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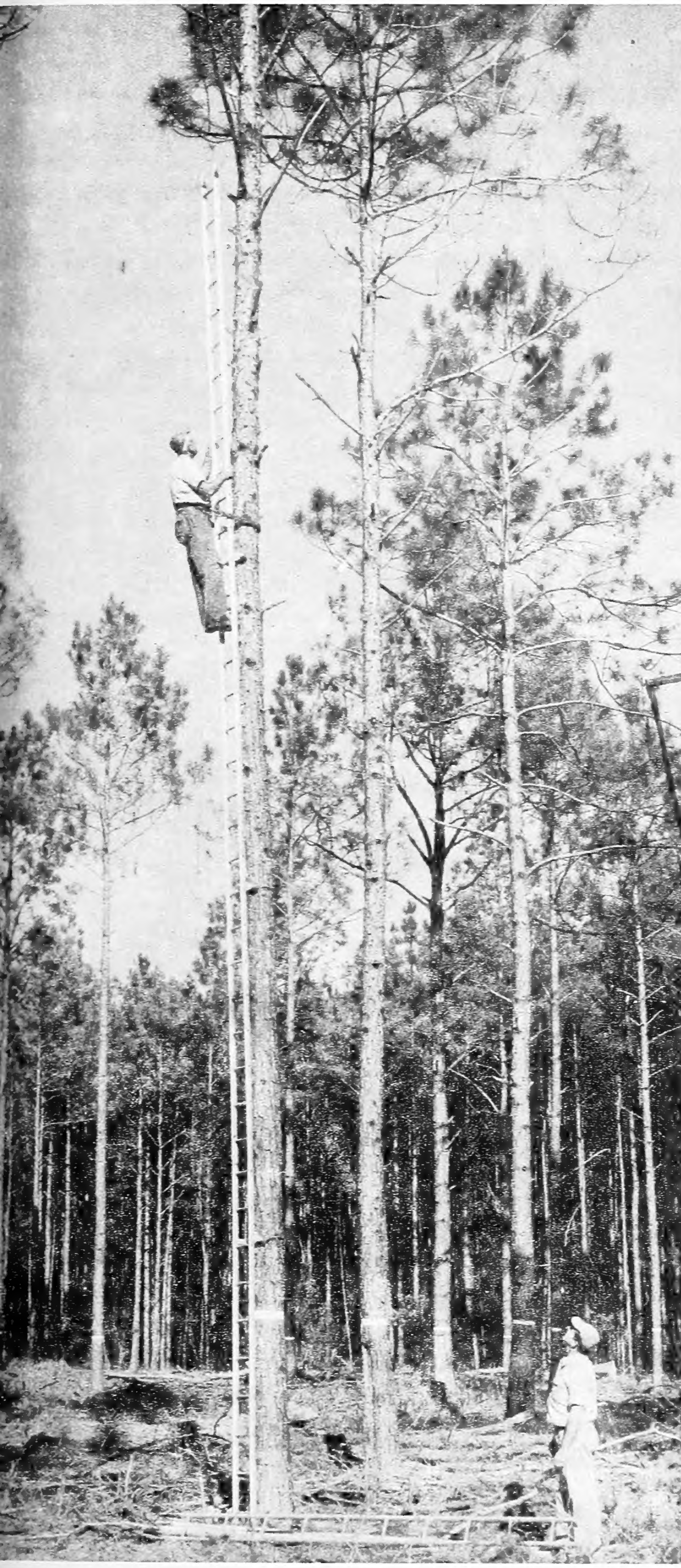

Tree Improvement Research at the Lake City, Florida, Research Center

A Project Analysis

by

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and

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Director

U. S. Department of Agriculture - Forest Service

FOREWORD

Forest genetics at the Lake City, Florida, Research Center is financed jointly by the Florida Board of Forestry and the U. S. Forest Service. Another cooperative agreement with the University of Florida's School of Forestry provides for the exchange of technical information on the project and joint use of facilities.

Initially this research program was concentrated on the inheritance of gum production, a field in which the basic relationships have now been determined and one in which this project will continue to provide leadership. Turpentining, however, no longer is the major end product of slash and longleaf pine in this region. Naval stores now is being integrated with other forest use. Therefore, the improvement of growth rate, quality, and resistance to disease and insects must also be considered. It has already been determined that gum yield is correlated with growth rate. Thus, primary emphasis is being given now to improvement of growth and quality, with gum yield as a secondary objective.

The Lake City Tree Improvement Project complements correlated research in other southern research centers, i. e., the fundamental southwide studies at the Southern Institute of Forest Genetics, Gulfport, Mississippi; the applied aspects of tree selection and breeding being undertaken cooperatively by the State of Georgia and the Southeastern Forest Experiment Station at Macon and the University of Georgia School of Forestry at Athens, Georgia; the educational and research program in Forest Genetics at the School of Forestry, University of Florida, Gainesville, Florida; the research and educational program in Forest Genetics of the Texas Forest Service, College Station, Texas; and related projects at Crossett, Arkansas, and elsewhere in the South.

The first efforts in forest genetics at Lake City were begun by V. L. Harper as early as 1929. In 1935-1936 T. A. Liefeld established the first gum inheritance tests. The present program was initiated in 1941 by H. L. Mitchell; field work was started in 1942 by Albert G. Snow, Jr., Keith W. Dorman, and C. S. Schopmeyer. It was carried on during the period 1943-1948 by Keith W. Dorman, and continued by A. A. Downs until placed on a maintenance basis for lack of funds in 1949. Two years later T. O. Perry spent a few months on the project before accepting a formal appointment at the University of Florida. In 1952 François Mergen began an intensive study of vegetative propagation while reactivating all previous studies and initiating needed additional studies, with the assistance of Pieter E. Hoekstra, Wm. H. Davis McGregor, Elwood E. Miles, Johnnie K. Dobson, Jr., Doris Ray, and Lillian Gemmer. The project now is under the general supervision of Research Center Leader Kenneth B. Pomeroy, Mergen having accepted a research-teaching professorship in forest genetics in October 1954 at Yale University, New Haven, Conn.

The authors gratefully acknowledge the contributions of all their predecessors and associates. Special recognition is extended to J. W. Duffield, Forester, Forest Industries Tree Nursery, Nisqually, Washington; J. W. Wright, Geneticist, Northeastern Forest Experiment Station, c/o Morris Arboretum, Chestnut Hill, Pennsylvania; Bruce Zobel, Silviculturist, Texas Forest Service, Forest Genetics Laboratory, College Station, Texas; and C. E. Ostrom, Chief, Division of Forest Management, Southeastern Forest Experiment Station, Asheville, North Carolina, for their helpful suggestions during technical review of this project analysis.

E. L. Demmon

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INTRODUCTION

The expanding economy of the Coastal Plain Region of Florida and Georgia received much of its initial impetus from the turpentining and lumbering of virgin slash and longleaf pine forests. This virgin resource was finally depleted and for the past three decades most of the gum and lumber has come from second-growth stands. The new trees, being younger and smaller, produced less gum and poorer quality lumber. Consequently, there has been a gradual decline of the gum naval stores and lumbering industries since 1929.

During the same period, the pulp and paper industry became established in the Coastal Plain region and year by year made increasing use of the young second-growth forests. This expansion, by offsetting the decline in the older industries, has enabled forestry to maintain its place in the regional economy. However, this is not sufficient. An appraisal of current trends and future needs indicated that resources used by forest industries should be improved as much as possible. This conclusion is supported by Stefan H. Robock's analysis (40) of "Industrialization and Economic Progress in the Southeast." Exerpts from this report follow: "Over the period 1939 to 1947 more than 550,000 production workers were added to the labor force in the Southeast, a gain of 46 percent. The most important sources of new factory jobs were: (1) Lumber and products (excluding furniture), (2) textiles, (3) food and kindred products, (4) chemicals, and (5) apparel. In 1952 manufacturing employment in the Southeast was about 10 percent above the relatively high 1947 level. During the 1947-1952 expansion period the paper industry replaced lumber products in providing the largest number of new jobs. The forest resource alone accounted for one out of four new factory jobs established in the Southeast."

Increased factory employment is the most effective means of increasing the general level of welfare in the region. The rapid increase in the Southeast per capita income (still below the National average) has been largely due to the region's shift from a predominantly agricultural area to an expanding industrial region. From 1929 to 1952, factory jobs in the Southeast expanded by 74 percent, whereas farm employment declined by 43 percent. In terms of future possibilities the opportunities in manufacturing appear to be even greater than in farming.

During the decade 1940 to 1950, 814, 000 workers left agriculture, there were 2, 070, 000 new entrants in the labor market, and 767, 000 unemployed found work, or a total of 3, 651, 000 individuals. These workers were distributed as follows; 2, 500, 000 entered new nonfarm jobs, the armed forces expanded by 246, 000 persons, and 905, 000 workers migrated out of the region.

Anticipated growth in population during the 1950 to 1960 decade will cause an increase in the labor force of approximately 2. 3 million in the Southeast. The movement out of agriculture can probably make another 600, 000 workers available for nonfarm jobs. Thus, almost 3 million new nonfarm jobs will be required by 1960. With more available workers and more population in the region, large numbers of new jobs will be needed to maintain the present level of per capita income.

How will the forest industries meet their share of the economic load in future years? Will it be through depletion as during the period of initial exploitation, or can the forest resource be increased to keep pace with additional demand?

At present, net growth and drain of all tree species are approximately in balance in the Georgia-Florida Coastal Plain. But there are some severe internal stresses. Large sawtimber-size trees required for the manufacture of quality lumber are disappearing rapidly. And inferior hardwood species, particularly scrub oaks, are claiming much land that formerly supported pine forests. Nevertheless, much, but not all of the increasing need can be met through better utilization of low-value species, improved stocking of present stands, reforestation of denuded areas, control of noncommercial weed species, and fire protection.

These intensive practices have a predictable maximum effect in raising the available volume of forest products per acre. To go beyond this limit, it will be necessary to increase the inherent ability of trees to yield more oleoresin, more cellulose per unit volume of wood, or a better quality product. These and kindred objectives are the ultimate goal of the Tree Improvement Program of the Lake City Research Center.

SCOPE

Major emphasis in the Tree Improvement Program will be given to development of faster growing, better quality, higher yielding, disease and insect resistant slash and longleaf pines in the Coastal Plain of Georgia and Florida.

Although the objectives are to solve problems within this area, the results will be of regionwide, nationwide, and of profession-wide value and interest. The fundamental findings will be particularly useful.

In the subregion Florida and South Georgia, commercial forests occupy 32,135,400 acres, or 63 percent of the total land area (table 1, appendix). Slash and longleaf pine types make up 60 percent of the forests, (table 2) while another 7 percent should be in pine but is now covered with worthless scrub oak.

These slash-longleaf pine forests support 93 percent of America's gum naval stores industry (tables 3 and 4) and in addition furnish the major source of other forest income within the Coastal Plain. For example, in 1948 pine provided 78 percent, hardwood 12 percent, and cypress 10 percent of the commodity drain in Florida (21). Pulpwood accounted for 34 percent and saw logs 31 percent of the total cubic volume harvested. Veneer bolts, poles, cooperage bolts, and piling, ranked in order of importance, together made up another 7 percent of the total cut. The remaining volume was used for chemical wood, fuel wood, hewn ties, posts and other products of little concern in a tree improvement program.

Statistics for Florida and Georgia indicate a total income from forestry of nearly one billion dollars.[1] This figure represents the wholesale manufactured value of all products. Pulpwood accounted for 67 percent and lumber 15 percent of the total. The pulp and paper industry in the United States is the fifth largest and third fastest growing industry. However, the stumpage value of sawtimber exceeded that of pulpwood by a ratio of approximately 2 to 1.

Estimates of the sources of forest income in Florida and Georgia (table 5) indicate that efforts to improve slash and longleaf pines should be directed, first, toward better quality and more rapid growth of trees to be utilized by the lumbering and pulpwood industries, and second, toward improvement of gum yield for the naval stores industry. The veneer, pole, and piling industries likewise will benefit indirectly from efforts to improve trees for sawtimber and pulpwood.

1/ News releases of Florida Forest Service and Georgia Forestry Commission.

DISCUSSION OF THE MAJOR PROBLEMS

Production of seedlings with superior qualities is the most important problem and the one likely to yield the greatest return. Nearly eight million acres, or 30 percent of the area suitable for pine, is in need of planting (table 6). In addition many acres of partially stocked pole-size stands will be clear cut and replanted to more desirable species in order to bring these areas into full production (table 7). Plantations established within the region considered in this problem analysis cover about 700,000 acres (41). The all-time peak in seedling production was reached in 1953 with 73,000,000 in the Florida State nurseries,[2/] 93,000,000 in the Georgia State nurseries,[3/] and perhaps another 30,000,000 in private nurseries. Less than 1 percent of those planted in the Coastal Plain were longleaf pine. Some loblolly pines were planted in Georgia but slash pine has been the predominant species. Unfortunately, most of the seedlings planted to date have been of ordinary, and sometimes inferior parentage. Foresters in both States recognize this deficiency and are taking steps to improve the quality of stock for future plantations. Present estimates indicate a reforestation program of about 150,000 acres annually for the next decade within the slash-longleaf pine belt of Florida and Georgia.

Development of better genetic seedlings involves several intermediate stages:

1. Identification of the best racial strains.
2. Location of the best stands, and establishment of seed production areas.
3. Better seed collection practices, i. e., seed from better phenotypes.
4. Finding individual parents of superior attributes.
    a. Rapid growth rate.
    b. Early juvenile growth of longleaf pines.
    c. Resistance of longleaf pines to brown spot disease.
    d. Resistance of slash pine to fusiform rust.
    e. Good form, straight grain, high density.
    f. Development of hybrids for special purposes.
5. Establishment of seed orchards for the production of improved strains of seedlings.
6. Development of criteria for selecting the best seed trees in stands to be regenerated naturally.
7. Improve the yield of oleoresin from living pines.

2/ Personal communication from C. H. Coulter, 1954.
3/ Personal communication from Guyton DeLoach, 1954.

For the time being and perhaps for many decades to come, most harvested stands will be regenerated naturally. Past turpentining and logging practices have been conducive to stand degradation, as economic incentives have always resulted in utilizing the largest and best quality trees first.

Coupled with this lowering of growth rate, quality, and yield, is a failure of some timber types to regenerate adequately. Of course, carelessness with fire and poor cutting practices have an important effect on the establishment of seedlings, but table 8 indicates that the problem of natural regeneration may be more complex. This tabulation indicates that on the average whenever a southeast Georgia landowner harvested 100 acres of pine or upland hardwood timber, 86 acres have restocked naturally and only 14 acres needed to be planted. But in northeast Florida only 56 acres would restock naturally, and in south Florida only 27 acres. Is this striking difference due to site, climate, fruitfulness of seed trees, viability of seed, seed losses to insects, disease, or rodents, or perhaps some combination of all factors?

As for improving oleoresin yield, in bygone days of cheap labor and virgin timber one man could chip 10,000 faces each week and produce 300 barrels or more of gum per year with the aid of dippers and other woods laborers. Today a good worker can still chip a crop if he uses bark chipping and acid treatment on a 14-day schedule, but the average yield had declined to 192 barrels per crop. Smaller trees and fewer faces per acre account for the decline. In contrast, agricultural workers have increased their productivity two or three fold in the past two decades with the aid of new mechanical devices, improved cultural techniques, and better strains of cultivated plants. Workers in forest industries other than turpentining also have increased their output per man-day of labor. Consequently, the gum producer has been forced to raise wages without securing a corresponding increase in productivity. These high production costs, coupled with unstable markets and severe competition from substitute products, have reduced the gum naval stores industry to one-third of its predepression size.

While the gum naval stores industry currently is at a low ebb, an analysis by Schopmeyer (43) indicated that future production of rosin from stumps and as a by-product of the sulfate pulp industry cannot supply the total domestic and export market. Consequently, there will be a continuing need for gum rosin, and rosin constitutes nearly 80 percent of the dollar value of the naval stores industry.

In order to take advantage of the potential market, gum producers must increase the productivity of their laborers, and this can best be accomplished by increasing the yield of gum per tree. The yield level of virgin timber can be regained by growing present stands to larger size before turpentining. This will afford some relief but still does not enable turpentiners to match the increased output per man-day in other industries. Nor is there any prospect that some new technique will greatly increase the gum yield of wild stands. But it may be possible to grow cultivated stands in which each tree will yield several times more gum than the average forest tree of similar size (8). A yield increase from a 200-barrel average to 400 barrels per crop would save about 6 man-hours production labor per barrel. At $0.80 per hour, the rate being earned in the Olustee Farm woodland study, such a labor saving would be worth $4,800,000 annually to an industry producing 1,000,000 barrels of crude gum each year.

In developing the gum yield objective it will also be necessary to include rate of growth, quality, disease, and insect resistance so that naval stores pines may ultimately be used for other forest products as well.

REVIEW OF PAST AND CURRENT WORK

IDENTIFICATION OF GEOGRAPHIC STRAINS IN SOUTHERN PINES

A knowledge of those variations in a tree species which are determined by provenience or source of collection, helps to define the area which can benefit directly from a forest tree improvement program. Failure to utilize the information on racial strains in planting or breeding programs can cause significant losses. Results from a preliminary study by Wakeley (47) with loblolly pine illustrated the financial losses brought about by planting trees ill-adapted to a particular area. This stimulated a South-wide cooperative seed source study of loblolly pine, longleaf pine, shortleaf pine, and slash pine by the Committee on Southern Forest Tree Improvement. The task is being directed and coordinated by Wakeley (46). One of the outplantings of the slash pine seed sources is located in Baker County, Florida (G-20). The analysis of height measurements of the 2-year-old seedlings showed that the seedlings grown from seed collected in Polk County, Florida, were significantly shorter than those from any other seed source (25). The Cooperative Study was able to consider only 6 collection points for slash pine because of the wide scope of these studies and the extent of the natural range of slash pine. Consequently, several of the collection points are located along the extremities of the range. This study will tell whether or not distinct geographic races are present within the slash pine species. In order to complement this investigation and to prepare precise maps with collection zones for the States of Florida, Georgia, and the southeastern part of Alabama, an expanded seed source study was undertaken by the Lake City, Florida, Research Center (29). With this objective in mind, collections were made within the principal commercial part of the natural range of north Florida slash pine (G-7).[4]

[4] Letter and number indicate study designation of the Lake City Species Improvement Program. Details of studies can be found in the Appendix.

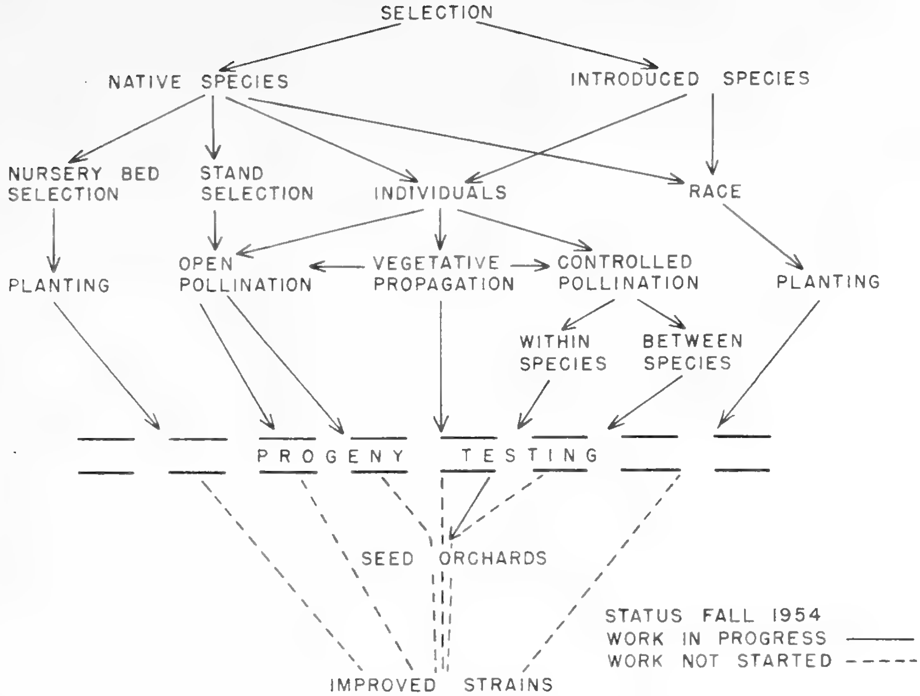

Figure 1.--Progress from present species to improved strains of forest trees can follow several avenues of research. Few shortcuts are possible as progeny testing is necessary, but a balanced program along all promising lines offers the greatest opportunity for early success. The approaches being followed in Tree Improvement at Lake City are shown in the above diagrammatic outline.

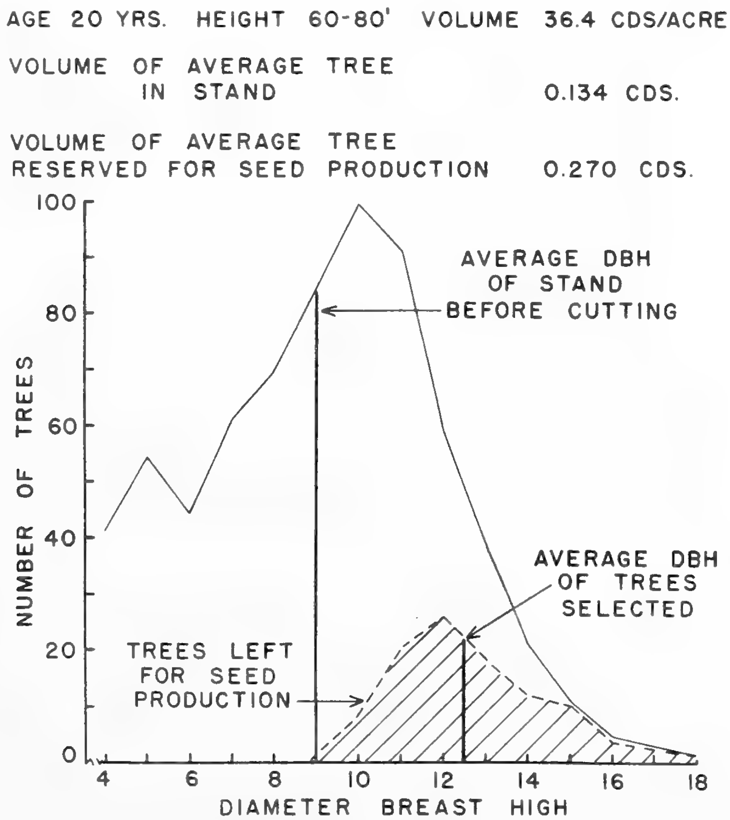

Figure 2.--Diameter distributions in a natural even-aged slash pine stand on a good site. The diameter frequency before cutting is shown by the solid line and after cutting by the hatched area. Undesirable and slow-growing trees were removed, leaving the best and most vigorous trees to develop into large-crowned seed producers.

The objectives of the study are:

1. To test the hypothesis that distinct rates of germination are associated with different proveniences.

2. To test the hypothesis that clinal changes in growth habit in north Florida slash pine are associated with different proveniences. Results on seed yield and germination of seed showed that differences in these two characteristics were associated with different collection points.

A small outplanting with longleaf pine seedlings from six geographic sources was established during the winter of 1953-1954. The seedlings were those left over from a "Series" of the Cooperative Study and only 60 seedlings per provenience were available for outplanting (G-15).

There are no complete outplantings for either longleaf, loblolly, or shortleaf pine of the Cooperative Study in the Lake City, Florida area.

Sometimes distinct tree races are associated with different soil types. To investigate this possibility for slash pine, seed from a wet site and a dry site respectively were collected. The resulting seedlings have been outplanted on dry and wet sites in both north and south Florida. Additional outplantings were made in several locations in Texas (G-2). Results from the study should indicate whether or not two distinct ecotypes in slash pine are associated with a wet and a dry site.

STAND SELECTION

Stands that appear to be outstanding have been selected within the geographic limits of existing races or main clinal distributions to furnish seed for replanting programs. On the Westvaco Experimental Forest this approach has been used since 1949 to supply their seed needs (12). Suggestions for converting the best natural stands of slash pine into seed-producing areas were prepared by Mergen and Pomeroy (31). One advantage of this method is that seedlings of local origin become available, and further degradation of the planting stock is prevented. Also some genetic improvement by stand selection should result. Slash pine seed-production areas have been established by pulpwood companies and on several of the National Forests in Florida. An 86-acre plantation with slash pine of local seed source was converted into a seed-production area by foresters of the National Container Company in order to fill their annual need of 2000 bushels of cones (39).

Managing these seed production areas efficiently will present several problems, as there is scant knowledge of the physiology of

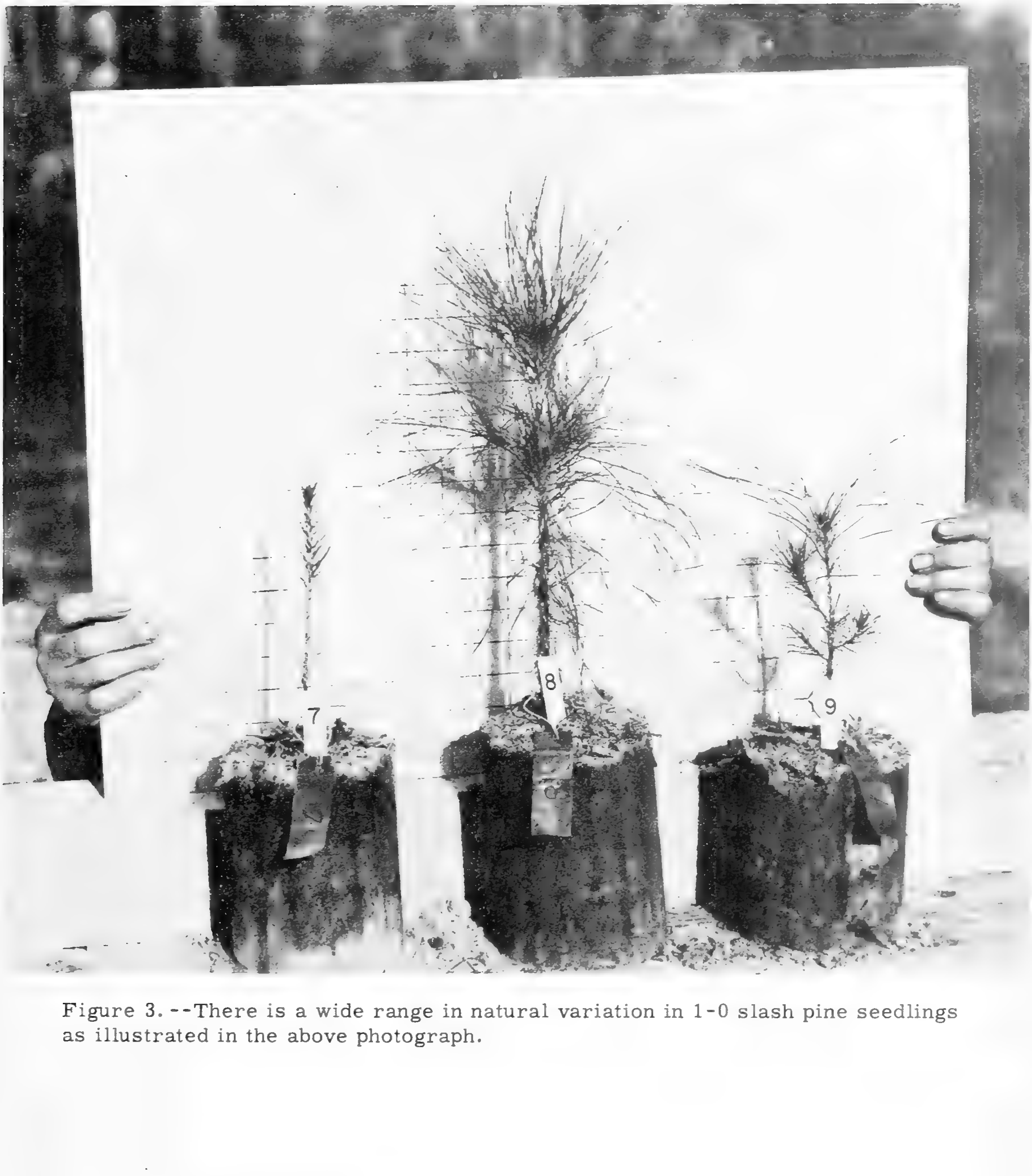

Figure 3. --There is a wide range in natural variation in 1-0 slash pine seedlings as illustrated in the above photograph.

flowering in pine trees, the protection of cones against disease and insects, and on the collection of cones. Wenger (48, 49) reported some beneficial effects on cone supply by releasing and fertilizing loblolly pine trees in the 25-year-age class. Gemmer (14) showed that fertilizing and irrigating longleaf pine trees increased cone production. Allen (1) reported similar benefits after he fertilized longleaf pine trees.

No published results of seed stimulation studies with slash pine are available but seed trapping on the Olustee Experimental Forest indicates a similar response to release. During the spring of 1954, an experiment was installed in a seed production area to observe the effect of fertilizer treatment and mechanical injury on the production of female and male flowers in slash pine.5/ Two types of fertilizer, applied at two levels were used along with an injury treatment of the stem (G-10).

In loblolly pine, insects are responsible for a great loss of seed (37). Information is urgently needed on how to protect the flowers and cones of forest trees from insects and diseases. By spraying the flowers or cones at opportune times, it should be possible to curtail some losses. A slash pine cone protection study in which insecticidal sprays were applied to the formative cones at various stages was started with the cooperation of the Division of Entomology (G-17).

The studies of flower stimulation and cone protection should help to prepare a guide for the management of seed-production areas. By keeping records on the performance of the seed from various cone-collection areas through all stages of extraction, cleaning, nursery sowing, and outplanting of the young seedlings, the true capabilities of the provenience stands can be estimated. Superior stands can then be certified according to their capabilities, and mediocre or unproductive stands can be eliminated. Information of this type, along with results of geographic seed source studies, will be very useful.

INDIVIDUAL TREE SELECTION

The improvement of forest stands by the application of genetic principles is based on the selection of good breeding material. Selection has its place in forest genetics programs even when large-scale hybridization programs are planned. The selected trees should form the breeding stock for the trees of improved characteristics.

5/ Stimulation of seed production on 20-year-old slash pines. Southeast. Forest Expt. Sta. Working Plan. 10 pp. 1954.

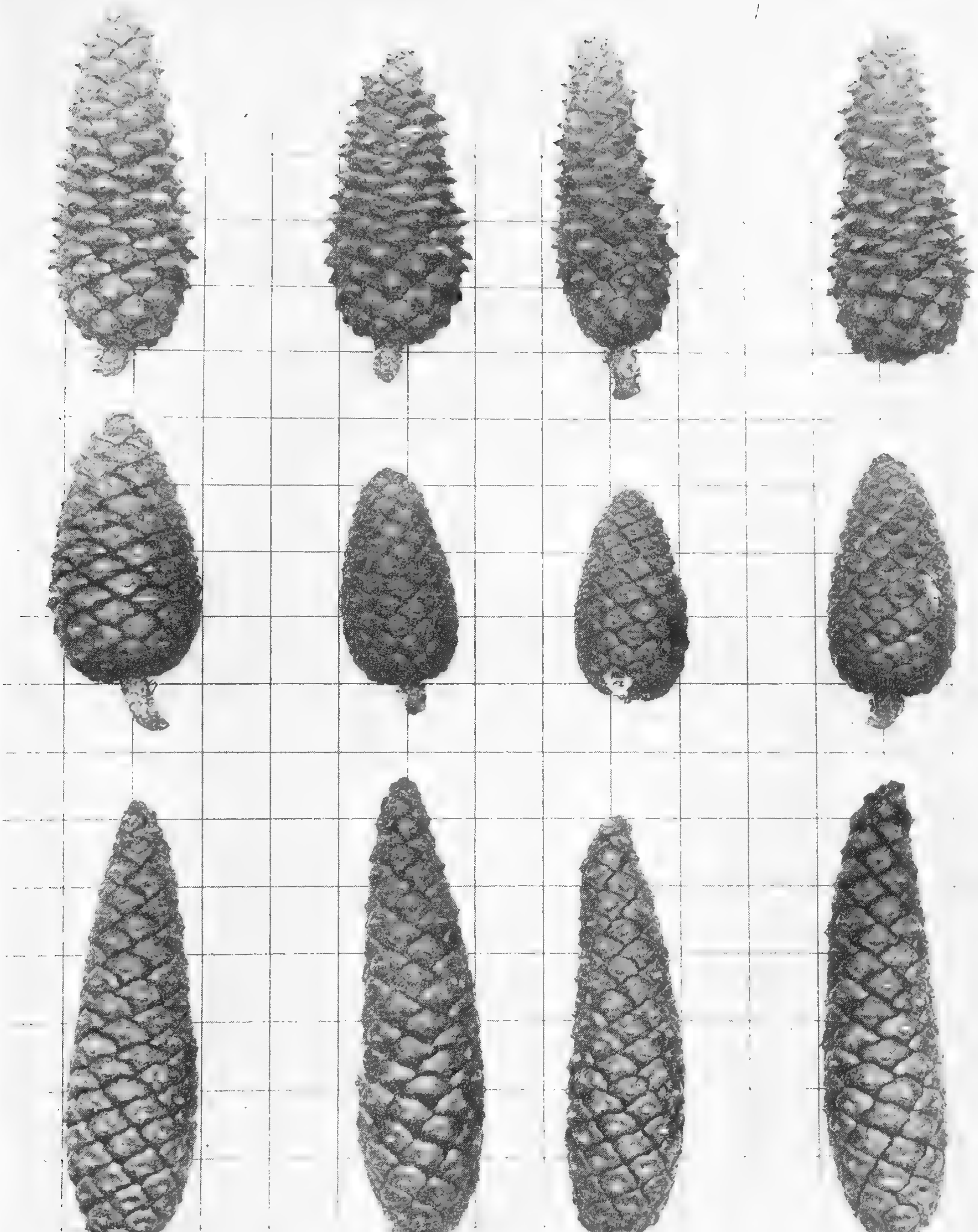

Figure 4.--Three types of slash pine cones occur in the Lake City, Florida area. The cones in the upper row have a rough appearance as a result of thick scales armed with stout incurved spines. The seed from this type of cone has also a rough coat. The cones in the center row, are ovoid-conical, with flat scales ending in minute prickles. The cones in the lower row are long ovoid with smooth scales. The seed in the last two types have smooth seed coats. Each set of cones comes from a different tree. These trees had the same type of cones during three consecutive years, indicating that a particular type of cone is a distinct character of an individual slash pine tree. Cones of the "rough" type persist on the trees for longer periods after ripening than those of the other types. Lines on grid are at 1-inch intervals.

Forest genetics is based on two biological principles which at first glance appear diametrically opposed, namely: (1) the presence of variation, and (2) the inheritance of genes which determine characters. Heredity is a conservative phenomenon and it is the tendency of the offspring to resemble their parents. Variation, on the other hand, is the tendency of the progeny to differ from their parents. The external and internal differences which exist between the individuals of a species can be divided into two main groups. In the first group we have the modifications which are not inherited and which resulted from specific environmental or external factors to which an individual was exposed. In the second group we have the variations which are heritable. These differences resulted through mutation or through crossing (hybridizing) of two different species or varieties. These variations combine in various ways and thereby give rise to individuals which are sometimes unlike either of the parents. Without the inheritable variations in our forest trees, improvement by selection would not be possible. In our forest trees, however, there are differences in such attributes as growth rate, form, oleoresin yield, strength, crown shape, needle length, and many others.

Sometimes it is difficult to assess these differences, especially when the trees being compared are not growing next to each other. Also, when the changes in form or growth rate are gradual, e. g., in uneven-aged stands, the existing differences are not so striking. These natural variations form the foundation of a forest tree improvement program which is based on the principals of genetics. However, not all the variations between trees are inheritable. Some have been brought about by present or past environmental conditions. As we see a tree in a forest, its phenotype is the visible result of the interaction between the genetic factors of the tree and the conditions of the environment.

Pauley has discussed the scope and terminology of genetics as applied to forestry (36).

The genotype of the trees selected on the basis of their phenotypic characters must be assessed to determine whether or not the selections were superior because of their genetic make-up, or because of favorable growing conditions. Once outstanding trees have been located and thoroughly tested, they are used as breeding stock to supply seed of superior quality.

Selecting longleaf pines with an early juvenile growth.--The wide spread in time, up to 20 years, during which longleaf pine seedlings, growing under similar environmental conditions, emerge out of the grass stage suggests that genetic factors are of significance. It is important to find trees without a prolonged grass stage in order to study the genetic factors which control early height growth. We have no knowledge to guide our selections in mature stands toward parent trees which started height growth without delay. Therefore, we have to restrict our selections to natural stands or plantations where the past history is known.

Figure 5.--Four types of protective bags have been tested in the isolation of female flowers during controlled pollinations. They are in a clockwise direction: kraft paper, canvas bag with plastic window, polyethylene plastic, and plastic sausage casing. Plastic sausage casings were found most satisfactory. The black tape on the bags closes the puncture made with the needle of the pollen injector.

One outstanding longleaf pine tree has been selected in a plantation of known origin where the trees had received the same treatment from seed collection through the nursery phase to plantation establishment (26). Open-pollinated seedlings are being raised from this tree to obtain an indication of the possible benefit that can be derived from natural seedlings obtained from mother trees of rapid juvenile growth. This tree was control pollinated during the 1954 breeding season in an attempt to study its genotype (G-5).

Alabama "Mountain" longleaf pine supposedly has no grass stage, or a grass stage which is of very short duration. Foresters of the Southern Forest Experiment Station collected seed from the "Mountain" source and from a normal source for testing. During 1951 the Alabama seedlings were superior, but Bruce [6] felt that the difference might be explained on the basis of variation in nursery density. By 1953 there were no clearcut results available from these studies.

A small percentage of longleaf pine seedlings add up to several inches of height growth in the nursery beds. Most of these seedlings have a stem and are not true longleaf pines, but are Sonderegger pines (Pinus x sondereggeri, H. H. Chapman), natural hybrids between longleaf and loblolly pine (6). Some of these seedlings start height growth without delay but it is quite varied, ranging from 1/2 to 10 inches after the first-growing season. This indicates that the hybrids are not all from the first filial generation of longleaf x loblolly pine, but are the result of recurrent backcrossing to either of the parent species. Some seedlings without a true grass stage possibly are true longleaf pines which inherently have no grass stage. Two outplantings of 400 "longleaf" trees without a grass stage were established during the 1953-1954 planting season (G-3). The planting stock was selected from nursery beds of the Florida Forest Service Nursery at Olustee, Florida. Both of these outplantings are located on "tough" sites and the relative growth of these Sonderegger pine seedlings is being compared with that of slash, ordinary longleaf, and loblolly pines. Survival of the selected longleaf pines after the first summer in the field compared favorably with that of the other three species. It was 79 percent as compared to 83 percent for longleaf, 74 percent for loblolly, and 87 percent for slash.

Sherry (44) from South Africa selected outstanding longleaf pine seedlings in the nursery beds. After 5 years in a plantation, the vigorous seedlings had a larger d.b.h., were taller, and had survived better. He was fully cognizant of the possibility that these seedlings might be Sonderegger pines and scored them according to their degree of hybridity. He tabulated 29 percent as apparently normal longleaf pines. Of these, seven trees were as vigorous as the Sonderegger pines and he planned on using some of these superior seedlings for future breeding work.

6/ Personal communication from David Bruce, 1953.

Figure 6.--Control breeding slash pines of the F_1 generation growing in an 8-year-old progeny testing plantation. A ladder-equipped pickup truck permits rapid movement from tree to tree without damage to tree crowns.

Selecting for resistance to disease.--Pathologists at the Southern Forest Experiment Station selected thirty 2-0 longleaf pine seedlings which were not attacked by brown spot in the nursery. None of these seedlings was truly resistant, as all trees were infected subsequently (45).

Zak (52) has been selecting shortleaf pine for resistance to the little-leaf disease. He planned to establish his selections as clones in a seed orchard.

Selection for form, rapid growth, straight grain and high density.--Results of past progeny testing studies with conifers indicate the degree of benefit to be gained through selections from wild populations (19, 20, 32, 2, 44, 50). The results of these studies were reviewed in detail by Dorman (9). He concluded that in general "traits both good and bad may be transmitted to some of the next generation regardless of the male parent."

During 1942, the Queensland Forest Service selected good phenotypes and poor phenotypes to gain information on the inheritance of form. These tests indicated, for example, that S-bending is genetically controlled in the open-pollinated progeny. Seventy-eight percent of the progenies in three successive years' planting showed a defect similar to that in the mother tree (22). In Florida, a tally of sweep on slash pine trees in an 8-year-old progeny testing plantation indicated that the tendency to form a sweep in the lower 12 feet of the bole is subjected to strong genetic control (27). The crosses involving a particular parent which had a sharp S-bend, had a greater than average percentage of progeny with sweep. These percentages were 68, 73, and 76 when that particular tree was used as female parent. The effect was also pronounced when the tree was used as male parent--69 percent of trees from such crosses had sweep.

Selection for desirable attributes in slash, loblolly, and longleaf has been under way since 1950 at the Ida Cason Callaway Foundation (10). Individual trees with twice the cubic wood volume of the average tree of the same age growing in the same stand were located. Total height, crown form, limb, size, and resistance to disease were also taken into account. These selections have been used as parents in both natural and controlled crosses.

Zobel (53) has been surveying the existing stands of loblolly, shortleaf, and longleaf pines in Texas to locate trees which have the best silvical and wood characters possible. He also selected trees with the densest and lightest wood to study the role which genetics plays in the determination of wood density of loblolly pine. If possible he will develop strains of loblolly pine which produce wood of exceptionally high or low densities.

Figure 7.--Plantation of rooted cuttings established to multiply and preserve the germ plasm of selected slash pine trees. Many of these young trees have produced both male and female flowers. Consequently controlled crossing, inbreeding, and hybridization between species were made near the laboratory without time-consuming travel to outlying forests.

Hawley[7] has selected rapid growing trees in plantations on the George Walton Experimental Forest for use by others in species improvement programs. Grafts from 9 of his selections have been established in the Olustee area, and air-layers have been prepared on the trees (G-6).

An experiment in progress now is designed to study the genetic control of the inheritance of undesirable characters in slash pine (G-4). During 2 consecutive years natural progeny was obtained from deformed trees and grafts were established (G-6).

A general appeal by the Lake City, Florida Research Center was made to foresters and people interested in forestry to report outstanding trees for use in the forest tree improvement program. The reports on good phenotypes are being followed up by careful examination in the field.

By developing slash pines of rapid growth, the naval stores industry will also gain by this selection because these trees will reach chipping size sooner and larger trees yield more gum than smaller trees.

Barber (4) prepared a working plan for "The Selection of Superior and Aberrant Forest Tree Phenotypes" to guide the locating and cataloging of individual trees on the Hitchiti Experimental Forest and on lands of local cooperators.

During mass selection of superior trees in mature stands, the selection work is restricted to a limited number of individuals. By selecting outstanding seedlings in the nursery beds, a large number of individuals can be evaluated in a relatively short period and this method may lead to a shortcut in species improvement. If by this type of selection plantations of better than average trees can be established, it might lead to a good method for establishing seed orchards. With this objective in mind, a plantation of 1,000 outstanding slash pine seedlings was established to observe the relationship between rapid juvenile height growth and subsequent development (G-1).

The variation in the nursery beds of south Florida slash pine (P. elliottii var. densa) indicates that there is a fair amount of natural hybridization between the south Florida slash and north Florida slash pine varieties. Seedlings of both the typical south Florida, and north Florida varieties, along with seedlings having characteristics intermediate between those species, were outplanted to obtain further information on the relationship between the juvenile and mature trees (G-16A;B).

7/ The selection of superior slash pine trees in planted stands. Southeast. Forest Expt. Sta. Working Plan. 1953.

Figure 8. --Propagation bench in the greenhouse planted with slash pine cuttings. A high degree of humidification was maintained by spraying a fine mist on the cuttings during the rooting period.

SEED ORCHARD ESTABLISHMENT

Once the genetic superiority of selected trees has been demonstrated, it is planned to establish seed orchards for the mass production of superior quality seed. The idea of seed orchards for forest tree seed is relatively new and was first proposed by European foresters during the period between 1920-1930. In 1928, Bates (5) proposed the establishment of tree "seed farms" to produce forest tree seed of desirable qualities. Seed orchards of tested genotypes have been established in various parts of Europe and during recent years a small number of plantations have been set out in this country for the sole purpose of producing high quality seed. Scions from superior slash pines have been grafted onto seedlings in the Lake City, Florida, area for the production of seed of superior quality (G-6). Several research workers are establishing seed orchards before the genotype of the selections has been established. While the genotype of the selections is being tested, these orchards develop and will be ready to produce seed once the superiority of the selections has been determined; grafts proven inferior by the tests will be climinated from the orchards.

Seed orchards can be divided into clonal-graft or rooted-cutting plantations, and seedling plantations. European foresters have discussed at great length the theoretical considerations in laying out seed orchards (15, 42, 3, 16, 17, 18, 51). From the discussion of these authors, the following items appear to apply for slash and/or longleaf pine seed plantations:

Clonal-graft plantations.--The individual trees of the various clones can be so spaced that random cross-pollinations between the various clones take place. The number of clones in each outplanting should be large enough to minimize the risks of inbreeding. The minimum number of clones varies with the recommendations of the authors and ranges from 12 to 25. Using a sufficiently large number of clones increases the pool of available genes for combinations. The flower phenology of the various clones should be very similar, otherwise great variations in pollen supply can be expected as a result of climatic influences. The outplantings should be located in an area isolated from a contaminating pollen source. This can be achieved by planting in an isolated area, outside the range of the species, or in an area surrounded by trees of a species which do not flower at the same time as the trees in the orchard.

Orchard for control pollination. In this type of orchard the flowers are control pollinated by standard techniques. The method has several advantages, such as a reduction in travel time to the isolated trees, work can be done from the "ground" with ladder trucks, and the progress of the flowers can be closely followed. Also the trees can be subjected to

Figure 9.--Air-layered slash pine branches. The roots which form after girdling become visible through the plastic wrapping material. This enables the propagator to observe their development without disturbing the rooting medium. Note large number of roots produced by this method.

cultural seed-stimulation treatments. As pollen source, single tree crosses can be made, but polycross methods will probably be more successful. The latter type should increase the seed yield by minimizing possible incompatible combinations.

Plantation with seedlings.--This type of orchard is established with seedlings arising from controlled pollination between selected trees. By fertilizer or mechanical-injury treatments the seedlings are stimulated to flower at an early age. In using chemical stimulants for flower production, there exists a danger of selecting for trees which respond to that particular treatment. Having this type of selection superimposed on the original selection will not be desirable.

Hybrids between slash and longleaf pine might possibly be produced in this manner if an early-flowering strain of longleaf pine could be interplanted with a late-flowering strain of slash pine. Any non-hybrid seedlings can be detected and eliminated from the nursery beds.

Seed orchard establishment and management is a new concept in America, so no results on the various approaches are known. A study in progress now tests flower stimulation by chemical and mechanical treatments in a 6-year-old plantation (G-9).

CRITERIA FOR SELECTING THE BEST SEED TREES FOR NATURAL REGENERATION

At present adequate natural regeneration is the most economic way to return an area to timber production after a final harvesting. In the Southeastern part of the United States it is the method most widely used at present, and with an increase in the knowledge of silviculture it probably will increase in extent. Some silvicultural systems of natural regeneration lend themselves well to the practice of sound eugenic forestry.

The methods most commonly used in this region can probably be classified under modified shelterwood or seed-tree systems. Some type of shelterwood system or seed-tree system, provided the seed-tree cut is preceded by improvement cuttings or thinnings, is best from the tree improvement point of view, as the inferior trees are cut out during intermediate cutting or cuttings. The undesirable trees should be removed at least 2 years before the regeneration cut so that male and female parents are both the best possible phenotypes.

The criteria by which to select the seed trees for natural regeneration will vary with species and objectives. Dorman (9) has pointed out the important items to be considered in selecting superior trees for improvement work. He prepared plans for slash pine, loblolly pine, and yellow

Figure 10. --Scion from a slash x loblolly pine hybrid developed at the Institute of Forest Genetics, Placerville, California, flown to Lake City, Florida, and top-grafted to a native slash pine. By the grafting method selected specimens can be exchanged between tree improvement scientists throughout the world.

poplar. It is understood that the recommendations can be modified to suit the particular needs. The Forest Genetics Steering Committee prepared a guide for the selection of superior trees in the Northern Rocky Mountains (13). They discussed the traits that are generally considered important for high quality timber trees such as (a) rapid height and diameter growth, (b) evidence of resistance to injury by economically important diseases and insects, and other seriously injurious agents, (c) straight, clean bole with little taper, (d) narrow crown, (e) slender or fine branches, (f) few limbs per whorl. In his report on research in tree improvement at Lake City, Pomeroy (38) covered the main considerations of the aspects of natural regeneration along eugenic lines. The Southern Region of the U. S. Forest Service is preparing an outline to help with the selection and tabulation of desirable trees to leave as parents for natural regeneration, and also for use in breeding work. Under most instances the geneticist's recommendation for the selection of parent trees for natural regeneration would be little different from a silviculturist's recommendation. Therefore, they can be included in intensive silviculture without enlarging its present scope.

It must be stressed that selecting good parent trees is difficult because we know very little about the heritability of desirable characters. The trees have to be rated on superior genotype using phenotypic characteristics of the F_1 and F_2 offsprings resulting from progeny tests which are used in the evaluation. As the results from progeny-testing plantations become available, the original selection guides will be revised so that better and more accurate selection criteria can be prepared. By careful evaluation of the environmental factors and by leaving those trees which have the greatest preponderance of desirable characteristics, many of the selected trees should have good inherent traits. We know that undesirable traits are inherited, so why leave trees of undesirable form, take unnecessary chances, and gamble against unfavorable odds?

IMPROVE THE YIELD OF OLEORESIN FROM LIVING TREES

The first attempts to evaluate the importance of hereditary factors which determine gum yield in longleaf pine were made by Liefeld in 1935 (O-100-Informal). He collected wind-pollinated cones from two groups of longleaf pines whose gum-yielding ability had been determined. One group had gum yields varying from slightly below average down to two-thirds of average, while the second group ranged from slightly above average to one and one-half times average yield. A check of the gum-yielding ability of the 17-year-old progeny from these two groups of trees was made. It showed that the longleaf trees from above-average mother trees had significantly higher yields than those originating from below-average trees (23).

Figure 11.--Inarching 10-month-old slash pine seedlings into the crowns of mature trees to induce early flower formation. This method is helpful to shorten the normal breeding cycle of 8 to 12 years. A, The root system of the seedling was placed in a polyethylene bag along with moist sphagnum moss. A kraft paper bag was wrapped around this to prevent desiccation of the root system and the entire "package" was tied to a flower-bearing branch. The stem of the seedling was then inarched into the branch using an approach graft method. The union was tied with a grafting rubber, taped, and waxed. B, After the union had formed, the root system of the seedling and the terminal part of the branch from the older tree were clipped off. Good success was obtained with this method. Stresses between the graft partners at the union were negligible because the entire graft was able to swing freely with the wind.

When the present Species Improvement program was initiated in 1941, its objectives were the selection and production of a strain of pine which was superior in naval stores products (33, 34, 35).

During the initial phase of the program, trees with an outstanding gum-yielding ability were identified and selected in natural stands on the basis of accurate yield determinations. As a result of this selection for high yields, 12 pine trees have been located in Georgia and Florida which produced at least twice as much gum as the average tree of the same diameter growing on the same site. These trees have been used as parents in past breeding work at this station (0-116; 0-146), rooted cuttings were outplanted to preserve the germ plasm (0-132), and scions were grafted in seed orchards (G-6). A check on gum yield of the progeny resulting from controlled and natural crosses of these selections showed that gum yield in slash pine is a heritable characteristic and that increased gum yields result from the crossing of outstanding parents (30). The viscosity of the oleoresin, a factor which influences the gum yield significantly, proved to follow a well defined inheritance pattern. Also, a comparison of the viscosity of rooted cuttings with that of the original trees showed that the viscosity of the oleoresin is a fixed character in slash pine. The variations as a result of age, soil, and environmental conditions were minor. Since viscosity is an important factor which determines gum yield, and because it can be determined accurately, it will prove to be a valuable criterion for selecting superior naval stores trees. Scions from the outstanding trees resulting from the crosses of the original selections have been grafted for use in seed orchards.

HYBRIDIZATION WORK WITH SOUTHERN PINES

Intraspecific and interspecific hybridization is considered by some people to be the approach which will contribute the greatest benefits to forestry. Tree breeders at the Institute of Forest Genetics in Placerville, California, have used this method as the most prominent feature of their program. A large number of hybrid combinations have been obtained at Placerville and a number of these exhibited great potentialities with respect to some characters. Duffield and Righter (11) summarized the results from tests with these hybrids. Several cross combinations with southern pines are included. For the shortleaf x slash (P. echinata, Mill. x elliottii Engelm.) they reported that the hybrid "appears to have narrower crown and finer branches than shortleaf. Potential value seems to be in putting a faster growing, better formed tree on shortleaf pine sites to the north and west of natural distribution of slash pine. May prove to have some value in developing a pine more resistant to fusiform rust than slash pine, in which case it may be of importance in the general range of slash pine." In a small test with loblolly x slash (P. taeda x elliottii, Engelm.), "this hybrid appears to have somewhat better form than loblolly. May be valuable in bringing a better-formed, faster-growing tree into the loblolly region, and in breeding a slash pine more resistant to fusiform rust."

Figure 12.--Succulent slash pine grafts protected by polyethylene bags under full shade in the lathhouse. After the unions form and the succulent tissues harden, then the successful grafted seedlings are outplanted in a seed orchard isolated from sources of "wild" slash pine pollen.

From the Southern Forest Experiment Station, the Institute of Forest Genetics in Placerville, California, and the Lake City Research Center have come successful crosses of slash x longleaf and longleaf x slash. Seedlings resulting from these crosses were intermediate in growth rate between their parents and they did not go through the characteristic grass stage of longleaf pine. One slash x longleaf hybrid had a total height of 24 feet and a diameter at breast high of 5.2 inches at the start of its ninth growing season (26). This particular hybrid combination appears to hold great promise as stock to reforest some of the drier sites where slash pine trees do not prosper.

During the 1952-1953, and 1953-1954 breeding season the following interspecific combinations were attempted at Lake City, Florida: Slash x longleaf, longleaf x slash, slash x south Florida slash (elliottii var. densa, Little and Dorman), longleaf x south Florida slash, slash x sand pine (P. clausa, (Engelm.) Sarg.) and longleaf x sand pine. Slash pine pollen collected in Mississippi was used during the 1953-1954 season in intraspecific crosses to obtain possible hybrid vigor (G-5).

Scions from hybrids developed at Placerville, California (G-6), and hybrid seedlings developed at the Southern Station (G-14) have been established at Olustee, Florida, for use in future breeding work.

FACILITATING STUDIES

Even though accepted biological principles are being followed in a forest tree improvement program, the methods of application cannot be followed without modifications or changes.

Vegetative propagation problems especially needed attention to obtain ways of rooting and grafting cuttings from selected individuals. Hence, vegetative propagation experiments were carried on, and the results with naval stores pines have been brought together and summarized (28).

With our present methods, slash pine can be asexually propagated either by rooting or grafting. Whenever possible, the air-layering method should be used to obtain rooted propagules (24). For field grafting with dormant scion material, best results were obtained (95 percent success) when the bottle-graft technique was used. Shading the newly established grafts was found to be beneficial. Dormant scion material can also be grafted on potted plants in a shaded greenhouse or lathhouse with the bottle-graft method.

By grafting during the succulent stage, the effective grafting season was prolonged for several months. A cleft graft into the leader, covered with a polyethylene bag and well shaded gave good results. Short periods

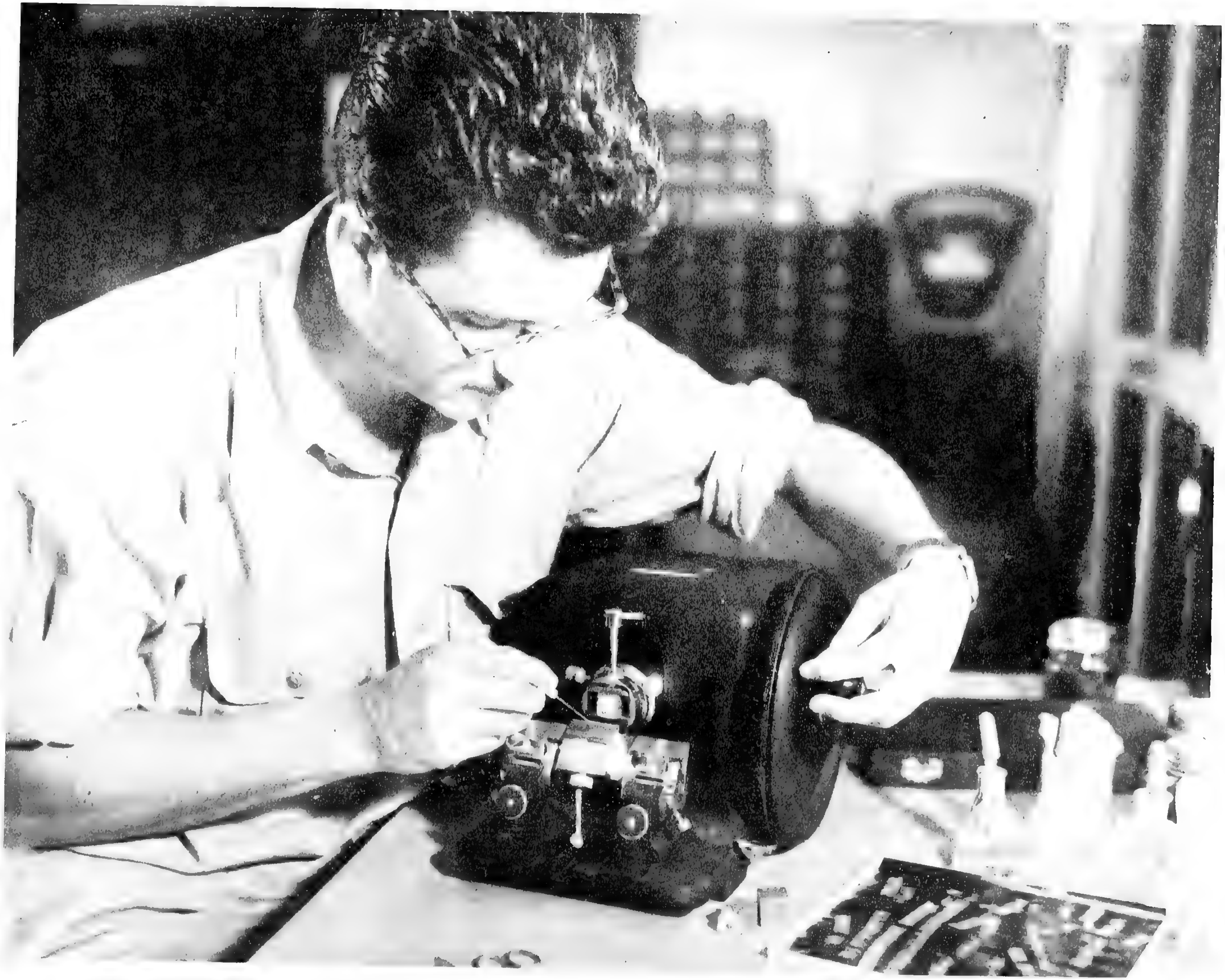

Figure 13. --Preparing sections of graft unions with a rotary microtome. The specimens were embedded in paraffin for serial sectioning.

of direct insolation resulted in failures of the graft. Grafting with succulent tissue was also used to establish heteroplastic grafts for flower-induction studies.

A study of knitting of a union showed that parenchymatous cells of medullary rays, phloem, cortex, and cambium, participated in bridging the space between stock and scion. A continuous bridge between the graft partners was apparent after 6 weeks.

Controlled pollination problems were not extensively studied, mainly because existing methods were applicable without major changes. The techniques used in control pollinations of the naval stores pines followed in general the techniques described by the Institute of Forest Genetics, Placerville, California (7). Modifications have been made in the methods, such as pollen extraction equipment, pollen storage, pollinators used, and type of bag. Plastic sausage casings so far have proven superior to either canvas bags or Kraft paper bags. Also, plastic sausage casings make ideal unit pollen extractors.

Field testing in the past has followed standard designs which will allow a statistical analysis of the data. It is felt that experimental designs for progeny tests need to be modified by and for the tree breeders.

NEEDED INFORMATION

The problems presented in this section are not arranged in order of priority but are discussed under the major headings of the program, with some consideration for present knowledge, work in progress at other research centers, and the present status of the forest industries.

SELECTION STUDIES

Species selection, both native and exotic, should be made to determine which species to work with. It is understood that most of the work is to be done with slash and longleaf pine, but exotic conifers to provide possible germ plasm for hybridization should not be overlooked. A pine arboretum is being established (G-8), and at present it would seem desirable to maintain and enlarge this arboretum as a combination breeding-introduction garden.

Race or cline selection is of great importance to this program and needs direct attention. Information on the extent of variation due to geographic origins in our major species (slash, longleaf, and loblolly) is urgently needed.

Figure 14.--Micro-chipping method to obtain oleoresin samples from young progeny. A uniform piece of bark and cambium was lifted out with a metal punch and the exposed wood surface sprayed with 50-percent sulfuric acid. This method was successfully used to demonstrate the inheritance of the oleoresin-yielding ability of longleaf and slash pines.

Ecotype selection, especially for slash pine, will prove its value after additional years of fire protection by answering the question whether or not this species has differentiated into wet site and dry site strains.

Stand selection for the conversion of natural stands into seed production areas will be important if the best possible seed sources are to be used. One of the first tasks will be to determine the extent to which some stands are actually superior to others growing in the same locality. Also, forest managers need to know how to select the trees within these stands and how to manage these stands for maximum yield.

Individual tree selection will form the basis for the control interspecific pollination program. Selection criteria need to be developed or perfected for such attributes as gum yield, form, rate of growth, natural pruning, wood quality, and disease and insect resistance. We need to know how to recognize superior phenotypes in the field in order to put the selection work on an efficient basis. This selection will be carried out: in older or mature stands, where the characteristics at maturity or close to maturity are assessed directly; and in nursery beds, where potential characteristics are judged on the basis of performance in the juvenile stage.

Both these types of selection have a place in the over all program, one advantage of nursery-bed selection being the ease and rapidity by which several million trees (seedlings) growing in relatively uniform conditions can be evaluated. The drawbacks of this method, however, are obvious. Therefore, we need information about selection criteria, and on the dependability of the phenotype in a juvenile stage as compared to the phenotype at maturity.

CONTROL POLLINATIONS

Intraspecific pollinations will be used to a greater extent as outstanding trees are being located. The benefit of this type of pollination, which includes self pollinations, will be evaluated as the results from progeny tests become available. Its value has been proven for studies on gum yields, but relatively little is known of its application when the objective is better growth rate or form.

Interspecific hybridization with the breeding material available should help to evaluate the extent of variability obtainable with our southern pines, and provide some information of a phylogenetic nature. Work in interspecific hybridization should be confined to crosses where at least one of the parents is indigenous to this area. We need much information on the use of interspecific hybridization to develop trees particularly well suited to certain planting conditions (dry sites, ice belts, or resistance to certain pests). It is also necessary to outplant under local conditions hybrids which were developed at other centers.

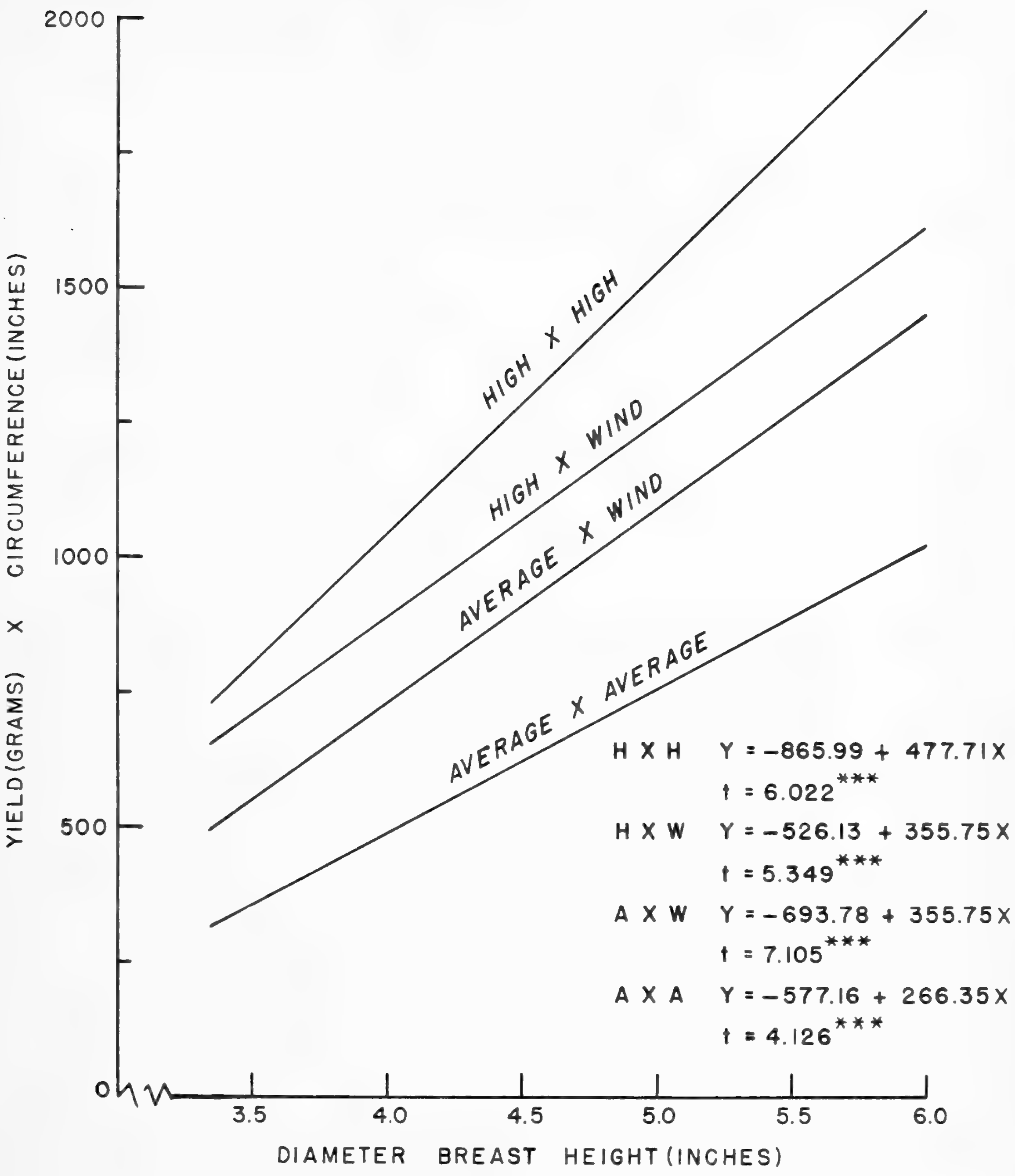

Figure 15. --Regression lines for four progeny groups in a slash pine oleoresin-yield inheritance test. The progeny whose male and female parents were both high yielders produced the greatest amount of oleoresin. When open-pollinated cones were collected from high yielders the resulting progeny produced higher yields than the natural progeny of average trees, or of controlled cross between two average parents.

FIELD TESTING PROCEDURES

Field testing forms the core of a species improvement program. Only after careful field testing can the possible benefits be predicted or the mode of inheritance studied. Most of the progeny tests are of long duration; therefore, more and more material will accumulate. The maintenance and protection of the experimental stock in itself will require a considerable expenditure of labor.

Rooted cuttings are being outplanted to protect the germ plasm and to guess at the genotype of the selection. Evaluation of such attributes as growth rate will be difficult unless the cuttings are graded very carefully before outplanting. Differences in root size and number greatly influence the subsequent performance, and it is hoped that with air-layers a larger supply of propagules can be obtained to enable heavy culling and outplantings set out according to a statistical design.

Grafted plants have been used to establish seed orchards and to preserve or multiply desirable germ plasm. Our knowledge concerning the establishment of seed orchards is very limited and in view of the importance of this step in the program, information on the establishment and management of orchards is urgently needed.

Control pollination progeny plantations should be established so that the maximum information can be extracted from these outplantings. Sensitive field designs which will lend themselves well to accepted statistical procedures should be used. Little research has been done by biometricians on devising the best possible field designs. These outplantings are mostly unbalanced by necessity because unequal numbers of progeny are available. Some field tests can be established with reliable cooperators when large numbers of seedlings are available.

Natural progeny tests or open pollinated progeny tests are being used but are subject to several possible errors. However, if repeated over a period of several years and by collecting cones from various locations on the crown, such effects as wind direction and climate at time of pollination can be minimized. One advantage for tests of this type is that they can be started without delay and can give an indication of the possible benefits obtainable by collecting open pollinated cones from selected trees. On the average, rather large numbers of open pollinated seeds can be obtained from a given tree, which allows test outplanting in commercial planting operations. This points to the need for determining the best type of experimental outplanting under commercial conditions.

Racial outplantings are mostly of standard randomized plot design. However, we need information on the most opportune spacing at which the most information "per tree planted" can be obtained.

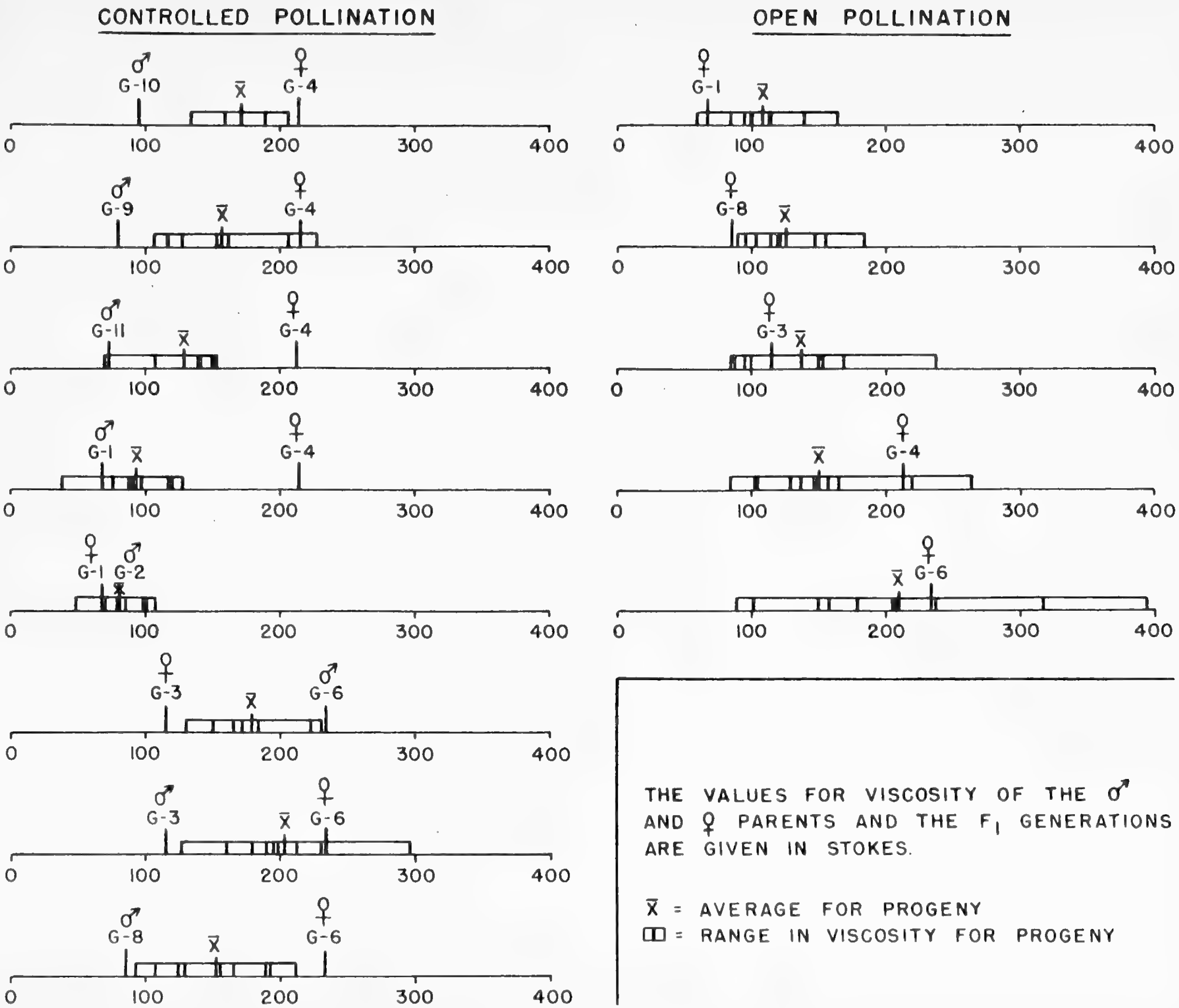

Figure 16.--Chart of inheritance pattern for viscosity of oleoresin in slash pine.

FACILITATING STUDIES

Reproduction studies in the techniques of pollinations can be carried out along with the regular control pollinations. There is a need of better pollinators with mixing chambers for the pollen. Also, flowers and conelets need better protection from insects and disease during their time of development. As for techniques in vegetative propagation, they should be relatively dependable after results from current studies on air-layering become available (G-13). Techniques on rooting and grafting can be modified and perfected during the course of normal vegetative propagation work. Also, the protection of the scions from insects, after the grafts have taken, needs attention.

Flower primordia initiation is being studied in slash pines to form the basis for further studies on the physiology of flowering (G-21). First we need to know when vegetative growth changes into reproductive growth, so that flower-induction treatments can be properly timed. Very little is known about the initiation of flowers in pines, and current studies should help to guide future research. Various growth regulators which have been used successfully with other plants should be tried, as the induction of flowering is important during several steps of the program.

Pollen collection, pollen handling, pollen storage, and pollen germination will be carried out as part of the regular control pollination program. The effect of humidity at time of collection and during storage needs attention.

Seed collection, seed extraction, and seed handling for experimental purposes present only minor problems. Unit seed extractors and storing equipment should prove helpful in keeping the seed from contamination.

FUNDAMENTAL INVESTIGATIONS

Cytological studies of normal and abnormal types of our southern pines should help to bring about a clearer understanding of these species. Studies with mutagens will be of fundamental interest also.

Anatomical studies of our southern pines will help us to devise selection criteria and to study inheritance of these characteristics.

Taxonomic and morphological studies will lead to a better understanding of the natural variations and the evolutionary status of our species. It will be interesting to find out what a typical slash pine or longleaf pine looks like and to determine the degree of natural hybridization which occurs in our southern pines.

RESEARCH ASPECTS OF PROBLEM

The selection phase of the project should be very sensitive to a comprehensive research program. As long as selection is based strictly on phenotypic appearance, the ratio of selected genotypes to selected phenotypes will be low. In other words, a large number of so-called plus trees will inevitably be selected because they were growing under favorable conditions, since some desirable characteristics, such as growth rate or natural pruning can be greatly changed by different environments.

One of the first tasks in a breeding program is to assess the natural variation which exists in a species. After the range of variation of the various characters has been studied, determined attempts should be made to devise relatively simple diagnostic methods for selection. A thorough knowledge should be gained of the cause-and-effect relationships between the factors which bring about desirable or undesirable phenotypic expressions. When we can use simple biochemical or biophysical tests to evaluate our initial selections, we will be increasing the ratio of selected genotypes to selected phenotypes. In some fields of selection this knowledge is being used, e. g., tannin content of bark in chestnut as an indication of resistance to the chestnut blight, viscosity of oleoresin as an indication of gum yield from slash pine, and resin on pine branches as an indication of resistance to resin midge.

Research of a fundamental nature in the physiology of our trees will help to elucidate some of the relationships such as heartwood formation and natural pruning in southern pines, lignification of cells in early spring flush and straightness of stems, chemical composition and resistance to insects and fungi, and many more.

If we had better criteria for individual tree selection, we could prepare better guides for selecting trees for seed producing areas and for silvicultural systems which aim at natural regeneration.

Nursery bed selection can only be of value if the characteristics for which the seedlings are being selected in the juvenile stage maintain their superior attributes through maturity. Although some of these trees might maintain their desirable characters, nursery bed selection has a place in a forest genetics program only if these factors are subject to strong genetic control. Information on the relationship between juvenile characters and their performance at maturity is needed. Geneticists have demonstrated that the development of organisms is epigenetic--the mature organism is not performed and hidden away in the germ cells. We have also learned that our forest trees have an open system of growth. These two fundamentals of biology make it appear unlikely that the degree of correlation between juvenile and mature characteristics of trees will be great. It seems expedient to attack first those characters which are revealed in young trees--characters which "mature" early, such as viscosity of oleoresin, early height growth in longleaf, and perhaps some of the anatomical cell characteristics. Studies on the efficiency of the net photosynthetic rate of the needles of young seedlings might be an objective way to evaluate selected seedlings.

The results on our inheritance study of oleoresin yield in slash pine point very strongly toward a high degree of heterozygosity in this species. Few tree characters of interest to foresters are subject to simple Mendelian inheritance; most are controlled by multiple-factor inheritance. Inheritance of viscosity of oleoresin is possibly a good example of this, and further studies on the mode of inheritance of individual factors which cause a desirable or undesirable character should be fruitful. It should also be pointed out here that heterozygosity as found in our trees presents great opportunities to the tree breeder.

Unless forest tree improvement work is carried out within the framework of existing or postulated geographic races, the research program can suffer serious setbacks. Seed-source studies in progress now will be invaluable in future work and also in preparing recommendations for practical application of research findings. Results on the nature of geographic differences of economic importance can be directly applied by practicing forestry organizations.

By interspecific crossing it should be possible to minimize some of the undesirable effects of heterozygosity in the southern pines and produce a tree which is well suited for a particular condition. All possible species combinations with the available breeding material should be attempted. Intraspecific hybridization with trees growing at the extremities of the range of a species should be conducted also, to evaluate the possibility of heterosis in the resulting progeny.

Inbreeding is a classical approach to a genetics program, but with forest trees this method has little direct practical value. However, a number of selfings should be made during each season to provide material for a breeding arboretum. Some of these selfed trees should prove very valuable assets after some 10 to 20 years.

As slash and longleaf pine reproduce best by seed and can only be propagated with difficulty by vegetative means, the establishment of seed orchards for superior trees is the logical way to plan a tree improvement program. The concept of seed orchards for forest trees is new and therefore opens up expanded fields of research. Such problems as spacing of trees, number of clones represented in an orchard, width of isolation strip, soil fertility, irrigation, flower stimulation, and cone protection need attention. All these problems, being relatively well defined, should be susceptible to solution by research.

Until seed orchards of tested parentage are in production, a large percentage of seed will be collected from present seed-production areas. The management of these areas needs attention if large quantities of seed are to be produced and collected from these stands. Wood-using industries which have established seed production areas will gladly cooperate with research organizations to solve such problems as: selection and spacing of "seed producers," fertilization of soil, cone protection, and cone collection.

Results of the gum-yield phase of the tree breeding program at the Lake City Research Center are a good example of the knowledge which can be gained by a sustained research program. Since the beginning of this program in 1941, the following information has become available:

1. Slash pines yielding at least twice as much gum as average trees of similar size have been located in natural stands.
2. Techniques have been developed to propagate these trees vegetatively, and clonal plantations have been established.
3. The selected trees have been control cross-pollinated to study the inheritance of oleoresin yield, and progeny is growing in testing plantations.
4. The inheritance of gum-yielding ability has been demonstrated in both longleaf and slash pine.
5. The relationship between initial 24-hour rate of flow and the size and number of horizontal resin ducts, and the viscosity of the oleoresin has been demonstrated.
6. During a 2-week flow period, viscosity of oleoresin showed a highly significant association with yield.
7. Viscosity of oleoresin is a fixed character in slash pine and is subject to multiple-factor inheritance.
8. Increase in yield as a result of control crossing of high-gum yielders has been demonstrated.
9. Efficient techniques to graft scions from superior trees for seed orchard establishment have been developed and seed orchards have been established.

Succeeding stages of plantation establishment, management for maximum gum yield, and integration with timber production will be undertaken in cooperation with the gum naval stores and forest management research projects. Grazing of young turpentine plantations may be another source of supplemental income, and if so, would also bring the range management division into the over-all problem.

PROPOSED PROGRAM

The various problems listed below have been assigned a priority based on importance, urgency, susceptibility to solution through research, and work under way at other centers.

Problem	Importance	Urgency	Susceptibility to solution through research	Priority
Species selection (native and exotic)	Medium	Medium	Good	Medium
Race or cline selection	High	High	Good	High
Ecotype selection of slash pine	Medium	High	Good	Medium
Stand selection of slash and longleaf pine	High	High	Average	High
Individual tree selection				
Early juvenile growth of longleaf pine	High	High	Average	High
Resistance of longleaf to brown spot disease	Medium	Medium	Average	Low
Resistance of slash pine to fusiform rust	Medium	Medium	Average	Medium
Slash and longleaf of good form, straight grain, rapid growth, high density (mature stands)	High	High	High	High
Slash and longleaf of rapid growth (nursery beds)	High	Medium	Good	Medium
Slash and longleaf of high gum yields	High	High	Excellent	High

Problem	Importance	Urgency	Susceptibility to solution through research	Priority
Intraspecific pollinations	High	High	High	High
Interspecific pollinations	High	Medium	High	Medium
Progeny testing by means of				
a. rooted cuttings	Medium	Low	Medium	Medium
b. plantations of controlled progeny	High	High	High	High
c. natural progeny	Medium	High	Medium	High
Seed orchard establishment	High	High	High	High
Seed orchard management	High	High	High	High
Facilitating studies				
a. pollination studies	High	Medium	High	Medium
b. cone-protection studies	High	High	Medium	Medium
c. vegetative propagation studies	Medium	Medium	High	Medium
d. flower initiation studies	High	High	High	High
Fundamental studies				
a. cytological studies	Low	Low	High	Low
b. anatomical studies	High	Medium	High	Medium
c. taxonomic and morphological studies	Low	Low	Medium	Low

A forest tree improvement program which has direct practical benefits to forestry as the objective is in a dynamic state. Once the methods and techniques to bring the program through the various logical phases have been developed, emphasis should be placed on the feasibility of practical application to forestry. The logical steps for such a program are selection, progeny testing, and seed orchard establishment. Most studies will be of a seasonal nature and the extent of some of these will be dictated by weather conditions, such as the studies on control pollinations. A division of work load according to the technical background of the personnel and with an eye on peak loads will increase accomplishment. For some objectives such as gum production the program is now in the seed-orchard stage, while for other objectives rigorous selection studies are still needed. A yearly re-evaluation of the research results of this program as well as those of kindred projects is needed to decide on current studies. Studies of high, medium, or low priorities will be carried out concurrently so as to make the most efficient use of manpower, time, and equipment. There are some problems with a high priority which have been installed but need little attention during the next decade. Also, outlines for several "package" research studies well suited for thesis or dissertation problems should be kept in mind for reliable cooperators.

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APPENDIX

Table 1. --Total land area
(In thousands of acres)

Location 1/	Forest land		Agric-ulture 2/	Other 3/	Total
	Commercial	Non-commercial			
SE Georgia	7626.8	50.4	2211.8	710.3	10599.3
SW Georgia	3057.5	--	2402.6	180.7	5640.8
NE Florida	7601.7	92.0	1285.2	546.7	9525.6
NW Florida	5928.0	132.1	935.1	324.7	7319.9
Central Fla.	5747.2	232.0	1370.5	2429.3	9779.0
S. Florida	2174.2	1139.8	877.9	3662.2	7854.1
Total	32135.4	1646.3	9083.1	7853.9	50718.7
Percent	63.4	3.2	17.9	15.5	100.0

1/ As defined in Forest Survey Releases 30, 31, 32, 33, 37, and 39.
2/ Includes fenced native and improved pastures.
3/ Marsh, dunes and beaches, urban and other nonforested areas.

Table 2. --Commercial forest area by forest type and stand-size class in Florida and South Georgia
(In thousands of acres)

Forest type	Large saw-timber	Small saw-timber	Poles	Seedling-sapling	Poorly stocked	Total
Longleaf pine	45.2	1101.1	2244.6	923.4	5332.7	9647.0
Slash pine	174.7	2110.0	1616.3	1737.6	2204.7	7843.3
v. densa		33.7	123.1	108.6	1490.1	1755.5
Loblolly pine 1/	184.2	283.2	296.0	268.4	272.9	1304.7
Pond pine	20.9	82.8	143.6	177.6	257.2	682.1
Sand pine	--	15.6	91.2	144.0	131.2	382.0
Hardwood-pine	120.5	147.6	367.9	446.4	526.7	1609.1
Scrub oak	--	--	2.0	50.9	2145.3	2198.2
Lowland hardwood	693.2	969.7	1292.5	1195.2	759.2	4909.8
Cypress	59.0	601.1	494.9	266.3	241.3	1662.6
Palm	--	--	--	--	141.1	141.1
All species	1297.7	5344.8	6672.1	5318.4	13502.4	32135.4
Suitable for pine	545.5	3774.0	4884.7	3856.9	12360.5	25421.6
Percent pine site by condition	2.1	14.9	19.2	15.2	48.6	100.0

1/ Included 74,300 acres of shortleaf pine and 20,600 acres of red cedar.

Table 3.--Number of turpentine pine trees by working status and tree size [1/]
(In thousands of trees)

Working Status	Poles	Small saw-timber	Large saw-timber	Total
Round	422,003	133,421	4,826	560,250
Working [2/]	2,501	51,864	3,156	57,521
Resting	2,440	30,051	3,041	35,532
Worked out	1,127	14,867	1,861	17,855
Total	428,071	230,203	12,884	671,158

1/ Based on 1952 Forest Survey in south Georgia, Units 1 and 2, and on 1949 Forest Survey of Northeast Florida, Unit 1. West Florida and Central Florida are excluded, as turpentining has declined considerably in these Units since the 1949 survey was taken.

2/ The 1953 Participation Report of the Naval Stores Conservation Program lists a total of 48,799,597 faces worked in 1953, of which 38,024,244 were in Georgia (77.9%) and 7,347,152 were east of the Apalachicola River in Florida (15.1%). Nearly all the remaining turpentine faces are in west Florida, Alabama, and Mississippi.

Table 4.--Area of turpentine timber crops by working status [1]

Crop working status	Area	
	Thousands of acres	Percent
Round timber		
SE Georgia	885.1	--
SW Georgia	464.1	--
NE Florida	882.1	--
	2231.3	41.7
Working timber		
SE Georgia	1223.6	--
SW Georgia	338.0	--
NE Florida	484.9	--
	2046.5	38.2
Resting timber		
SE Georgia	426.8	--
SW Georgia	94.5	--
NE Florida	305.9	--
	827.2	15.5
Worked-out timber		
SE Georgia	138.2	--
SW Georgia	26.8	--
NE Florida	81.9	--
	247.2	4.6
Total	5352.2	100.0

1/ SE Georgia surveyed in 1951, SW Georgia in 1950, and NE Florida in 1948.

Table 5.--Estimated value of forest products for entire states
(In dollars)

Product	Wholesale manufactured value		
	Florida 1/	Georgia 2/	Total
Lumber	47, 475, 000	156, 123, 000	203, 598, 000
Pulpwood 3/	216, 600, 000	212, 719, 500	429, 319, 500
Gum naval stores	5, 295, 000	33, 851, 691	39, 146, 691
Wood naval stores	26, 011, 000	20, 919, 500	46, 930, 500
Crossties	2, 845, 000	7, 630, 800	10, 475, 800
Fuelwood	5, 712, 000	27, 724, 800	33, 436, 800
Poles and piling	5, 429, 000	16, 545, 100	21, 974, 100
Posts	1, 496, 000	6, 250, 000	7, 746, 000
Veneer and cooperage	10, 933, 000	54, 504, 400	65, 437, 400
Plywood	--	9, 600, 000	9, 600, 000
Furniture	--	35, 700, 000	35, 700, 000
Miscellaneous	1, 365, 000	12, 000, 000	13, 365, 000
Total	323, 161, 000	594, 568, 791	917, 729, 000

1/ 1952

2/ 1950

3/ Pulpwood production in 1953 was 15 percent greater, adding about $64, 000, 000 to the total wholesale value.

Table 6.--Area of seedling, sapling, and poorly stocked stands by plantability class in Florida and South Georgia
(In thousands of acres)

Forest type	No planting required	Suitable for machine planting	Hand planting required	All classes
Longleaf pine	3043.1	2646.0	208.8	5897.9
Slash pine	1867.1	981.4	301.4	3149.9
v. densa	408.0	858.0	224.1	1490.1
Loblolly pine 1/	292.2	82.2	45.8	420.2
Pond pine	269.8	74.0	33.3	377.1
Sand pine	34.3	71.3	25.6	131.2
Upland hardwood 2/	627.9	130.2	176.0	934.1
Scrub oak	224.6	1516.9	454.7	2196.2
All types	6767.0	6360.0	1469.7	14596.7

1/ Includes 13,200 acres of shortleaf pine in Georgia.
2/ Includes 308,400 acres of hardwood-pine type in Georgia.

Table 7. --Stocking[1] on commercial forest area by forest type, Florida and South Georgia

(In thousands of acres)

Forest type	0-9 percent	10-39 percent	40-69 percent	70-99 percent	100 + percent	Total
Longleaf pine	4053.8	3458.4	1270.3	480.9	383.6	9647.0
Slash pine	1582.8	2102.3	1226.8	766.5	2164.9	7843.3
v. densa	1364.6	346.3	36.5	8.1	--	1755.5
Loblolly pine [2]	188.2	280.6	258.1	123.9	453.9	1304.7
Pond pine	175.2	279.9	123.1	38.7	65.2	682.1
Sand pine	110.6	124.1	43.6	23.5	80.2	382.0
Hardwood-pine	387.9	325.5	181.8	152.2	561.7	1609.1
Lowland hardwood	422.6	883.2	1095.6	667.3	1841.1	4909.8
Cypress	165.8	261.5	262.3	301.5	671.5	1662.6
Scrub oak	1999.2	157.3	32.9	8.8	--	2198.2
Palm	141.1	--	--	--	--	141.1
All types	10591.8	8219.1	4531.0	2571.4	6222.1	32135.4

1/ All sound trees 1.0 d.b.h. and larger.

2/ Includes 24,700 acres of shortleaf pine in Georgia.

Table 8. --Percentage of satisfactory regeneration by forest types [1]

Location	Long-leaf pine	Sand pine	Slash pine	Pond pine	Lob-lolly pine	Hard-wood-pine	Up-land hdwd [2]	Ave. all types
SE Georgia	81	--	89	89	91	85	85	86
SW Georgia	74	--	78	100	74	76	68	75
NE Florida	55	89	54	70	63	--	61	56
NW Florida	58	9	35	68	62	--	85	54
Central Fla.	32	11	40	21	25	--	41	34
S. Florida	--	--	27	--	--	--	27	27

1/ Compiled from table 21 of the Florida and Georgia Forest Survey reports.

2/ Exclusive of scrub oak.

SPECIES IMPROVEMENT FIELD INSTALLATIONS
(As of August 1954)

Olustee Headquarters

Nursery phase of slash pine seed source study, G-7.--This study is set up to investigate possible clinal changes in growth characteristics associated with different proveniences of slash pine within its natural range. Collection zones of slash pine seed will be mapped if the study shows large enough differences.

Outplantings will be made in Baker County, Florida, Lake County, Florida, Calhoun County, Florida, Dooly County, Georgia, and Effingham County, Georgia.

Germination differences between the 15 sources sampled in 1953 were observed in a replicated seedbed study.

Arboretum, G-8.--A collection of pine-species and proveniences will fill the need for an arboretum and introduction garden.

At present there are 107 different lots in nursery and transplant beds, to which additional acquisitions will be added. Seed is sown upon arrival, then the seedlings are transplanted for one year and subsequently planted in the arboretum where each lot will be represented by 25 trees.

Grafts (1953-1954), G-6.--High-gum yielders and rapid growers have been grafted on 2 to 3-year-old potted seedlings. Grafts of "mutant" and undesirable trees were made for estimation of the genotype.

Grafts of hybrids and exotics from scion material supplied by the Institute of Forest Genetics, Placerville, California, are also included.

Heteroplastic micrografting, 159-A.--Scions from 1 to 4-month-old slash pines were grafted on stock of another species or genus to stimulate early flower production. No flowers were observed the first season after grafting.

Anatomical study of flower primordia initiation in slash pine, G-21.--Buds were collected during the summer of 1954 to see when male and female flowers are laid down in slash pine.

Plantation of rooted-slash pine cuttings, 0-132.--A clonal outplanting to evaluate the genotype of selected high-gum-yielding slash pines. At the same time continuation of valuable germ plasms is safeguarded. Plantation is used for controlled breeding.

Check on viscosity of oleoresin showed that this is a fixed character in slash pine.

Graft outplanting, G-18. --Study of performance of bottle, veneer, and cleft grafts.

Auxin treatment of longleaf seed, 0-165. --Dosage-response study of 2 methyl-4 chlorophenoxy-acetic acid treatment to stimulate early height growth of longleaf pine seedlings.

Progeny testing plantation, 0-146. --A 4-year-old plantation of slash pines resulting from controlled and open pollinations with parents of different gum-yielding ability. Planting followed a statistical design with 8 blocks and 4 replacement blocks. In $\pm$ 8 years the progeny will be tested for gum-yielding capacity.

Species-site relationship study, G-3. --Slash, loblolly, longleaf, and Sonderegger pine planted in randomized blocks on an adverse site to observe and compare the performance of each. An identical outplanting is in central Florida (Lake County).

Pecan Orchard

Cone-protection study, G-17. --Slash pine cones are sprayed with BHC and DDT, in water and in oil, once and repeated after 3 months, to protect against insect attack. The oil solution has already proved itself unsatisfactory, since it killed the cones as well as the insects.

Seed-production area, G-19-A. --A 3-acre area of an 18-year-old slash pine stand was cut to 33 stems per acre, leaving the best-formed trees which had also at least 50 percent more volume than the average tree of the stand before thinning.

It is an example of a method for improving seed quality, which can be carried out by most woodland owners.

Slash pine selection plot, G-19-B. --Outstanding slash pine trees in a natural "pond" area.

Grafting plot, O-159-B. --Study on feasibility of field-grafting slash pine. Cleft, veneer (side slit), and bottle grafts were used under partial shade with and without moisture chamber. The bottle graft in the open was most successful (95 percent). Some hybrids of Southern pines were also grafted. One of them bore 2 flowers after one year.

Air-layering study, G-13.--Only half of this experiment is located in the pecan orchard (see item also under Lake City Airport). The study involves the effect of age, application-time, and concentration of indole-butyric acid on air-layering of slash pine. Age: 6 (Airport) and 23 (Pecan Orchard) years. Time: June and September 1954. Concentration: 0.4, 0.8, 1.2 percent in talcum powder.

Progeny testing plantation,' 0-116.--This 8-year-old plantation resulted from controlled and open pollinations, with parents of different gum-yielding capacity. The plantation consists of 7 randomized blocks and 3 replacement blocks. Slash x longleaf and a slash x loblolly hybrid are present in a replacement block.

The plantation produced a large number of flowers in 1953-1954 which were used for back-crossing, cumulative breeding and hybridization work

Gum-yield inheritance study, G-11-A, B, C.--Plantation 0-116 was used in June 1954 to conduct a study of gum-yield inheritance in slash pine. Study G-11-A compared the gum yield from progeny of known gum yielders (0-116). Gum yield was determined during a 4-week flow from 1-inch punchwounds which were sprayed with 50-percent sulfuric acid. Study G-11-B determined the physical factors which control gum flow in the 10 living "G" trees. Viscosity of the gum, as well as size and number of resin ducts were measured in Study G-11-C.

Seedling-variation study, 0-163-A, B.--An annual outplanting of 20 selected slash pine seedlings to show and observe extremes in development under commercial conditions.

One-parent progeny test, G-4.--Six slash pine trees were selected for their extremely poor form. Their open-pollinated progeny grows in randomized blocks so that inheritance of form may be observed. Previously, the hypothesis of a relationship between cone size, seed size, and seedling size was tested.

South Florida-slash pine study, G-16.--Selected and average south Florida slash pine seedlings along with seedlings of the north Florida type were outplanted to observe their development. The stock came from 2 nurseries, one located in south Florida and one in Baker County, Florida.

Slash pine ecotype study, G-2.--This study investigates the possibility of two distinct ecotypes associated with a wet and a dry site respectively. Seed from the two sites was sown in the Olustee nursery. The resulting seedlings grow in a randomized block design in two plantations. The Pecan Orchard plantation is on a dry site. The wet site plantation is on land of the National Container Company.

Plantation of hybrids, G-14.--Twenty hybrids developed by the Southern Forest Experiment Station have been outplanted for observation.

Lake Butler Road

Longleaf plantation, 0-100-Informal.--Open-pollinated progeny from parents of known gum-yielding capacity were planted in 1936. The study showed inheritance of gum-yielding ability.

Extreme variation in height growth showed up in the plantation. Therefore, the outstanding tree with respect to growth is being used in the breeding program.

National Container Land

Southwide geographic seed source study, G-20.--Slash pine seedlings from 6 geographic locations, covering the entire range for this species, were brought together in a randomized block plantation for observation of possible clinal growth differences. The Lake City Research Center cooperates with the Committee on Southern Forest Tree Improvement in this study.

Nursery bed selection study, G-1.--For this study 1100 "superior" seedlings were selected from the Florida State Nursery (0.004 percent) and outplanted for observation of subsequent behavior. A measurement plot in the center of the plantation, where 3 rows of selected plants alternate with 3 rows of average seedlings, serves for statistical comparison.

Slash pine ecotype study, G-2.--The wet-site plantation of this study (see study G-2 under Pecan Orchard) is located in this area.

Longleaf pine seed source study, G-15.--From 6 sources scattered over the longleaf range, seedlings are outplanted in a randomized block design for observation and comparison.

A small plantation of Sonderegger seedlings from these sources extends the range of observation.

Slash pine seed source study, G-7.--The seedlings from 16 geographic locations covering the entire commercial range of slash pine will be outplanted in the fall of 1954 in a randomized block design. The study is designed to supplement and support study G-20. On the basis of these two studies, it is hoped that collection zones of slash pine seed can be mapped.

Clonal grafting plot, G-6.--As part of the 1953-1954 grafting program, scions of high yielding and rapid-growing slash pines were grafted directly onto 3-year-old seedlings of a slash pine plantation. Concurrent performance tests will decide which grafts are to be used in the controlled breeding program.

Seed-stimulation study, G-10.--On a 3-acre tract within the National Container seed production area, the effect of 2 fertilizers at 3 levels, combined with injury to the stem on seed production is tested on 20-year-old slash pines.

Lake City Airport

Seed-stimulation study, G-9.--In a 6-year-old slash pine plantation, 4 levels of fertilization combined with 2 types of stem injury and one root injury treatment, are tested for their effect on seed production.

Air-layering study, G-13.--Here the treatments as described under Pecan Orchard are tested on 6-year-old slash pines.