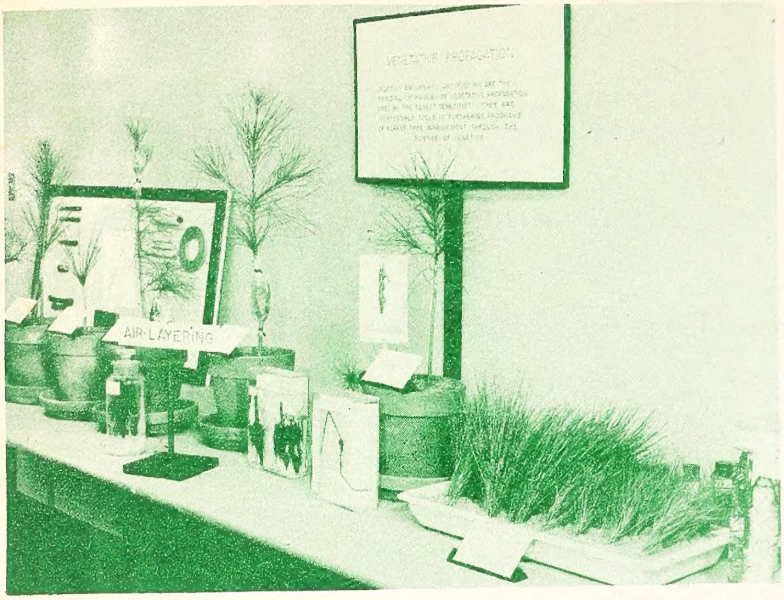
Proceedings of third southern conference on forest tree improvement. Southern Forest Expt. Sta. 1955.

Better seed for better southern forests. Subcommittee on Genetic Control of Seed, T. E. Maki, Chairman. N. C. State College School of Forestry Tech. Rpt. 9. 1955.

Forest tree improvement for the South. Committee on Southern Forest Tree Improvement, T. E. Bercaw, Chairman. 1955.

Supplement No. 1 to the original working plan of September 12, 1952, for the southwide pine seed source study. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman.

Time of flowering and seed ripening in southern pines. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman, and John C. Barber. Southeastern Forest Expt. Sta. Paper 72. 1956.



Compiled and Processed by the
Southeastern Forest Experiment Station
Forest Service, U. S. Department Of Agriculture
School Of Forestry, University Of Georgia
Georgia Forestry Commission

May, 1957