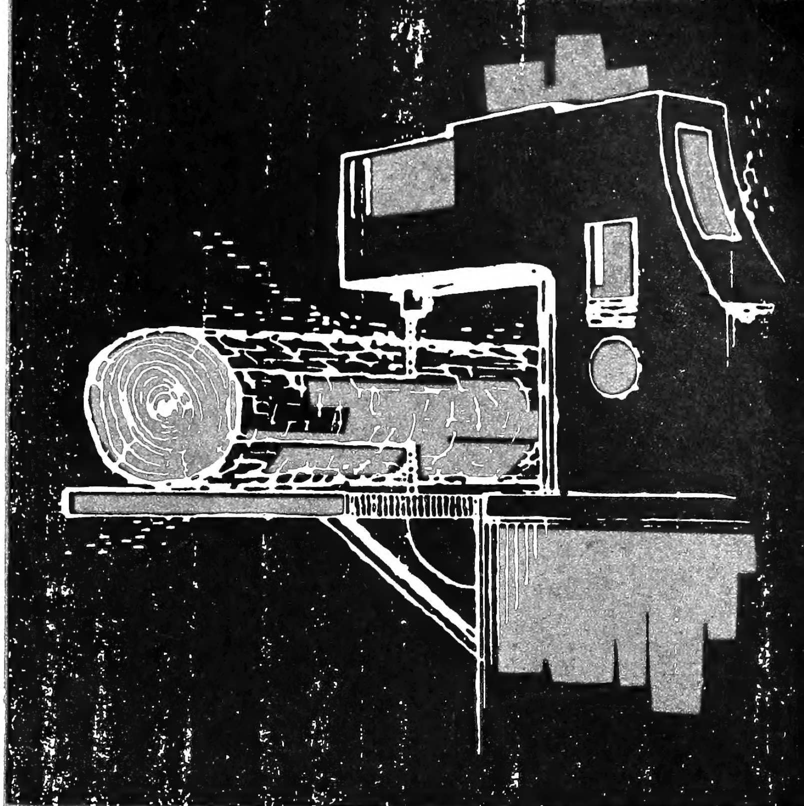
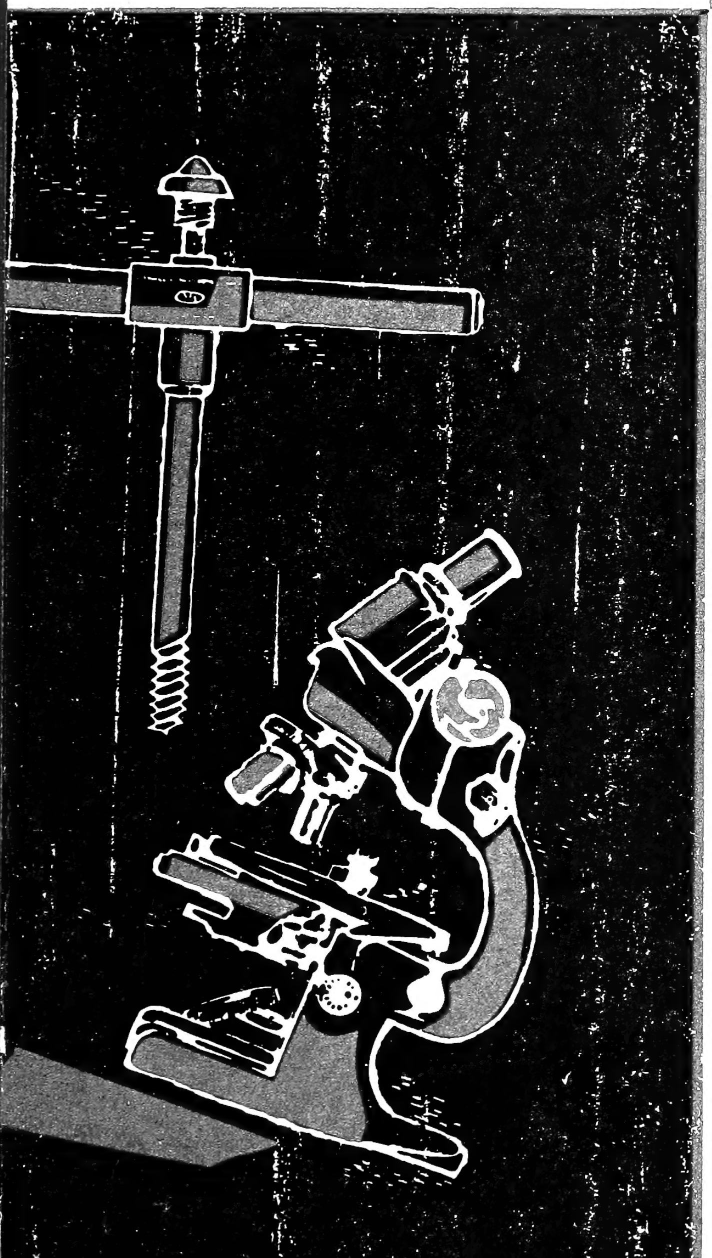
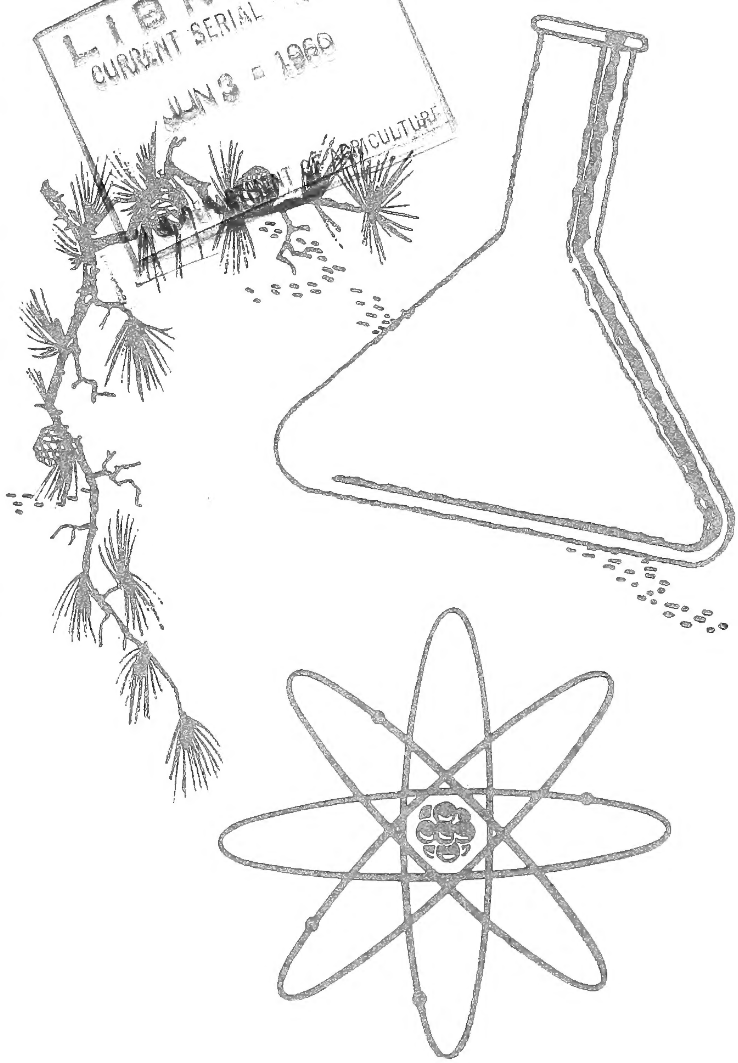
PROCEEDINGS OF THE FIFTH SOUTHERN CONFERENCE ON FOREST TREE IMPROVEMENT

SCHOOL OF FORESTRY
NORTH CAROLINA STATE COLLEGE
RALEIGH, NORTH CAROLINA

JUNE 11-12, 1959







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School of Forestry

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THE FIFTH SOUTHERN TREE IMPROVEMENT CONFERENCE

The Fifth Southwide Conference on Tree Improvement, sponsored by the Southern Forest Tree Improvement Committee was held June 11-12, 1959 on the campus of North Carolina State College, Raleigh. Papers presented at the conference represented a cross-section of work in both the basic and applied fields of forest tree improvement being conducted by workers throughout the southeastern United States. The theme of the conference was "The Application of Tree Improvement in Forest Management".

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This is the nineteenth technical paper released under the sponsorship of the committee on Southern Forest Tree Improvement.

CONTENTS

First Session

Moderator: Joseph F. Pechanec, Southeastern Forest Experiment Station

Second Session

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Page

Five-Year Results of the Southwide Pine Seed Source Study

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It is still too early to delimit the southern pine seed-collecting zones that the Southwide Pine Seed Source Study is designed to map. Only 53 percent of the trees in the study have been 5 years in plantation. In many of even the older plantations, survival and growth are still under-going rapid modification by brown spot, tip moth, or fusiform rust. Any conclusion regarding general patterns of racial variation and the influences from which they have originated would be premature. It would be the height of impropriety to immortalize such conclusions in the proceedings of this Conference. They might distrub or even mislead planting agencies, and would surely be quoted here and abroad and remain in the literature to haunt us forevermore. This report is therefore limited to incontrovertible facts that cannot becloud later issues.

First and foremost of these facts is the status of the study itself.

The study was proposed and undertaken at the First Southern Conference on Forest Tree Improvement, at Atlanta, in January 1951, partly in view of the need for the information it would yield, partly in view of the opportunity offered by the general seed crop due to mature the following fall.

Active preparations started in July 1951. Seed was collected in 1951 and again in 1952. In 1952-53 and 1953-54, hundreds of individuals in dozens of agencies in 16 States cooperated in establishing 9 test plantations of slash pine and 19 plantations apiece of longleaf, loblolly, and shortleaf (table 1). These were installed in accordance with the study working plan of September 12, 1952.

A principal feature of the study is that at or near each source of seed, stock representing that source is tested in comparison with stock representing several other sources of the same species. The study does not, however, test every source at every other source. To keep seed requirements and and plantation layouts within bounds, sources were grouped in "series" to test hypotheses regarding the effects of temperature, evapotranspiration rate, gross soil differences, and plant migration upon the evolution of geographic races. Series within species are linked together by inclusion of certain sources that they share in common, and plantations representing both series

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1/ Chairman, Subcomittee on Geographic Source of Seed, Committee on Southern Forest Tree Improvement.

Table 1. Status of Southwide Pine Seed Source Study as of June 1, 1959 1/

Date of plantation establishment, and species	Plantations				Plots				Measurement trees 2/				All trees, including border rows 2/			
	Active	Doubtful	Abandoned	Total	Active	Doubtful	Abandoned	Total	Active	Doubtful	Abandoned	Total	Active	Doubtful	Abandoned	Total
1952-53; 1953-54																
Longleaf pine	10	-	9	19	228	-	216	444	11,172	-	10,584	21,756	27,588	-	26,136	53,724
Slash pine	8	1	-	9	174	28	-	202	8,526	1,372	-	9,898	21,054	3,388	-	24,442
Loblolly pine	18	-	3/ 1	19	588	-	3/ 36	624	28,812	-	3/ 1,764	30,576	71,148	-	3/ 4,356	75,504
Shortleaf pine	12	2	5	19	312	52	120	484	15,288	2,543	5,880	23,716	37,752	6,292	14,520	58,564
Subtotal, all species	48	3	15	66	1,302	80	372	1,754	63,798	3,920	18,228	85,946	157,542	9,680	45,012	212,234
1956-57																
Longleaf pine	28	1	-	29	666	24	-	690	32,634	1,176	-	33,810	80,586	2,904	-	83,490
Shortleaf pine	32	1	-	33	812	24	-	836	39,788	1,176	-	40,964	98,252	2,904	-	101,156
Subtotals, both species	60	2	-	62	1,478	48	-	1,526	72,422	2,352	-	74,774	178,838	5,808	-	184,646
Grand total, all years and species	108	5	15	128	2,780	128	372	3,280	136,220	6,272	18,228	160,720	336,380	15,488	45,012	396,880

1/ Exclusive of plantations lost and replaced the next year by means of seed from the same crop, and of certain side studies and supplementary plots.

2/ Approximate numbers planted, including trees that have subsequently died.

3/ Destroyed by incendiary fire shortly after 5-year reexamination.

have been established in the vicinity of such common or "link" sources.

Adverse influences, particularly the 1953 and 1954 droughts, depleted or destroyed so many of the original longleaf and shortleaf plantations that, with the concurrence and help of the original and many new cooperators, more seed of these 2 species was collected in 1955 and 29 new longleaf and 33 new shortleaf plantations were established in 1956-57. The series represented in these new plantations paralleled as closely as possible, although they did not exactly duplicate, the original series of the same species.

To date, 128 plantations, including 3,280 plots, about 161,000 "measurement" trees, and nearly 400,000 trees in all, have been established in the course of the study. These totals exclude several side studies and several plantations reestablished a year late with stock from seed carried over as insurance.

As of today, 15 plantations have been abandoned, but 14 have been replaced with later plantations. The status of 5 plantations is in doubt. On the list for further reexamination are 108 plantations, all of which have already been remeasured at least twice (during spring and fall of the first year) and 48 of which have been remeasured 4 or more times. These active plantations are not all equally suitable for the purposes of the study; some have been marred by accidents, or are on sites less uniform than might be desired, or have suffered enough mortality to reduce their effectiveness for evaluating infection, infestation, and growth. The majority are quite satisfactory, however, and some are outstandingly successful. As a group, the 108 active plantations, which contain 2,780 separate plots and 136,000 measurement trees, are of tremendous research value. They constitute an accomplishment of which the cooperators and the forestry profession may well be proud.

One of the clearest, most interesting, and economically most important results of the study to date is evidence of racial variation of loblolly pine, significant at the 5-percent level and in some instances at the 1-percent level, in susceptibility to southern fusiform rust. The findings confirm and extend the results of racial-variation studies of loblolly based on seed from the 1925 [2/] and 1935 [3/] crops. As they form the main theme of the next paper on this program, I will leave the details to be presented by Dr. Henry.

Differences in fifth-year survival, attributable to geographic source of seed and significant at the 1-percent level, have shown up in all 4 species in this study. They have not appeared in all series of each species, or in

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2/ Wakeley, Philip C. 1954. Planting the southern pine. U. S. Dept. Agr. Agr. Monog. 18, pp. 14-16.

3/ Wakeley, Philip C. 1951. Importance of geographic strains. In Report 1st So. Conf. Forest Tree Improvement, 9 pp. (Processed.)

every plantation of any one series. Attempts to elucidate a pattern must await further analysis, including covariance analyses of the effects of latitude, longitude, elevation, temperature, seasonal and annual rainfall, extent of rust infection, and distance of plantation from seed source. It may be, also, that fifth-year survival of trees alive at the end of the first year will be more revealing than absolute survival, which in many cases has obviously been affected by nursery treatment, site variation, and first-year drought. The following examples, however, illustrate the type of variation in survival which has appeared so far.

Loblolly Series 1 represents Somerset County, Maryland; Onslow, North Carolina; Pamlico, North Carolina; Wilcox (and adjacent Crisp), Georgia; Cullman, Alabama; Jefferson, Alabama; Livingston Parish, Louisiana; Angelina County, Texas; and Clark County, Arkansas. The series was planted in Worcester County, Maryland. Survivals after 5 years (transformed to arc sin $\sqrt{\text{percent}}$ for analysis) varied at better than the 1-percent level of significance. They ranged downward from 96 to 76 percent. While the local (Somerset County, Maryland) source was fifth from highest in survival, its survival was 90 percent--exceeded by survivals of 94 to 96 percent for sources representing Pamlico, North Carolina; Jefferson, Alabama; Cullman, Alabama; and Clark, Arkansas, sources. In contrast, the southernmost, low-elevation Coastal Plain sources--Angelina, Texas, and Livingston, Louisiana--were eighth and ninth on the list, with survivals of 84 and 76 percent, respectively.

Except for the Cullman County, Alabama, source, for which stock was unavailable, the same loblolly series was planted in Pearl River County, Mississippi, near the Gulf Coast. Five-year survivals again varied at better than the 1-percent level of significance, ranging downward from 98 to 73 percent. Here, however, the Angelina, Texas, and Livingston, Louisiana, stock, instead of doing least well, survived best -- 98 and 95 percent, respectively. Stock representing Somerset, Maryland, had next to the lowest survival -- 83 percent.

In a Cherokee County, Texas, plantation of Loblolly Series 1, also in the southern part of the loblolly range, 5-year survivals barely missed significance at the 5-percent level. (This plantation includes only 2 replications of each source, instead of the usual 4.) Here, as in Pearl River County, Mississippi, stock from the Angelina, Texas, source showed best survival--53 percent. Livingston, Louisiana, dropped to sixth place of eight, with 17 percent survival. Somerset, Maryland, dropped to last place, with a survival of 6 percent.

Right next to the Pearl River County, Mississippi, plantation of Loblolly Series 1, just discussed, is a plantation of Loblolly Series 2 that illustrates another element in the survival pattern. Series 2 includes 3 sources that appear in Series 1: Onslow County, North Carolina; Livingston Parish, Louisiana; and Clark County, Arkansas. It includes 6 additional sources:

Newberry, South Carolina, Clarke, Georgia; Spalding, Georgia, Clay, Alabama; Prentiss, Mississippi; and Hardeman, Tennessee.

Loblolly Series 1 in Pearl River County represents 3 average annual temperature zones--57° F. (1 lot), 62° F. (4 lots), and 67° F. (3 lots). In contrast, all of the 9 sources in Series 2 except that from Livingston Parish, Louisiana, are from the 62° or 63° average annual temperature zone. In other words, Series 1 represents, roughly, two or three up-and-down transects of the range of loblolly pine, radiating south and southwest from Maryland. Series 2 represents, essentially, a single east and west transect of the range, almost wholly in one temperature zone.

The contrast in 5-year survivals in the two series in Pearl River County is striking. In Series 1, survival, as already noted, varies with seed source at the 1-percent level of significance; survival percents range downward from 98 to 73 percent. In Series 2, survivals range downward from 95 to 85 percent, and do not approach significance even at the 5-percent level.

The southernmost source of slash pine included in the study may be mentioned as having consistently low survival, even though it is not significantly low in more than one plantation. It is, furthermore, suspected of containing an admixture of South Florida slash pine (*Pinus elliottii densa*), perhaps from pollen contamination. This Polk County, Florida, source has had the lowest 5-year survival of 5 or 6 sources in all 6 plantations in which it has been tested, from Bladen County, North Carolina, to Polk County, Florida, and west to Pearl River County, Mississippi.

The southernmost source of longleaf seed in the study, Hillsborough County, Florida, has shown almost equally consistent low survival. Stock planted in 1953-54 survived least well, at 5 years, of 4 or 5 sources tested in Virginia, North Carolina, Mississippi, and Louisiana. It survived next to best of 4 Sources tested in Dooly County, Georgia--the nearest of the 5 plantations to the geographic source.

Retested in the new 1956-57 longleaf plantations, the Hillsborough County, Florida, source had the lowest 1-year survival of 6 sources in 6 out of 8 plantations, and next to the lowest in the other 2 plantations. One of the 2 exceptions was again in Dooly County, Georgia.

So much for survival, the pattern of which may be expected to change somewhat as fusiform rust takes lethal effect, as years of climatic extremes occur, and particularly as crowns close and competition begins within individual plots.

Average heights at 5 years vary with seed source, at the 1-percent level of significance, in some plantations of longleaf, slash, and loblolly. In shortleaf, height differences closely approach the 5-percent level. (The shortleaf plantations in which the treatest differences in height growth were logically to be expected were lost in the 1953 and 1954 droughts.) Heights of the plantations on which only 1 year's growth has been measured can hardly be expected to show much variation, and have not yet been analyzed.

A noteworthy example of variation of height with source of seed is the Longleaf Series 1 plantation in Dooly County, Georgia. Average heights at 5 years range from 6.2 to 9.0 feet, with the 2 nearest sources (which are from, as well, the most similar climates) well ahead of the other 4. The variation is significant at far better than the 1-percent level. This is one of the first instances on record of such unequivocal racial variation in growth rate of longleaf pine.

The Worcester County, Maryland, and Pearl River County, Mississippi, plantations of Loblolly Series 1, however, and the Pearl River County plantation of Loblolly Series 2, already discussed in connection with 5-year survival, perhaps give a better idea of the results beginning to appear in terms of height.

The 5-year average heights, like the 5-year survivals, varied with seed source, at the 1-percent level of significance, in both the Maryland and the Mississippi Loblolly Series 1 plantations. As with survival, the variation in 5-year heights in the Mississippi plantation of Loblolly Series 2 (the east-west transect of the loblolly range, representing mainly one temperature zone) fell far short of even the 5-percent level of significance.

In the Maryland plantation of Loblolly Series 1, Somerset County, Maryland, stock did best, with an average 5-year height of 10.1 feet. Angelina County, Texas, and Livingston Parish, Louisiana, stock did least well, with average 5-year heights of 7.6 and 6.6 feet, respectively.

In the Mississippi plantation of the same series, by contrast, the Louisiana and Texas stocks stood first and second, with average 5-year heights of 8.4 and 6.6 feet, respectively. Stock from the Somerset County, Maryland, source, although in fifth place of 8 on the list, had an average 5-year height of only 5.6 feet, 2.8 feet less than that of the Louisiana loblolly source.

Graphic analysis shows that, in the Maryland plantation of Loblolly Series 1, there is a strong positive regression of average 5-year height over latitude of seed source. In the Mississippi plantation, there is a weak but still distinct negative regression of average 5-year height over latitude of seed source. In the light of Perry's studies at Gainesville, Florida,[4/] and

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4/ Perry, Thomas O., and Wang, Chi Wu. 1957. Second progress report, Cooperative Forest Genetics Research Program. Univ. Fla. School Forestry Res. Rpt. 4, pp. 21-22.

of observations of onset of dormancy in the fall (both in the Southwide Pine Seed Source Study and in an earlier study), it is surmised that day length as well as temperature may affect the height relationships shown in Loblolly Series 1. If this surmise is correct, variation in height in Series 1 may be expected to intensify as time goes on. Whether significant variations in height will also develop in Series 2, which includes sources having a much narrower range of latitude and hence of day length, remains to be seen.

To sum up briefly, the Southwide Pine Seed Source Study comprises at present 48 plantations established in 1952-53 or 1953-54, and 60 more (all longleaf or shortleaf) established in 1956-57, plus a few ragged remnants of other plantations and a few special studies. The 108 successful plantations have been reexamined 2 to 5 times each, depending on age and on special features of interest. Survival percents and average heights have been worked up for all reexaminations, and pest incidence for many.

Detailed analyses now under way have already shown variations of 5-year survival, of all species, attributable to source of seed and significant at the 1-percent level. They have shown similar variations in average height, also significant at the 1-percent level, in longleaf, loblolly, and slash pines, and approaching the 5-percent level in shortleaf. They have shown widespread variations in the rust-susceptibility of loblolly pine, attributable to seed source and significant at the 5-percent level, the pattern of which will be described in the next paper. Examples of the variations found in survival and height have been given here, but a full report must await further analysis.

Diseases and Insects in the Southwide Pine Seed Source Study Plantations During the First Five Years [1]

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Detailed data on the occurrence of diseases, insects, and other forms of damage have been taken at the end of the first, second, third, and fifth growing seasons on 33 of the 57 Southwide Pine Seed Source Study plantations established during the winter of 1952-53. Details of the study and its establishment are available (1, 2), as are two earlier reports of pest incidence (3, 4). The next examination of the plantations is scheduled for the end of the tenth growing season.

The locations of the 33 plantations and the seed sources, by States, are given in table 1. A plantation consisted of stock from several seed sources, with each source represented by 4 square plots of 121 seedlings each. The center 49 seedlings in each plot were individually inspected for pests at each examination. The seedlings were healthy 1-0 stock when planted. Survival after 5 years averaged 55 percent or better in 29 of the plantations; the Tennessee loblolly and one of the Arkansas shortleaf plantations averaged 43 percent. The longleaf planting in North Carolina averaged 40 percent, and the one in South Carolina 31 percent.

Of the many disease and insect pests that put in their appearance during the 5-year period, none were unexpected and, lucklily, most of them have caused only minor damage.

Brown spot, Scirrhia acicola (Dearn.) Siggers, was common on longleaf pine but, because of periodic application of fungicides for its control, data on its occurrence are not included in the pest appraisals. This disease and Hypoderma lethale Dearn. have also been reported on loblolly pine in some plantings.

The pine webworm, Tetralopha robustella Zell., was recorded during the first 3 years on all species in all plantations except the North Carolina and South Carolina longleaf plantings. It caused little damage, and was largely absent by the fifth year.

1/ Field data on which this report is based were taken by pathologists and entomologists of the Southern and Southeastern Forest Experiment Stations, Forest Service, U. S. Department of Agriculture, in conjunction with the cooperators who installed and maintained the plantations.

Other pests found occasionally in minor quantities were the needle blight and needle rust diseases, pales weevil, red-headed sawfly, *Pityophthorus* bark beetle, aphids, pitch midges, and scale insects.

Two old standby plantation pests are not to be dismissed so lightly, however. They are the Nantucket tip moth, *Rhyacionia frustrana* Comst., on loblolly and shortleaf pines, and the southern fusiform rust, *Cronartium fusiforme* Hedgc. and Hunt, on loblolly and slash pines.

Very little tip moth attack was noticed in any of the plantations at the end of the first year. Since then, it has been possible to group plantations by 3 rather definite patterns of attack: 1) Those plantations in which up to about 50 percent of the seedlings were attacked the second and third years and very few or none the fifth year; the 2 Louisiana and 2 Alabama loblolly plantings and the Louisiana and Alabama shortleaf plantings fall into this class. 2) Those in which there was a rather gradual increase in number of seedlings attacked, reaching 100 percent or near the fifth year; this group includes the Tennessee, 1 Georgia, and 2 North Carolina loblolly plantings and the Mississippi, Georgia, South Carolina, 2 Arkansas, and 2 Tennessee shortleaf plantings. 3) Those in which the buildup was very rapid to 100 percent of the seedlings attacked the third year and again the fifth year; this pattern appeared on the South Carolina, 2 Mississippi and 2 of 3 Georgia loblolly plantings.

No explanation of the 3 patterns is offered. Merely because the plantations in Louisiana and Alabama were lightly attacked, however, it should not be conjectured that tip moth is a lesser problem in these States than elsewhere in the South. The data do not indicate that differences in attack are related to seed source.

Incidence of fusiform rust has varied greatly between planting sites for both slash and loblolly pines. In the Tennessee loblolly planting, there has been no rust. In the others, infection generally has increased gradually from the first through the fifth year. The percentages of infection mentioned here are cumulative and are based on the numbers of living seedlings plus those that have been killed by the rust.

The amount of infection in the slash pine plantations at the end of the fifth year is given in table 2. The variation of incidence between plantations is obvious. It ranges from very high in the Louisiana to relatively low in the Alabama and Florida plantings. As a further indication of severity, it may be noted that 87 percent of the infected seedlings in the Louisiana planting are stem-cankered, with 13 percent already rust-killed; corresponding figures for the Mississippi planting are 70 percent and 15 percent; and for the South Carolina planting 43 percent and 1 percent. In the latter planting, most of the infection has occurred since the third year, so that fewer branch cankers have reached the stem. It is likely that stem-cankered 5-year-old seedlings will die prematurely or through stem-brooming be useless to man, and that at least some additional stem infection will occur. Hence the rust will make the Louisiana planting virtually a total loss, and will severely damage the Mississippi and South Carolina plantings. Of possibly more interest from the tree improvement standpoint is the fact that there is a significant difference between seed source and rust incidence only in the South Carolina planting, where the Florida source is significantly higher in infection than the other sources. The same source had the highest or one of the highest infection rates in the other 4 plantings, but the differences are not significant. Analysis of the third-year data gave identical results.

Tables 3 and 4 summarize the incidence of fusiform rust in the loblolly pine plantations at the end of the fifth year. Series 1 is the "Temperature Series" and Series 2 is the "Botanical Origin and Migration Series" (1). The tables omit the Tennessee plantation, where there was no rust, and the South Carolina and 2 of the 3 Georgia plantings, where there was less than 15 percent rust in any seed source. The range of infection between plantations is again wide, as it was with slash pine. The Coosa County, Alabama, planting and the Louisiana plantings, which are in the same place as the Louisiana slash pine planting, have the most rust. About 66 percent of the infected seedlings in the Louisiana plantings are stem-cankered, with 8 percent already rust-killed, while corresponding figures for the Coosa County, Alabama, planting are 93 and 8 percents. Consequent losses due to rust are certain to be heavy in such cases.

Though the relative amounts of stem cankering and of mortality due to rust do not appear to be affected by seed source, the total percentage of stock infected is definitely influenced, for the differences are significant in every plantation listed in table 3 and 4. Results at the end of the third year gave a similar picture. In general, the seed sources fall into similar susceptibility classes in the various plantations. Though later data may alter the picture, the present indications are that, as represented in this study, the Texas, Maryland, Arkansas, and Louisiana loblolly sources fall into a relatively low susceptibility group as compared with the North Carolina, South Carolina, Georgia, Alabama, and Mississippi sources. The one marked exception noted in this pattern is the inexplicably high infection of the Texas source and low infection of the Onslow County, North Carolina, source in the Talladega County, Alabama, planting.

Reaction to fusiform rust is but one of many ways in which racial differences may show up. Hence it seems reasonable to think that because of its restricted natural range slash pine would show little evidence of races while loblolly pine with its much wider range would show more evidence. From the standpoint of variation in the rust organism, these data indicate no racial complex, because the hosts (seed sources) reacted similarly when exposed from the Carolinas to Louisiana.

Thus, in summary, many diseases and insects have been noted during the first 5 years of the Southwide Pine Seed Source Study, but only 2 are of major importance. Tip-moth injury was and is severe in most of the shortleaf and loblolly plantations, irrespective of seed source, and most certainly is impeding height growth. Fusiform rust is variable in intensity among the slash and loblolly plantations, causing no damage in some and near total loss in others. Rust incidence consistently showed significant differences between seed sources in the loblolly pine plantings, but in only one case with slash pine. Evidence is negative for the existence of races of the rust fungus.

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2. Committee on Southern Forest Tree Improvement (Subcommittee on Geographic Source of Seed). 1956. Supplement No. 1 to the Original Working Plan of September 12, 1952, for the Southwide Pine Seed Source Study. 110 pp. [Processed.]

3. Henry, B. W., and Coyne, J. F. 1955. Occurance of pests in Southwide Pine Seed Source Study. Proc. Third South. Conf. Forest Tree Improvement, pp. 49-54. U. S. Forest Serv. South. Forest Expt. Sta. [Processed.]

4. Henry, B. W., and Hepting, G. H. 1957. Pest occurrences in 35 of the Southwide Pine Seed Source Study plantations during the first three years. U. S. Forest Serv. South. and Southeast. Forest Expt. Stations, 7 pp. [Processed.]

Table 1. Sources of seed and locations of plantations, by States

States	Loblolly		Slash		Longleaf		Shortleaf	
	Seed collection areas	Plantations studied	Seed collection areas	Plantations studied	Seed collection areas	Plantations studied	Seed collection areas	Plantations studied
	Number							
New Jersey	0	0	0	0	0	0	1	0
Pennsylvania	0	0	0	0	0	0	1	0
Maryland	1	0	0	0	0	0	0	0
North Carolina	2	2	0	0	2	1	0	0
South Carolina	1	1	1	1	2	1	1	1
Georgia	3	3	0	0	1	1	1	1
Florida	0	0	1	1	2	1	0	0
Alabama	3	2	1	1	1	0	1	1
Mississippi	1	2	1	1	0	1	2	1
Louisiana	1	2	1	1	2	0	1	1
Texas	1	0	0	0	1	0	1	0
Oklahoma	0	0	0	0	0	0	1	0
Arkansas	1	0	0	0	0	0	3	2
Tennessee	1	1	0	0	0	0	1	2
Missouri	0	0	0	0	0	0	1	0
Totals	15	13	5	5	11	5	15	9

Table 2. Slash pine; fusiform rust infection after 5 years in plantation

Seed source	Planted in:				
	Washington Parish, La.	Pearl River Co., Miss.	Monroe Co., Ala.	Baker Co., Fla.	Georgetown So., S. C.
	Percent				
Baker Co., Fla	81	34	11	6	68 1/
Colleton Co., S. C.	81	34	3	3	46
Monroe Co., Ala.	73	28	7	3	40
St. Tammany Parish, La.	66	25	9	4	34
Harrison Co., Miss.	-	24	-	-	-

1/ Significantly higher at 5-percent level.

Table 3. Loblolly pine series 1; fusiform rust after 5 years in plantation [1/]

Seed source	Planted in:			
	Washington Parish, La.	Pearl River Co., Miss.	Talladega Co., Ala.	Craven Co., N. C.
	Percent			
Angelina Co., Texas	15	3	28	4
Somerset County, Md.	21	4	6	6
Clark County, Ark. [2/]	35	7	1	4
Livingston Parish, La. [2/]	41	12	3	6
Pamlico County, N. C.	56	19	13	13
Onslow County, N. C. [2/]	67	9	5	22
Wilcox County, Ga.	71	21	21	15
Jefferson County, Ala.	71	26	21	19

1/ Differences among seed sources in each plantation are significant at the 5-percent level.

2/ Also in series 2.

Table 4. Loblolly pine series 2; fusiform rust after 5 years in plantation [1/]

Seed source	Planted in:				
	Washington Parish, La.	Pearl River County, Miss.	Coosa Co., Ala.	Spalding Co., Ga.	Craven Co., N. C.
	Percent				
Clarke Co. Ark. [2/]	44	6	29	-	3
Livingston Parish, La. [2/]	41	8	35	11	3
Hardeman Co, Tenn.	66	17	59	15	2
Prentiss Co, Miss.	73	27	71	28	8
Onslow Co, N. C. [2/]	67	24	82	31	20
Newberry Co, S. C.	86	36	66	35	12
Clarke Co, Ga.	74	38	80	25	14
Spalding Co, Ga.	82	29	75	31	15
Clay Co, Ala.	85	38	86	30	12

1/ Differences among seed sources in each plantation are significant at the 5-percent level.

2/ Also in series 1.

Disease Resistance Studies in Tree Improvement Research

by

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The term tree improvement research suggests different things to different people. It takes in a variety of sciences which, though often working separately, all have primarily the same purpose: to produce better trees. One phase of this expanding and important program is disease-resistance research. This is not a new field of work in forestry. Resistance studies have achieved varying degrees of success with such important diseases as mimosa wilt, littleleaf, white pine blister rust, chestnut blight, and several diseases of poplars. More recently research on resistance to fusiform rust has begun in the South. As this subject is of immediate interest, its application in the field of tree improvement will be discussed on the basis of present knowledge.

First, the fungus concerned is Cronartium fusiforme, a heteroecious long-cycle rust, requiring two hosts, pine and oak. The destructive stage occurs on the pine. Of the four major southern pines, slash and loblolly are the species most susceptible, longleaf is less susceptible, and shortleaf is considered resistant.

Chemical control in pine nurseries is common practice to provide rust-free stock for field planting. Chemical field control is considered impractical, at present. The application of disease resistance research to this problem is one of the most promising approaches. Though not far advanced, research findings indicate that the development of rust-resistance pines is a definite possibility.

It is a common observation that not all trees in a plantation are rust-infected even though the infection rate is very high. Usually a few individuals either escape infection or possess inherent ability to resist establishment of the fungus. If the latter be true, it is reasonable to assume that this resistance would, to some degree, be transmitted to the progeny from such trees. The heritability of resistance is suggested, though not confirmed, by results from Georgia (1) where after 2-3 years in the field considerable less infection was observed among one-parent slash pine progeny than in 4 lots of control slash seedlings. Progeny from one selection in particular showed a consistently low infection rate. At Gulfport, Mississippi, two local and one Georgia selection have shown indications of resistance in one-parent progeny tests under artificial inoculation conditions. Some of these progeny have been inoculated 2 years consecutively, and are still free of the disease. These findings are encouraging in that apparently some inherent resistance to fusiform rust is present in slash pine. Assuming this to be true, several applications are possible.

The establishment of grafts from tested selections in seed orchards would produce seed yielding a higher percentage of rust-resistant seedlings than would be obtained from bulk collections. To go a step further, it is reasonable to assume that if resistance is transmitted by a selected individual to open-pollinated progenies, intraspecific crosses between selected parents should increase the degree of resistance in the progenies. Seed orchards yielding such progenies would be a valuable asset to forest management in the South. Research is aimed at producing such parent stock.

We have information on the rust-resistance of interspecific hybrid progenies of shortleaf x loblolly, shortleaf x slash, and slash x loblolly. No fusiform rust has been observed in a small planting of shortleaf x loblolly put out as 1-0 stock 7 years ago, although a surrounding slash plantation is from 70-80 percent infected (2). These hybrids have good form and average 29.7 feet in height and 4.8 inches in diameter -- in some contrast to 15.0 feet and 1.9 inches for a shortleaf x shortleaf cross. In artificial inoculation of 1-and 2-year-old shortleaf x slash progenies, no rust galls have been observed, while comparable bulk slash pines were 80 percent infected. After 3 years in the field, shortleaf x slash and shortleaf x loblolly hybrids produced by R. M. Allen and N. M. Scarbrough[1/] show no rust infection and average 1.5 to 2.0 feet more in height than the shortleaf checks.

The most important lead gained from interspecific crosses involving shortleaf is that apparently whatever factor possessed by this species for resistance to fusiform rust is transmitted to its interspecies progenies in a dominant manner. Another encouraging point is the good growth and form of most shortleaf x loblolly, and shortleaf x slash hybrids.

The progenies from two slash x loblolly crosses in the aforementioned Allen-Scarbrough planting were of particular interest. These involved two slash trees crossed with one loblolly. The average height of the 94 hybrids from these crosses is about 6.5 feet, compared to 5.8 feet for 75 open-pollinated plants from the slash mother trees. Rust-infection on the hybrid progenies averaged 89 percent, with those from one cross having 46 of a total of 47 representatives infected; one tree had 41 rust galls. The rust-infection of the open-pollinated slash checks averaged 44 percent, or about half as much as the hybrids. As these are the only progenies of this interspecific cross in the area in any number, it is not known if the high rust susceptibility of the hybrid is unusual or to be expected with this type of cross. The point

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[1/] Allen, R. M. and N. M. Scarbrough. Data to be published.

is important, because in inheritance studies, susceptibility cannot be divorced from the resistance aims. Also, if such a cross consistently gives a high percentage of susceptible plants, these can then be used as check material against which to judge resistance in other progenies.

The ultimate aim of disease resistance research is to be able to incorporate the factors for resistance, in this case to fusiform rust, into trees possessing other superior traits as well. At present, geneticists and pathologists are working independently, for the most part, on particular problems in the two fields. However, once certain facts become known, i.e. how resistance increases or decreases with age of the host, how the pollen parent affects progeny resistance, type of intraspecific crosses among suscepts that produce resistance, etc., then the pathologist and geneticist will be able to combine their findings for improving our pines and be able to supply foresters with trees that are not only fast growing, of good form and desirable specific gravity, but also resistant to disease.

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Early Results of a Seed Source Study of Slash Pine In Georgia and Florida

by

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All southern foresters are aware of the extensive planting of slash pine in the South. Therefore, the need for information on racial variation in this species requires no elaboration.

In 1953 the Lake City Research Center, in cooperation with other organizations [1/], began a study to get some of this needed information. The study complements the Southwide Pine Seed Source Study which incorporates six seed sources scattered throughout the range of slash pine. In contrast, the Lake City test contains more seed sources and covers only that portion of the species range occurring in Georgia and Florida.

Review of Literature

In reviewing the literature we found that apparently only two other racial variation tests have been started in slash pine. The earliest of these entails trees from eight sources planted in four localities in South Africa and was reported upon by Sherry (1947). At 9 years, average heights of trees from different sources at all plantations varied only from 35.5 to 38.1 feet. However, the locality of origin of only six of the sources was known and these were from rather similar latitudes and climates.

The second test is the "slash pine series" of the Southwide Pine Seed Source Study which has already been mentioned. Mergen (1954), reporting on one of the plantations (Baker County, Florida), showed that 2-year-old seedlings originating from Polk County, Florida, were significantly shorter than those from four other sources in more northerly portions of the species range. However, he concluded that the Polk County trees may have been hybrids between typical slash pine and its south Florida variety. Wakeley (1955) summarized over-all progress in the southwide test, and Henry and Hepting (1957) covered diseases occurring during the first 3 years.

1/ Cooperators in the study are: Atlantic Land and Improvement Co., Florida National Forests, Owens-Illinois Glass Co., East Gulf Coast Research Center, St. Joe Paper Co., Cordele Research Center, Union Bag-Camp Paper Co., and Gair Woodlands Corp.

Methods and Materials

In the Lake City test slash pine seeds were collected from 15 localities scattered throughout south Georgia and Florida (figures 1 and 2). One of the collections was from trees of the south Florida variety of slash pine. In including this source along with typical slash pine sources, we do not mean to dispute the existence of the variety. In the test we attempt to correlate seed source differences with climatic factors and to gain some insight into the evolution of genetic variation. Such relationships, if found to exist, may be clinal and need not necessarily change abruptly at recognized varietal boundaries. Therefore, we feel that a comprehensive test should include sources from as many parts of the species range as possible, and by this means one may even be able to gain some insight into the evolution of recognized varieties.

One additional seed lot, from Escambia County, Florida, did not produce sufficient seedlings for outplanting.

Details of the seed collections were given by Mergen (1958). The seed lots and trees grown from them are designated by the counties from which they originated. One-year-old seedlings grown from the seeds were outplanted in seven localities in the winter of 1954-55, in 100-tree plots with four replications. Trees from each of the 14 typical slash pine sources were planted at 5 of the sites (Dooly and Effingham Counties, Georgia; and Liberty, Baker, and Lake Counties, Florida). Trees of six of the typical slash pine sources were also planted in Emanuel County, Georgia. Finally, trees of five of the typical slash pine sources and trees of the single South Florida slash pine source were planted in Collier County, Florida.

Our report covers growth and survival through the fall of 1957. Disease and insect damage, which was rather light at most of the planting sites, is not covered. Climatic variation within the range of slash pine and its south Florida variety was studied to aid in interpreting results on survival and growth.

Results

Growth, Survival, and Other Traits

Trees from different sources grew at different rates through their third year after outplanting and most of these differences were moderately consistent over all plantations (table 1). For example, trees from Taylor County (Fla.), Calhoun County (Fla.), and Brooks-Lowndes County (Ga.) grew relatively fast at most plantations, while those from Volusia County, (Fla.), Citrus County (Fla.), Laurens County (Ga.), and Dooly County (Ga.) grew slowly at most plantations. The former group grew an average of about 16

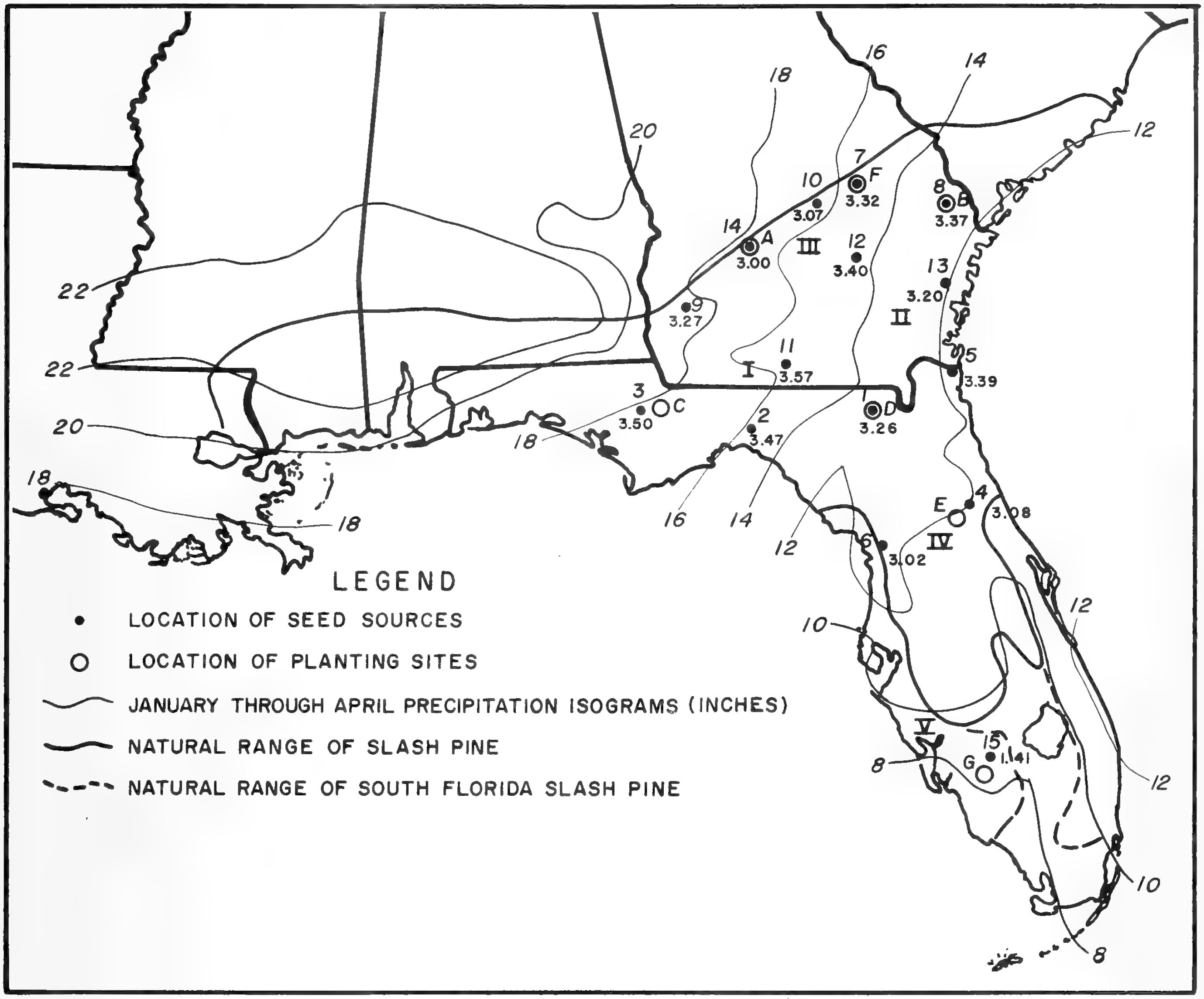

Figure 1.—A portion of Southeastern United States showing (1) the pattern of early-season rainfall, (2) approximate location of climatic zones (Roman numerals) discussed in text, (3) the location of seed sources and planting sites with their respective number and letter designations, (4) the average total height in feet (for all sites) of each seed source. Boundaries of the range of slash pine and its South Florida variety are from Little and Dorman (1954).

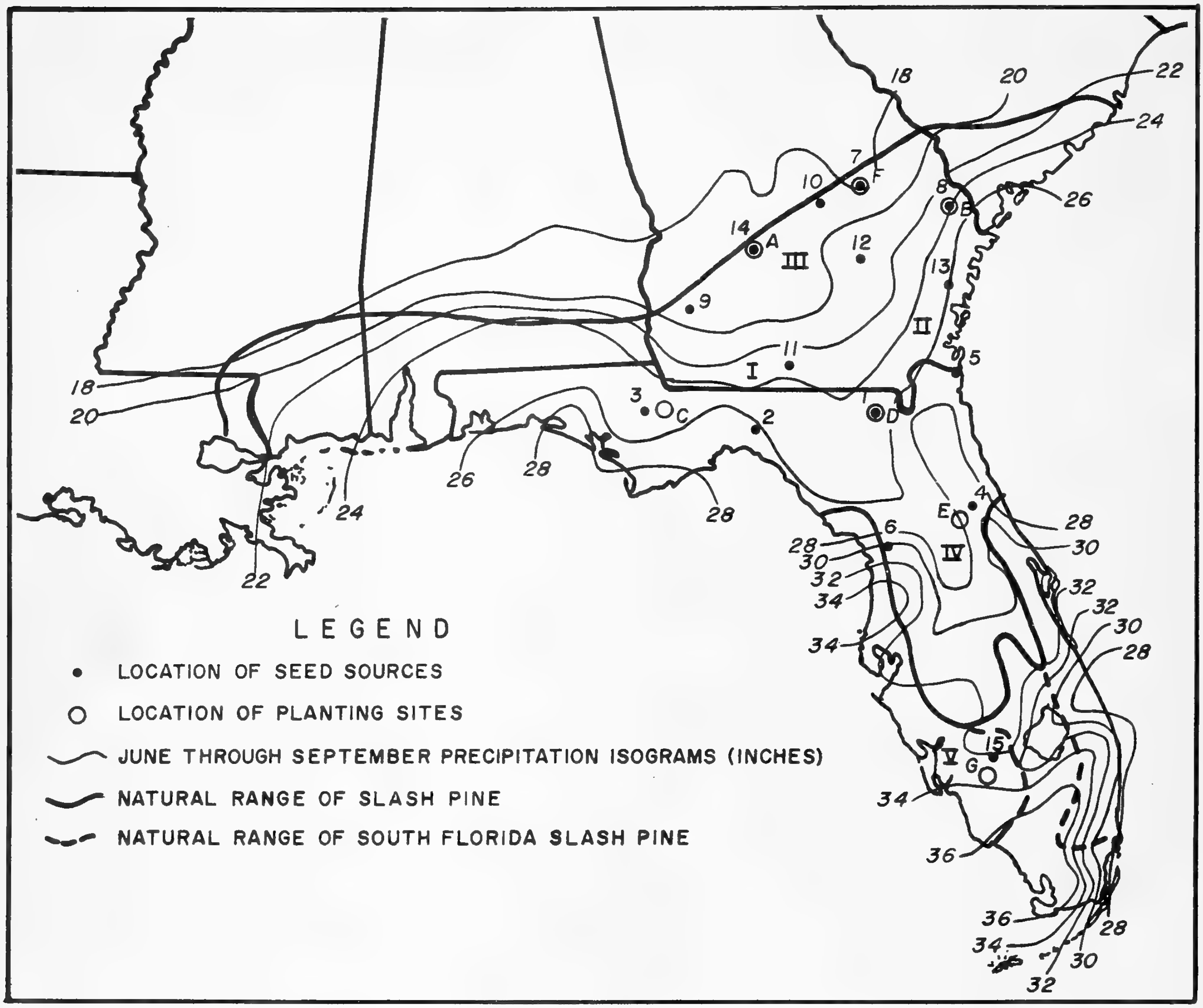

Figure 2.—A portion of Southeastern United States showing (1) the pattern of late-season rainfall, (2) approximate location of climatic zones (Roman numerals) discussed in text, and (3) the location of seed sources and planting sites with their respective number and letter designations. Boundaries of the range of slash pine and its South Florida variety are from Little and Dorman (1954).

Table 1. Average total heights of trees as of the winter of 1957-58 (4 years from seed) by seed source and planting site 1/

Seed source number and locations	Complete planting sites					Average A thru E	Incomplete planting sites		Average A thru G
	Dooly Co., Ga. (A)	Effingham Co. Ga. (B)	Liberty Co., Fla. (C)	Baker Co., Fla. (D)	Lake Co., Fla. (E)		Emanuel Co., Ga. (F)	Collier Co., Fla. (G)	
	Feet								
1 Baker Co., Fla.	3.22	4.70	3.32	3.18	2.14	3.31	(3.91)	2.37	3.26
2 Taylor Co., Fla.	3.41	4.85	3.60	3.21	2.20	3.45	3.98	3.03	3.47
3 Calhoun Co., Fla.	3.69	5.20	3.35	3.28	2.12	3.53	(4.17)	(2.68)	3.50
4 Volusia Co., Fla.	3.24	4.39	3.03	2.68	2.18	3.10	(3.66)	2.42	3.08
5 Nassau Co., Fla.	4.10	4.68	3.12	2.77	2.48	3.43	4.00	(2.60)	3.39
6 Citrus Co., Fla.	3.50	4.51	2.72	2.54	1.95	3.04	(3.59)	(2.31)	3.02
7 Emanuel Co., Ga.	3.44	4.32	3.74	3.18	2.16	3.37	3.86	(2.56)	3.32
8 Effingham Co., Ga.	3.42	4.87	2.96	3.46	2.30	3.40	(4.01)	(2.58)	3.37
9 Calhoun Co., Ga.	3.46	4.81	3.04	2.72	2.22	3.25	4.16	(2.47)	3.27
10 Laurens Co., Ga.	3.20	4.56	2.81	2.77	2.14	3.10	(3.66)	(2.35)	3.07
11 Brooks & Lowndes Co., Ga.	3.29	5.62	3.51	3.40	2.12	3.59	4.34	(2.72)	3.57
12 Jeff-Davis Co., Ga.	3.38	4.94	3.14	3.34	2.34	3.43	(4.05)	(2.60)	3.40
13 McIntosh Co., Ga.	3.13	4.53	3.16	3.23	1.98	3.21	(3.79)	2.56	3.20
14 Dooly Co., Ga.	3.00	4.94	2.65	3.06	1.93	3.12	3.52	1.92	3.00
15 Hendry Co., Fla. 2/	--	--	--	--	--	--	--	1.08 3/	(1.41)
Average	3.39	4.78	3.15	3.06	2.16	3.31	(3.91)	(2.51)	3.28

1/ Values in parenthesis are estimates made mainly to prevent bias in computing all-plantation averages. The estimated value for Calhoun Co., Fla. under Emanuel Co., Ga., for example, was computed as follows:

Average of all sources actually planted at Emanuel Co., Ga. = 3.98

Average of all planting sites for same sources planted in the first five plantations listed = 3.37

Estimated average for Emanuel Co., Ga. site = 3.31/3.37 x 3.98 = 3.91

Estimated value for Calhoun Co., Fla. source = 3.53/3.31 x 3.91 = 4.17

Seed source numbers and planting site letter designations (A thru G) correspond to those shown in figures 1, 2, and 3.

2/ South Florida slash pine, not included in averages.

3/ 3.28/2.51 x 1.08 = 1.41.

percent faster at all plantations than the latter. Some seed sources grew fast at some sites and slowly at others this "interaction effect" was significant at the 5-percent level. However, variation due to seed source was significantly greater (5-percent level) than variation due to interaction.

Note the large growth differences between plantations. These, unlike the differences between seed sources, cannot be interpreted with any degree of reliability. They may have been caused by effects of climate and soil, but also by such extraneous factors as differences in site preparation, ensuing competition, and others.

Highly significant differences in survival occurred among seed sources, with a rather high degree of consistency among all plantations (table 2). Trees native to the northernmost portion of the range of slash pine generally survived better than those from the southern portion.

Earlier reports of the study included differences in other traits that were attributed to seed sources. Mergen and Hoekstra (1954) noted variation in germination percent. Foliage of seedlings in the nursery possessed differences in number of resin ducts, stomates per millimeter, and marginal teeth per millimeter (Mergen, 1958). Langdon (1958) showed differences in insect attack in addition to growth and survival among trees from the five slash pine sources planted at Collier County, Florida.

Climate

Our analysis of weather records showed that seasonal distribution of rainfall and the length of growing season are two outstanding features of the climate within the test area. In contrast to annual rainfall, which varies little over the area in question, the seasonal distribution of rainfall not only varies greatly but the variation also follows a definite pattern (figs. 1 and 2). In the analysis we used (1) the average total rainfall occurring from January through April, which we shall call "early-season rainfall" and (2) average total rainfall occurring from June through September, which we shall call "late-season rainfall". All climatic data were obtained from Weather Bureau records and were usually based upon averages for the period 1921-1950.

Note in figure 1, that early-season rainfall increases in going from the southwest tip of Florida northward and also westward from the Atlantic coast through north Florida, and south Georgia. The pattern of late-season rainfall is similarly pronounced but increases in the opposite direction. Within the range of typical slash pine there may be as little as 10 inches of early-season rain combined with 32 inches of late-season rain in south Florida and as much as 18 inches of early-season rain with only 19 inches of late-season rain in central Georgia. In some parts of the range of South Florida slash pine there may be as little as 7 to 8 inches of early-season rain with 36 inches of late-season rain.

Table 2. Average percent survival of trees as of the winter of 1957-58 (4 years from seed) by seed source and planting site 1/

Seed source number and locations	Complete planting sites					Average A thru E	Incomplete planting sites		Average A thru G
	Dooly Co., Ga. (A)	Effingham Co. Ga. (B)	Liberty Co., Fla. (C)	Baker Co., Fla. (D)	Lake Co., Fla. (E)		Emanuel Co., Ga. (F)	Collier Co., Fla. (G)	
1 Baker Co., Fla.	43.0	48.4	77.0	76.6	36.7	56.3	(49.9)	77.3	58.4
2 Taylor Co., Fla.	53.9	41.8	77.0	76.2	56.2	61.0	51.2	86.7	63.3
3 Calhoun Co., Fla.	43.4	52.7	68.0	82.0	44.1	58.0	(51.4)	(72.3)	59.1
4 Volusia Co., Fla.	23.8	34.4	59.8	55.1	35.2	41.7	(37.0)	44.5	41.4
5 Nassau Co., Fla.	59.8	37.5	69.1	87.1	55.1	61.7	57.4	(76.9)	63.3
6 Citrus Co., Fla.	42.6	46.1	71.5	69.5	55.2	57.0	(50.5)	(71.0)	58.0
7 Emanuel Co., Ga.	58.2	47.3	78.5	84.0	64.4	66.5	59.8	(82.9)	67.9
8 Effingham Co., Ga.	51.2	47.3	75.8	82.4	50.0	61.3	(54.4)	(76.4)	62.5
9 Calhoun Co., Ga.	50.4	50.0	74.6	79.3	43.7	59.6	62.9	(74.3)	62.2
10 Laurens Co., Ga.	55.1	54.7	72.6	79.7	53.9	63.2	(56.1)	(78.8)	64.4
11 Brooks & Lowndes Co., Ga.	40.6	40.6	71.9	78.9	48.0	56.0	52.3	(69.8)	57.4
12 Jeff-Davis Co., Ga.	51.2	42.2	69.9	86.3	48.8	59.7	(52.9)	(74.4)	60.8
13 McIntosh Co., Ga.	44.5	45.3	74.2	75.4	44.9	56.9	(50.5)	71.9	58.1
14 Dooly Co., Ga.	49.6	59.8	71.1	86.7	57.8	65.0	44.1	69.5	62.6
15 Hendry Co., Fla. 2/	--	--	--	--	--	--	--	42.2 3/	(34.5)
Average	47.7	46.3	72.2	78.5	49.6	58.8	(52.2)	(73.3)	60.0

1/ Values in parenthesis are estimates, made mainly to prevent bias in computing all-plantation averages. See footnote 1, table 1, for method of computation.

Seed source numbers and planting site letter designations (A thru G) correspond to those shown in figures 1, 2, and 3.

2/ South Florida slash pine, not included in averages.

3/ 60.0/73.3 x 42.2 = 34.5.

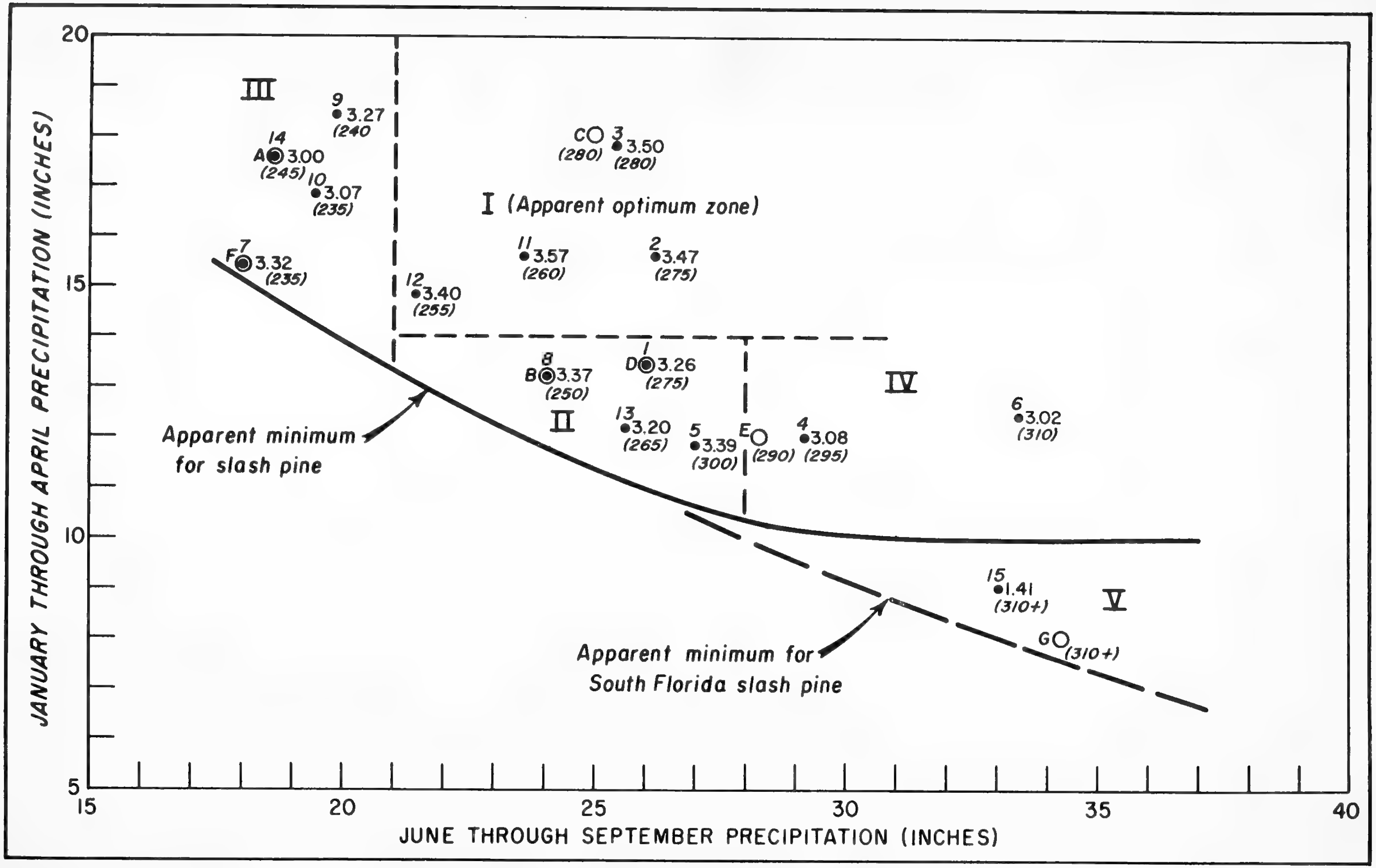

Figure 3.—Early-season rainfall plotted over late-season rainfall for each of the seed sources (dots) and planting sites (circles). At each point the following are also shown: (1) number and letter designation for seed source and planting site, respectively, (2) the length of growing season (figure in parentheses, days), and (3) average total height in feet (for all sites) of each seed source.

Any of a number of temperature factors could be related to racial variation in slash pine. Although summer temperatures vary little, such factors as length of growing season (frost-free periods), average winter temperatures, minimum winter temperatures, and others are highly variable within the species range. Without studying each of these thoroughly we decided to use the length of growing season in our analysis of growth on the assumption that it is a combined expression of temperature factors. The approximate length of growing season for the localities of seed origin and planting sites is shown in figure 3 (Anonymous, 1941). Mean January temperature was also used in the analysis of survival data.

Climate and Clinal Variation

How are growth rate and the climatic variables related? It is very possible that seasonal distribution of rain and length of growing season were instrumental in causing the apparent inherent variation found in growth rate. Note in figure 1 that trees usually growing the fastest originated from the north-central part of Florida (Calhoun and Taylor Counties) and the south-central portion of Georgia (Brooks and Lowndes Counties). The area encompassed by these seed sources may well be an optimum climatic zone. Trees originating from areas to the north, east, and south of this supposed optimum zone generally grew more slowly in our tests. Unfortunately no sources from areas west of this zone were included in the study. Within the optimum zone early-season rainfall varies from about 14 to 18 inches and late-season rainfall from 21 to 28 inches, and length of growing season is more than 250 days (figs. 1, 2, and 3). To the north the growing season is shorter and late-season rainfall is less. To the east and south early-season rains decrease. To the west rainfall remains generally within the supposed optimum, but length of growing season varies from as much as 290 days in parts of the southern portion to less than 230 days in parts of the northern portion.

Because of this apparent relation of growth rate to climatic factors, we decided to group the seed sources and planting sites according to similarities in climate. Figure 3 shows the basis for the grouping and delineation of climatic zones. We do not wish to imply here that the zones represent different ecotypes. Conversely, our results indicate that the inherent variation is clinal as will be discussed later. Grouping of the data and delineation of climatic zones was done merely to facilitate further interpretation of the results.

Note that trees originating from south-central Georgia and north-central Florida (zone I), representing the apparent optimum climatic area and the "heart" of the slash pine range, generally grew tallest of all areas (table 3). The growth differences were greatest when trees were planted in areas which appear to be the best sites from the climatic viewpoint. Trees from southeast Georgia and northeast Florida (zone II), which has high late-season rain but low early-season rain, were generally second best in growth rate. Those

Table 3. Average total heights and survival of trees, as of the winter of 1957-58 (4 years from seed) by climatic zones[1/] of seed sources and planting sites.

Climatic zone of seed source	Climatic zone of planting site				
	I	II	III	IV	V
	- - - - - - - - - Average height in feet - - - - - - - - -				
I	3.40	4.23	3.79	2.20	2.76
II	3.14	3.93	3.70	2.22	2.53
III	3.06	3.80	3.54	2.11	2.32
IV	2.88	3.53	3.50	2.06	2.36
V	--	--	--	--	1.08
	- - - - - - - - Average survival in percent - - - - - - - -				
I	71.7	62.6	49.6	49.3	75.8
II	74.0	62.5	51.3	46.7	75.6
III	74.2	67.7	54.5	55.0	76.4
IV	65.6	51.3	38.5	45.2	57.8
V	--	--	--	--	42.2

1/ See text and figure 3 for description of climatic zones.

from the northern extremities (zone III), with high early-season rain, low late-season rain, and short growing seasons, were third best. Those from central Florida (zone IV) were fourth best. "Central Florida" was kept distinct from "southeast Georgia and northeast Florida" partly on the basis of latitude. The former gets more late-season rain than the latter, and early-season rains are about equal. However, early-season temperatures in central Florida are higher and hence less moisture is likely available to plants at this apparently critical period. Trees of the single South Florida slash pine source, representing very low early-season rain and very high late-season rain, grew very slowly at the single plantation representing its native climate (zone V). Thus, the results imply that growth decreases to the north of the apparent optimum zone with decreasing length of growing season and late-season rains. Similarly, growth decreases to the east and south of the optimum sone with decreasing early-season rains.

Survival data is again shown in table 3. Note that trees from the northern extremities (zone III) generally survived best of all plantations while those from central and south Florida (zones IV and V) survived poorest. The differences between sources from zone I, II, and III were, however, usually not great.

In a correlation analysis survival was found to be inversely related to mean January temperatures of the localities of seed origin (r = -.86, highly significant). Thus, clinal variation, associated with climate, is established for survival. From this relationship we might assume that natural selection among trees growing in the colder climates has favored resistance to frost or other winter damage.

The fact that trees of the northern sources (from zones I, II, and III) survived better than those of the central and south Florida sources (from zones IV and V), even when planted in the latter areas, was surprising. However, in considering this fact from the standpoint of the evolution of racial variation, we must remember that the trees were planted rather than established by seeding. If the seeds were sown under natural growing conditions, results may have been different. Under natural conditions in south Florida, time of germination and also seedling development may be adapted to low early-season rain. Planting of seedlings obscures inherent adaptation of this sort.

Some attempts were made to obtain statistical proof of the apparent clinal variation in growth rate. However, the association of the climatic variables appears to be too complicated and the number of sources too few for a thorough regression or correlation analysis. For example, the apparent effect of late-season rains is likely curvilinear, since there is undoubtedly a threshold beyond which additional rain has no further beneficial effect. The same may be true with early-season rain and length of growing season. Other factors, such as soil differences, which were not studied, may further comlicate the picture. Thus, statistical proof of the exact nature of the growth rate variation found will have to await further study.

For the purposes of future studies we might hypothesize that slash pine trees native to that portion of the species range where the climate is optimum are inherently superior in growth rate. This could come about by a natural selection over a period of many years. Assuming a heterogenous population, the more rapidly growing trees will on the average survive in greatest numbers to produce the next crop, eventually resulting in trees which are inherently superior in growth rate. At points progressively further away from this optimum zone, the climate may favor some other trait, at the expense of rapid growth. For example, in progressing northward from an optimum point, colder winters may cause more rigid selection for resistance to frost, with less stringent selection for rapid growth. The same could be true for rainfall at critical periods. The hypothesis, then, implies clinal variation deviating away from what may be the "heart" of a species range.

Whether or not growth rate is inherently good in the western portion of the range (southern Alabama and Mississippi and southeastern Louisiana) is unknown. The Southwide Pine Seed Source Study may eventually provide the answer and we can only speculate now. As seen in figures 1 and 2, the seasonal distribution of rainfall seems to be fully as favorable as the supposed optimum zone in south Georgia and north Florida. The length of the growing season in the approximate southern half of the western portion is also apparently optimum but it is considerably less in the northern half.

As mentioned earlier, Mergen (1958) presented evidence of clinal variation in stomatal frequency. Using earlier data in the Lake City test Mergen showed that trees originating from the eastern portion of the species range had more stomata per unit of needle length than those from the west. We suspected that this longitudinal relationship may have been caused by early-season rain which, as noted earlier, follows an east-west pattern over much of the species range. Hence, we computed the correlation coefficient between his stomatal data and early-season rainfall and found it to be highly significant (-.76). Stomatal frequency tended to be high where early-season rainfall was low and vice versa. Miller (1938), citing the work of several authors, pointed out that this same relationship was found with a number of other plant species. The exact cause of the association was not determined but some authors noted that plants grown under optimum moisture had larger epidermal cells and hence greater spaces between stomata. In any event it appears that stomatal frequency may be a useful tool for further genetic investigation of slash pine.

Larson (1957) showed that percentage of summerwood and specific gravity of slash pines growing in their native habitats increased with increasing June plus July rainfall and decreased with increasing January plus February rain. Thus, apparently trees in localities with light early-season rain and heavy late-season rain grew mostly in summer. Conversely, under heavy early-season rain and light late-season rain relatively more growth occurred in spring. On first thought this would seem to be strictly an environmental effect. However, it could well be that these same environmental factors, operating as natural selection forces, could have caused genetic variation in summerwood percent and specific gravity. For example, trees which inherently start growth early in the season could conceivable often succumb to drought in those areas where early-season rains are deficient. Natural selection in those areas, then, may have favored those trees which inherently postpone their grand period of growth until summer. As soon as the trees in the Lake City test become of age we will be able to check this hypothesis by measuring summerwood percent and specific gravity along with phenology of growth.

Practical Application of Results

Results of the test suggest that inherent variation in growth rate exists and that use of local seed may not always be the best policy. Seed collected from an apparently optimum climatic zone seems to be moderately superior even when planted in other climates with no great loss in survival. These early results may change as the test trees grow older and new trials may give different results. But if these results hold we may in the future be able to deviate somewhat from the usual "local seed rule" to obtain a modest or even large genetic improvement in slash pine by wise choice of seed sources. Meanwhile, if possible, we should continue to avoid moving seed over great distances.

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An Evaluation of Growth and Form in 5-Year-Old Open Pollinated Progeny From Selected Loblolly Pine

by

R. E. Goddard,[1/] C. L. Brown[1/] and T. E. Campbell[2/]

Resume

Five year old open pollinated progeny of six loblolly pines selected for outstanding quality were compared with progeny from rough, mostly open grown check trees. Comparisons were made of height, d. b. h., limb length, limb diameter, limb angle and bole straightness. Progeny of two of the selections were no better than their respective checks in any of these characteristics. The remaining selected trees had progeny significantly better than checks in one or more characteristics but none were better in all characteristics.

The need for careful statistical design, adequate measurements, sufficient time for plants to express certain characteristics, the need for uniform controls, and the limitations of open pollinated progeny tests are discussed.

Introduction

The selection of outstanding trees to serve as parental stock has been proposed as one of the major methods of accomplishing forest tree improvement and probably every public and private tree improvement program has made some selections of this nature. The only test of the value of these selections as sources of seed for reforestation is the performance of their progeny. In this paper such a test of loblolly pines selected as outstanding is discussed.

Present Study

During the summer of 1951 a few "superior" pines were selected from a number of trees reported as outstanding by Texas Forest Service personnel throughout East Texas. The second selection was entirely subjective and was made on the basis of apparent superiority to other trees in the vicinity, using as criteria stem form, natural pruning, relative height, and such crown characteristics as limb length, limb angle and limb diameter.

1/ Texas Forest Service, College Station, Texas

2/ A. J. Hodges Industries, Many, La.

Among the trees selected were six loblolly pines from widely scattered locations as indicated on the map (Figure 1). Three "commercial collection" type trees in the general vicinity of each selected tree were chosen as checks[1]. Check trees were mostly open grown with large crowns, short clear boles and abundant cone production - the type tree a commercial cone collector paid by the bushel would favor. The trees were not the same age nor growing under the same stand conditions as the select trees.

Seedlings from open pollinated cones of select and check trees were out-planted in December, 1952, at the Arthur Temple Sr. Research Area near Alto, Texas, and at A. J. Hodges experimental area near Many, La. Unfortunately, due to extreme drought during 1953 and 1954 the planting at the Temple Research Area was almost completely lost. Survival in the Hodges area was more satisfactory, ranging from 60 to 83 per cent after five years in the field.

The site near Many, La. is fairly good. It is located on an old bottomland field. The top soil is a sandy loam 16 to 20 inches deep grading into a whitish mottled clay with rather poor drainage. Measurements of loblolly pine timber adjacent to the field indicate a site index of approximately 95 feet.

Two replications of each source were planted at the Many site. In each replication trees from each source were planted in 100 tree plots, ten rows of ten trees, at a spacing of 7 x 7 feet. Plot locations were randomly assigned selected trees with the respective check trees assigned to adjacent plots.

Periodic height measurements of the interior eight rows of eight trees have been recorded, the exterior plants serving as buffers. At the end of the fifth growing season after out-planting, both height and d. b. h. of all measurement trees were recorded. In addition, as an indication of form, the length, diameter and angle of the largest limb of the second and third major whorls as well as the stem diameters immediately above the whorls in question were measured (Figure 2, 3).

Results

Height Growth - Results of periodic measurements are summarized in Table 1. While it is evident that there has been considerable shifting of relative position in ranking of mean heights from year to year, various progeny means tend to remain either in the upper or lower portion of the range. The most notable exception is the progressively higher ranking of S62 progeny heights from seventh to first.

1/ The same check trees were used for the two select trees in the same county.

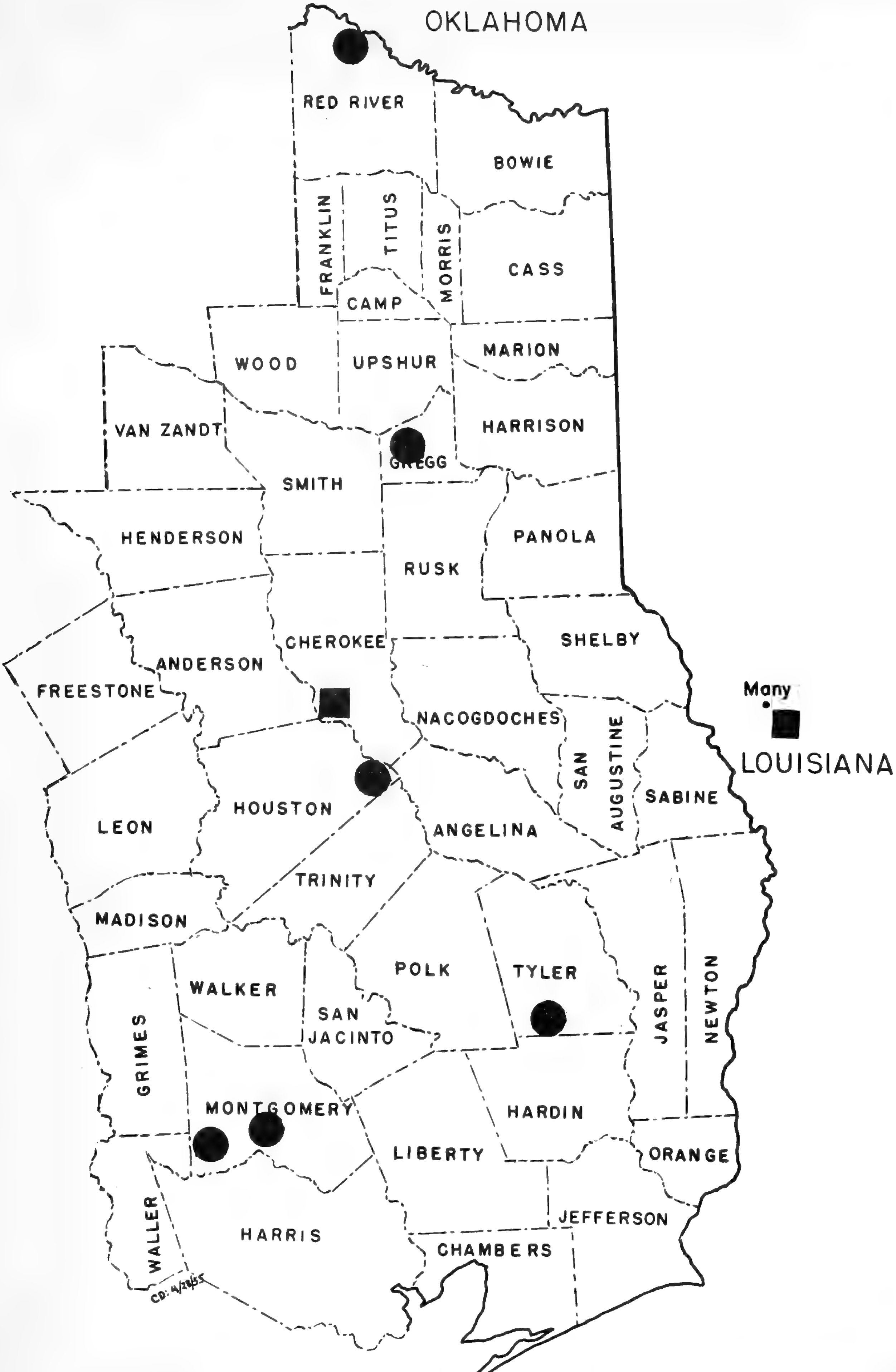

OKLAHOMA
RED RIVER
BOWIE
FRANKLIN
TITUS
MORRIS
CASS
CAMP
WOOD
UPSHUR
MARION
VAN ZANDT
HARRISON
GREGG
SMITH
HENDERSON
PANOLA
RUSK
CHEROKEE
SHELBY
ANDERSON
FREESTONE
Many
NACOGDOCHES
SAN AUGUSTINE
LOUISIANA
SABINE
HOUSTON
LEON
ANGELINA
TRINITY
MADISON
POLK
TYLER
WALKER
SAN JACINTO
JASPER
NEWTON
GRIMES
MONTGOMERY
HARDIN
LIBERTY
ORANGE
WALLER
HARRIS
JEFFERSON
CHAMBERS
CD: 4/28/55

Table 1. Average Heights of Progenies of Select and Check Loblolly Pines During First Five Years in the Field.

	First Year		Second Year		Third Year		Fifth Year	
Parent Tree 1/	Ht. (cm)	Rank	Ht. (cm)	Rank	Ht. (cm)	Rank	Ht. (cm)	Rank
S62	24	7	66	5	152	3	435**	1
S47	27	4	68	4	156	1	419	2
A110	28	3	68	2	148	4	412	3
S27	29	2	71	1	156	2	406**	4
S61	29	1	64	6	141	5	403	5
A47	23	9	58	10	135	8	403	6
A35	23	8	64	7	139	7	394	7
A61	19	11	55	11	127	11	392	8
S35	20	10	57	8	131	9	384	9
A27	26	5	68	3	141	6	380	10
S110	24	6	61	9	130	10	375	11

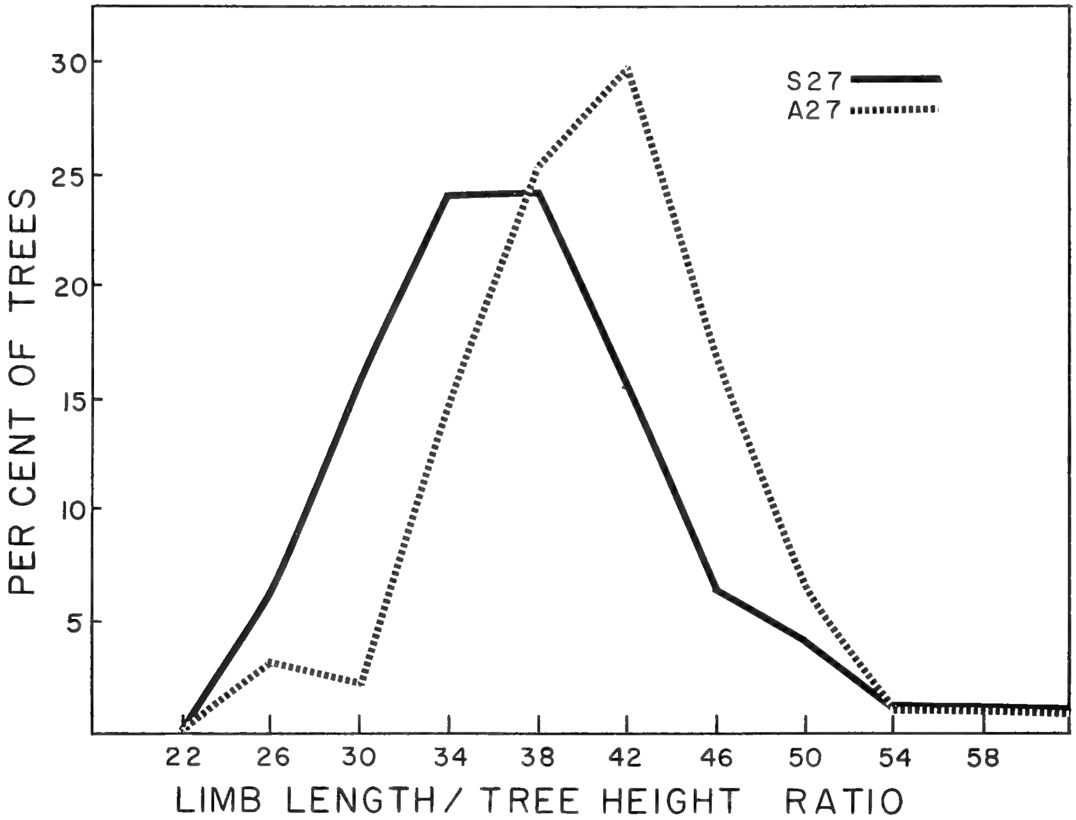
1/ S in parent tree designation signifies select tree, A signifies check.

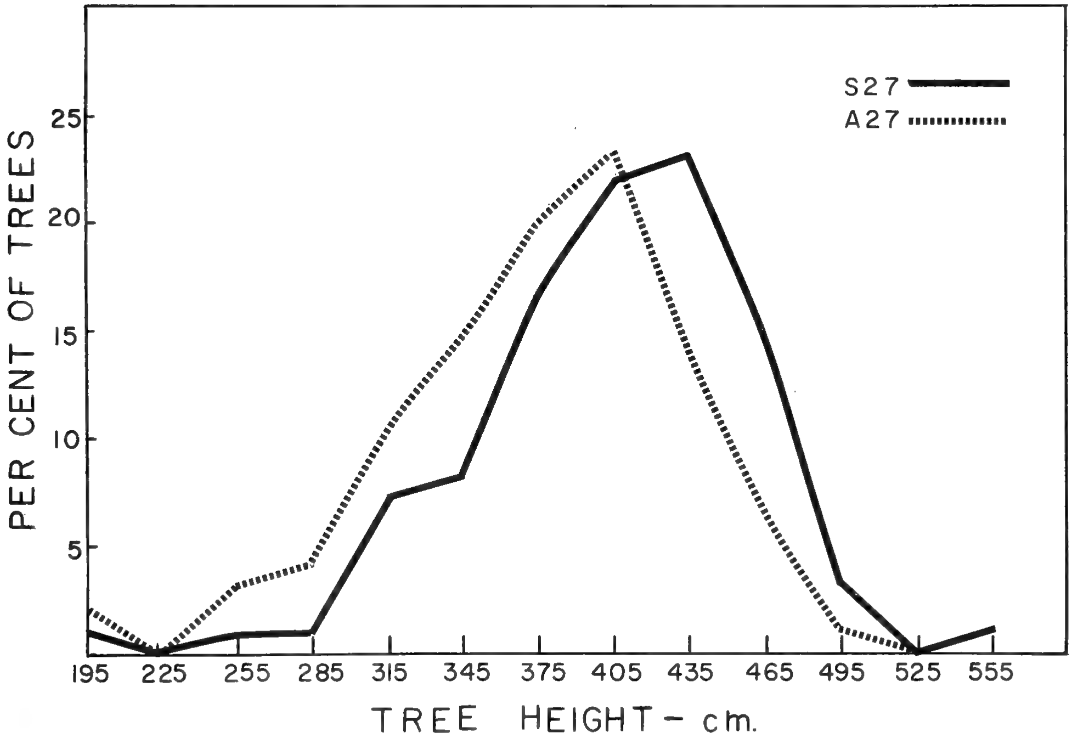
** Significantly better than respective check at 1% level.

It is of interest to note that four of the six groups with the greatest mean height are progenies of select trees. However, it should also be pointed out that the greatest difference in mean heights at the end of the fifth year is 60 cm., about two feet. It is pertinent to ask if these are real differences. Because the parent trees are located from the Oklahoma border to near the coastal prairies of Texas on a variety of sites, and because it did not seem advisable to compare progeny of one select tree with the progeny of check trees from a widely different location, the progeny of each select tree was analysed with only the progeny of other trees from the same area. On this basis, in only two cases were the mean heights of superior tree progenies better than the respective check tree progenies. The next figure illustrates the shift of the population curves in one of these comparisons (Figure 4).

Diameter Growth - While there is a considerable range in diameter at breast height of individual trees in this study and as much as one half inch difference between means, the variation within progenies of one mother tree was so large that in only one case was there a significant difference between select and check trees.

Limb Diameter - By measuring only two limbs per tree, and these the largest on each of the two largest whorls for trees of this age, the average


S27
A27
30
25
20
15
10
5
PER CENT OF TREES
22
26
30
34
38
42
46
50
54
58
LIMB LENGTH/ TREE HEIGHT RATIO


S27
A27
25
20
15
10
5
PER CENT OF TREES
195
225
255
285
315
345
375
405
435
465
495
525
555
TREE HEIGHT – cm.

limb size is by no means indicated. However, measurement of the largest limbs should indicate a potential for development of large or small limbs.

While there were no significant differences between means of absolute limb size of any of the superior and check tree comparisons, it was felt that a better indication of relative limb size would be the ratio of limb diameter to bole diameter at the level of the limb. The mean limb diameter bole diameter ratio of progenies from three of the select trees were significantly lower than their checks.

Limb Length - As was the case with limb diameter, there were no significant differences in absolute limb length between select tree progenies and their checks. As an indication of relative limb length, the ratio limb length/total tree height was calculated for each tree. The mean limb length/ tree height ratio of three of the select trees were significantly lower than their respective checks. Figure 5 indicates the trend for progeny of one select tree to have shorter limbs for a given height than progeny of its check trees.

Limb Angle - There was high variability and no significant differences between mean limb angles of select and check trees.

Bole Form - All trees of the progeny test were classified as straight, slightly crooked and very crooked, and any forking was recorded. Very few trees were found that fell in the very crooked or forked category and in most of these cases some environmental causes such as insect attack or broken leader was evident. There were no indications of inherent tendencies toward poor bole form in either select or check tree progenies.

Discussion

In Table 2 a summary of the results discussed above is presented. None of the select tree progenies are better than those of their check trees in all characteristics and two of them are in no way superior to the checks. There are several possible reasons for this situation, all of which may have some bearing.

First, the select trees may be no better than the checks genotypically. Selection techniques have been greatly revised since these selections were made and several methods are now in use which take more factors into consideration and attempt to reduce subjectivity in selections. In addition, the check trees were of different age and grown under different stand conditions than the select trees. It is entirely possible that the check trees might have developed a much more satisfactory bole and crown form had they been subjected to normal competition and no valid comparison of growth rates of select and check trees is possible. But no matter what selection criteria are used nor how high the degree of selectivity, it is only the phenotype that is being

Table 2. Comparisons of Means of Select and Check Tree Progenies for Four Characteristics

Parent Tree	Progeny Means			
	DBH (cm)	Ht. (cm)	LD/BD[1/]	LL/Ht.[2/]
S27	6.1	406**	31.1*	37.4**
A27	5.6	380	33.3	40.3
S35	5.1	384	29.9	38.1**
A35	5.3	394	31.2	42.6
S47	5.6	419	31.0	37.1
A47	5.3	403	29.4	37.6
S61	5.6	403	28.6**	35.8**
S62	6.4	435**	29.7**	38.4
A61	5.6	392	31.3	39.8
S110	5.6	375	32.2	37.2
A110	6.1	412	30.8	37.7

* Significantly different from check at 5% level.

** Significantly different from check at 1% level (highly significant).

1/ Limb diameter/bole diameter ratio.

2/ Limb length/tree height ratio.

judged. Possibly all desirable characteristics of forest trees are more or less drastically influenced by environment and if 60 percent or more of our selections pass on desirable traits to their offspring we might consider our selection technique successful.

Second, it may be too soon to detect some real differences between select and check tree progenies. After five years in the field these trees are just reaching their stage of most rapid height growth, and substantial diameter growth is some years in the future. Present differences in height and diameter may be widened or entirely changed in the future. However impatient we may be to assess the potential value of a selected tree as a future source of seed, it may not be advisable to make a final decision at this stage.

The design of the test or the measurements recorded may not be sensitive enough to detect real differences among the various sources. More replications and more measurements may be desirable. However, it must be considered that each replication in this small test required approximately 1 1/4 acres. With numerous selections to be tested, not only initial planting area and expense, but also subsequent measurements must be considered. Some limitations must be placed on the amount of data collected per tree with hundreds of individuals to be measured. This points out that very careful experimental design is required if the maximum amount of information is to be obtained from the space and labor available for the job.

Another and probably a major reason for the relatively small differences between the progenies of the select and check trees is the fact that both resulted from open pollination. After all, the mother trees furnished only 1/2 of the germplasm of their progenies. The expression of any particular economic characteristic of forest trees is most probably influenced by many genes. With such multiple factors the mean expression of a character should be expected to fall near the mean of the two parents. With numerous pollen parents, some of which may be very poor, the mean of the progenies cannot be far above the population average even though weighted to the side of the good mother tree. If we also consider that these characteristics are influenced by environment, in some cases to a large degree, it is obvious that some genotypic difference between the progenies of select and check trees will not be detected. This is a major limitation of open pollinated progeny tests and a strong point in favor of controlled pollinations.

In Table 3, parent trees have been ranked from best to poorest according to the means of their progenies for various characteristics. The survival percentage for each source has been included to indicate the lack of relationship between survival and any of the characteristics considered. In some cases the progeny of select trees were significantly better than the progeny of their check trees but ranked lower for that character than other check trees. These tests indicate possible inherent differences in the characters studied. They do not necessarily indicate the degree of improvement that would be attained by using the selected trees in seed orchards.

This points out the need for a common control to which all selections for a given area could be compared. As we are trying to improve the genetic quality of seedlings produced by state or company nurseries, it might be suggested that nursery run seedlings be used as controls. While this has some obvious advantages, there may be considerable variation in the quality of nursery run seedlings from year to year - even wide variation in seed source. The authors propose to use progeny of several trees in a seed production area as controls for future tests of selected trees. As the supply of seeds from these trees can be replenished as required, such seedlings could

Table 3. Ranking of Means of Select and Check Tree Progenies for Five Characteristics

Parent Tree	DBH (cm)	Parent Tree	LD/BD	Parent Tree	Ht. (m)
S62	6.4	S61	28.6	S62	4.35
S27	6.1	A47	29.4	S47	4.19
A110	6.1	S62	29.7	A110	4.12
S110	5.6	S35	29.9	S27	4.06
S47	5.6	A110	30.8	S61	4.03
S61	5.6	S47	31.0	A47	4.03
A27	5.6	S27	31.0	A35	3.94
A61	5.6	A35	31.2	A61	3.92
A35	5.3	A61	31.3	S35	3.84
A47	5.3	S110	32.2	A27	3.80
S35	5.1	A27	33.3	S110	3.75

Parent Tree	LL/Ht.	Parent Tree	Survival
S61	35.8	S110	83.5
S47	37.1	A35	78.1
S110	37.2	S27	75.7
S27	37.4	A27	74.2
A47	37.6	S62	74.1
A110	37.7	S35	72.6
S35	38.1	A61	69.5
S62	38.4	S61	64.8
A61	39.8	S47	62.4
A27	40.3	A110	61.7
A35	42.6	A47	60.1

serve as a basis of comparison of test plantings in various locations and years. Seedlings from seed production area trees may be of superior genetic quality to a hypothetical "average nursery run" seedling, but if careful selection shows improvement over them, improvement over nursery run trees is certainly indicated.

Selection, Scoring, Protection And Use Of Superior Trees

Orion J. Peevy, Research Forester
North Carolina Pulp Company
Plymouth, N. C.

The steep rise in the consumption of timber, and the rapid depletion of good individuals in the now seed-producing population, coupled with the fast diminishing amount of woodland available for purchase, has focused our attention on the improvement and development of that which we already have. In many ways the industry is being forced into a crash program. This sense of urgency should not, however, unduly hasten us into a make-do selection of the "next best" breeding stock. Careful screening of the best selections from existing stands should give us something really valuable to work with in the future. Once selected, the superior trees will cost no more to handle in the seed orchards than average trees for breeding stock.

The program of examining, selecting, scoring, protecting and using superior trees is not one to be viewed lightly. Such a program is a long-term undertaking with potentially far reaching results to the pulpwood industry; therefore, in a program of forest tree improvement through genetics, the cost which is inevitable, should be viewed leniently, in an effort to obtain the best from existing stands.

It is hoped through genetic selection we will obtain trees that are faster growing, disease and insect resistance, smaller and more efficient crowns, smaller limb diameter and flatter branching, greater height average, higher specific gravity and larger cellulose yields per individual tree. To obtain these things through selection, the following general loblolly pine characteristics are sought for the parent stock: Taller or equal in height of the stand, branching at right angle to the bole with branch diameter and length smaller than comparable trees, dense crown occupying not more than 25% of the bole height, straight bole of high form class, good pruning ability, disease free, and comparable in volume.

In order to find parent stock meeting these requirements for North Carolina Pulp Company it is necessary to examine many climatic and geographic stands and numerous sites intensively, both in the Coastal and Piedmont areas, since our company holdings are in both. We are developing North Coastal Loblolly, South Coastal Loblolly and Piedmont Loblolly seed orchards.

The actual selecting of trees for seed orchards is no easy task; pressured from above for results, pestered with ticks, chiggers, yellow flies, gnats and mosquitoes, and plain scared of snake bite, you sally forth acres to cover and miles to go. The first days are utter confusion with a kaleidoscope of words; spiral, compressed wood, cronartium, ununiform, unicorn and outvolumed all adds to the frustration. Never have I realized a tree was so imperfect. Into another stand the search is continued with exasparating results. A smoke break is taken, the mind begins reevaluating the words "Look for the outstanding tree", during this pondering the eyes are raised and one gaze into the distance, suddenly the realization, yon stands a tree not exacly the pattern of the majority of the stand, pulse quicken, a quick trip over and behold, the outstanding tree. With greater confidence we begin to examine the stand with a more understanding eye. The period of selecting has begun and with each selection comes more confidence. Each stand is examined much on the order of a 100% cruise, by beginning at an easily identified break in the woods, topography, or landmark and worked systematically in tiers or strips until covered. This is necessary to avoid duplication and not to overlook a prospective candidate that may be indiscernible in a uniform even-aged stand.

During my initial search, I take the following equipment: Pencil, tatum holder with select tree rating sheets, spray gun filled with paint, crayon, aluminum tags, compass, diameter tape, Abney level, nails, increment borer, and of course a machette. On the grading we use the same equipment plus soil anger, bark depth gauge, and a man size increment borer, that quickly separates the men from the boys.

Trees that are satisfactory (or that have an acceptable grade) are very rare; it is essential therefore, that the selector go into many stands to find them. He must be very critical and cannot be satisfied with mediocre trees, it is my belief that better trees are to be found. Since we know only that the progeny will eventually be planted on our lands graded roughly into North Coastal, South Coastal and Piedmont, it is desirable that our selections come from a variety of sites within the broader classifications listed above.

In the selection of trees our best results have come from even-aged stands, both large and small, and mixed stands of Loblolly and Shortleaf. Old field stocking usually seeded from hedge row and wood edge trees have consistently given poor results.

As I go through the woods searching a likely stand the first thing I look for is crown, the next straightness and in order; pruning ability, branch diameter and limb angle. Usually a tree with the above characteristics has superior or equal form class in comparison with the best crop trees within the select tree stand. In judging a selected tree for superiority, we have found by picking five dominate crop trees of the stand, with nearly as possible comparable characteristics to the selected tree, and averaging and comparing to the same characteristics of the selected tree, we come up with a fine specimen. Crop tree selection may go out as far as 100 feet, but confined to the selected superior tree stand and site.

I prefer the 40 to 60 year old class because of my belief that a tree must attain this maturity to demonstrate its' fullest superiority, although our rotation age is younger. By using trees of the 40 to 60 year old range for parent stock, I feel we are getting a more reliable stock for propogation.

Our larger and better stands have been found in Coastal Carolina. In this area trees of high superiority have been selected in stands as small as 1 acre. Avoidance is made of all areas where any thinnings or cuttings have taken place within the immediate generation. Areas cut to seed trees are ignored even though the best the previous stands offered are left, this due to insufficient comparable crop trees. Creek bottoms and sites of unusually high index are examined with caution, due to site being better than average in comparison to where progeny will eventually be planted.

In the Piedmont section different problems appear; suitable stands to select from are smaller, sites are more strictly confined, extremes are encountered from poor to excellent stands, stands are widely scattered, mixed loblolly, shortleaf and Virginia pines stands are prevalent, and larger crowns seem the rule.

Most of the woodland in the Piedmont area is privately owned. This presents a problem of trespass. We first secure permission from the owner to look through his woods. To determine who the owner is, we visit the County Agent, County Firewarden or ASC Manager's Office. The owner is then contacted with the following introduction: "Mr. Doe, I am Orion Peevy of the North Carolina Pulp Company. We are working in cooperation with State College, on a program of Forest Tree Improvement. I would like your permission to look through your woods for a superior pine tree that might be included in this program."

This works very well--but, he usually asks "What kind of a pine is that?" Other incidents, some insist on accompanying you, this slows you down and one usually has to give with conversation and being the nice fellow, another will steer you around, (and for a very good personal reason), a very likely looking stand near a creek. Only in one instance have I been refused, after going into all the explanations as to selection, marking and use, this gentleman and his FFA son stated bluntly, he was on a timber deal advantageous to him for some 300 acres, and he feared a tree, marked with yellow paint, might lead the prospective buyer to think other buyers had been in the timber and offered less than he had for the timber, thus disrupting the sale.

The selection in Piedmont stands is made in the same manner as for Coastal Loblolly. When a tree with the desired characteristics is found, it is usually more outstanding in the stand than one in the Coastal area. The select tree is always judged in relation to the 5 best crop trees available.

Following are some of the characteristics judged in the grading: Height should be not less than 10% of average crop tree, and scored 0 to 7 points, depending on site index and age. Form Class is determined by form paint method, the select tree being given 1 point for each form class greater than average less 1 point. Branch diameter and angle, from average to relative small, and flat respectively, 0 to 2 points. Crown Radius is judged subjectively, the individual select tree being compared to the 5 crop trees and scored 2 to 1 point if large for bole size and competition, 0 to plus 5 points if average to small for bole size and competition. Pruning Ability, the ability of the select tree to shed its lower limbs (dead or alive) when average or above checks, is given 0 to 3 points, the select haveing to be better than 3 checks. Straightness is judged subjectively for the individual select tree and not compared to the checks. Excess spiral and/or crook in two planes is not acceptable, nor crook in any one plan which will not allow a line from merchantable top to stump to stay within the confines of the bole; straightness scored 0 to 5 points.

In order to be acceptable to our company a tree must score a minimum of 10 points; Volume superiority is desired, but more as a bonus than as a basic characteristic. The importance of volume in determining superiority must be clarified, and its application understood, between cooperator and grader, otherwise the cost of search may be greatly increased.

We desire trees of high specific gravity and this is determined by wood samples taken with oversize borer. These cores are also used in determining cellulose yield and fibre length. The laboratory work being done by State College. Core holes are plugged as protection against insects.

All selected trees are tagged, banded with paint and given a company number. Check trees are numbered and sketched on a data sheet showing location to select tree. A trail is brushed out to an easily recognized landmark and spotted with paint. This select tree location is given to the landowner, and on company land to the District Forester, who is cautioned to preserve it under all circumstances. A map sheet gives owner, county, location, state, the company and Association clone number. The careful marking of the selected tree and brushing out of trail is repaid many times on later trips for grading, cone collection, scion collection, and wood core for laboratory studies.

The accepted tree is left intact until such time as we desire scions for propogation. Then we shoot limbs with the required number of scions from top half of the crown, using a .218 caliber rifle equipped with 4-X telescope. The scions are then selected and immediately cut and placed in polyethylene bag containing sufficient damp moss to prevent drying out, which is punctured for air circulation. The scions are taken to grafting site, each bag of scions being identified by placing inside bag aluminum tag with the clone number on it.

When grafted and placed in the orchard the graft is tagged with the respective clone number and staked.

In shooting out the scion material care must be taken to do the least damage to parent tree, since we have found it frequently necessary to go back for additional scions. In searching for select trees we sometime locate exceptionally good stands which then are marked as a seed production area.

Summary

The steep rise in the consumption of timber, and the fast diminishing supply of quality seed source has focused out attention on the development and improvement and improvement of that which we already have, through genetic selection. The program is long-termed and costly, yet rewarding in the fact we will have something really valuable to work with in the future and provide us with improved planting stock during development.

Selection is hard, and time consuming, necessitating going into many climatic and geographic similar stands and sites over a wide area. Although the standards are rigidly set for several characteristics, such trees are found occasionally, my average runs about 2 per week.

Our best results have come from even-aged stands of Loblolly pine. Experience and care pays off--at first I located many non-usable trees, now with the same effort and better understanding of the grading a much larger percentage is acceptable in the final grading.

Efficiency is gained by delineating stands, then systematically searching them. Certain standards for grading of tree are necessary and for convenience these are applied in the form of points, plus or minus, as compared to 5 crop trees.

After superior tree is selected and scheduled for inclusion in seed orchards, certain precautions are necessary to protect its' identity, location and use.

Superior Tree Selection -- A Comparison of Grading Systems

Franklin C. Cech [1/]

One of the most difficult problems in a selective type program such as our companies have underway is that of rating phenotypic characteristics to insure the incorporation of the few most outstanding trees in our seed orchards.

Some of the earlier selections such as those reported on today by Goddard, Brown, and Campbell were made subjectively, using the following criteria [2/]: (1) outstanding height and diameter growth, (2) limbs of small diameter, (3) an efficient crown, i.e., have a small narrow crown and dense foliage while still retaining better-than-average growth rate, (4) good natural pruning ability, (5) exceptional ability to be good competitors, and (6) straight bole with little taper. No attempt was made to put this selection on an objective basis, but each tree was compared to its immediate neighbors and the final selection made on the basis of these comparisons.

About the same time, Dr. T. O. Perry was initiating the first industrial drive for the establishment of seed orchards containing representatives of superior pine phenotypes. Because of the many individuals involved, some method of standardizing the selection procedure was needed. As a result, after a meeting with representatives from the participating industries, the first tree rating form was developed which made an effort to put superior phenotype selection on an objective footing. At this meeting, the concensus of opinion was that growth rate was the most important element and as a result, the first system gave a great deal of weight to vigor. The other items considered were bole straightness, branch diameter, natural pruning, and presence or absence of disease symptoms (although this criteria is not included on the rating sheet). Different values were assigned the various criteria in accord with their comparative importance. The superior tree candidate was compared to the 10 nearest dominants, codominants, and intermediates. The second year this system was in use, the comparison trees were limited to the nearest dominants and codominants.

This system fared differently with individual companies, depending on the person doing the final grading. When one man did all the grading, selection was better on the whole than where several men were involved. Where the individual making the original selection did the final grading, results were generally poor.

1/ Silviculturist, International Paper Company, Southland Expt. Forest, Bainbridge, Georgia.

2/ First Progress Report, Texas Forest Service Circular #35, October 1953.

When North Carolina began its industrial cooperative program, it was noted that many earlier selections made under the Florida system did not exhibit phenotypic superiority commensurate with the point score assigned. In addition, the great weight given volume seemed inappropriate because volume per se is not a strongly inherited character. A revision of the Florida system was therefore made emphasizing form which in general is more strongly inherited. Also, the number of comparison trees were cut to five and these were to be "crop" trees; dominants on the same site within reasonable distance of the superior tree candidate and of the same age or older. More significant, with the new rating form, one man was hired to rate ALL trees selected within the program. Thus, all superior trees in the entire program were put on a more or less comparable basis. The grader, since he was a specialist, became more skillful, and as a result, more consistent and more objective grading was possible.

Ten characteristics are graded by this system, those being: height, volume, crown, form class, bole straightness, pruning ability, branch diameter, branch angle, age, and specific gravity. In addition, cellulose determinations are made and although they are not used for computing the original grade, are used to assist in making the final decisions.

When the International Paper Company decided to combine its regional programs into a division-wide program, the North Carolina State system was adopted with some minor changes.

The State of Georgia, in cooperation with the U. S. Forest Service, has had an active program of superior tree selection, but under this system no attempt is made at a purely numerical rating for individual trees. Final selection is made by the individual in charge. This system is fine as long as an experienced geneticist or the equivalent is heading the program, but this system tends to break down when a personnel change occurs, or when the responsible individual is absent for any length of time.

More recently, the Texas Forest Service has initiated a new rating system which is still in its developmental stages. They have set up a list of 10 criteria, 8 of which must be satisfied to qualify the superior tree candidate. These include: bole straightness, spiral, limb diameter, limb angle, pruning ability, age, height, disease, and insect resistance, bole-crown ratio, and basal area increase-crown ratio.

Here again, there is no numerical system to help locate the best of many acceptable trees and in the final analysis, a subjective selection must be made unless all acceptable trees are to be used. In the event that more acceptable trees are located than are desirable in the orchard, a subjective selection must finally be made.

A comparison of the characteristics considered by each system is presented in Figure 1. Note that all systems grade identical characteristics in most cases. Main differences are in emphasis or point value assigned.

In many cases within the existing programs, trades of superior tree scions have been arranged between companies. This practice has now been extended to companies in different programs and it has been necessary to regrade trees so that they can be rated on a comparative basis.

There has also been much discussion as to the relative merits of the various systems and in many cases, the observation has been made that any system, well applied, will work satisfactorily. To test this hypothesis, 16 trees were rated by the North Carolina State, IP Company, Florida, Georgia, and Texas systems. Field grades of 10 points must be attained in the IP and N. C. State systems before trees are accepted. Acceptance under the Florida system is based on the highest scores and the number accepted is based on the number of trees needed. The acceptable trees under the Georgia system are chosen by a combination of numerically and non-numerically rated characters, while the Texas criteria is based on 8 of 10 acceptable characters.

The results of these trials show that of the 16 trees rated, 5 were accepted under all systems, and 3 were discarded. Of the 8 remaining trees, 4 were accepted by four of the five systems, and 4 were discarded by four of the five systems (Fig. 2). The highest number of trees were acceptable under the Georgia system and the lowest under the IP Company system, the numbers acceptable varying from 7 to 11. Where the discrepancies occurred; the IP system discarded two trees which were accepted by the others; N. C. State accepted one tree discarded by the others; Georgia accepted 2 trees discarded by the others, and Texas accepted 1 discarded and rejected 2 accepted by the others. Interestingly, the Florida system, when an arbitrary acceptance level of 25 points was selected, agreed with the majority in all cases. The discrepancies in the IP system were of a magnitude of 1 point in each case; that of the N. C. State of 3 points.

The results would seem to support the contention that the system is not nearly AS IMPORTANT as the grader. The human element is of prime importance and it seems essential that all grading be done by one man. Please note that not all of the trees selected for grading were acceptable, though each was a plausible candidate for a superior tree.

While the sample presented was necessarily small, it shows that standard, unbiased grading can only be attained by eliminating the human element as much as possible. This can best be done by having one disinterested party do the grading. I still feel that a numerical rating system is more practical, for in the final analysis, each tree must be rated against the other, and one man cannot carry a mental picture of every tree in his mind. Therefore, while the numerical system has faults, I believe it is somewhat better than the less objective descriptive systems.

COMPARISON OF GRADING CHARACTERISTICS

SYSTEMS	Height	Volume	Form Point or Class	Straightness	Spiral	Pruning Ability	Specific Gravity	Crown	Bole Volume/Crown	B·A· Increase/Crown	Branch Diameter	Branch Angle	Age	Disease and Insects	Seed Production	Summer Wood
GEORGIA	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	✓
FLORIDA	✓	✓		✓		✓	✓	✓	✓		✓		✓	✓		
I·P·CO·	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		
N·C· STATE	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓		
TEXAS	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		

Figure 1.

COMPARATIVE SUPERIOR TREE RATINGS

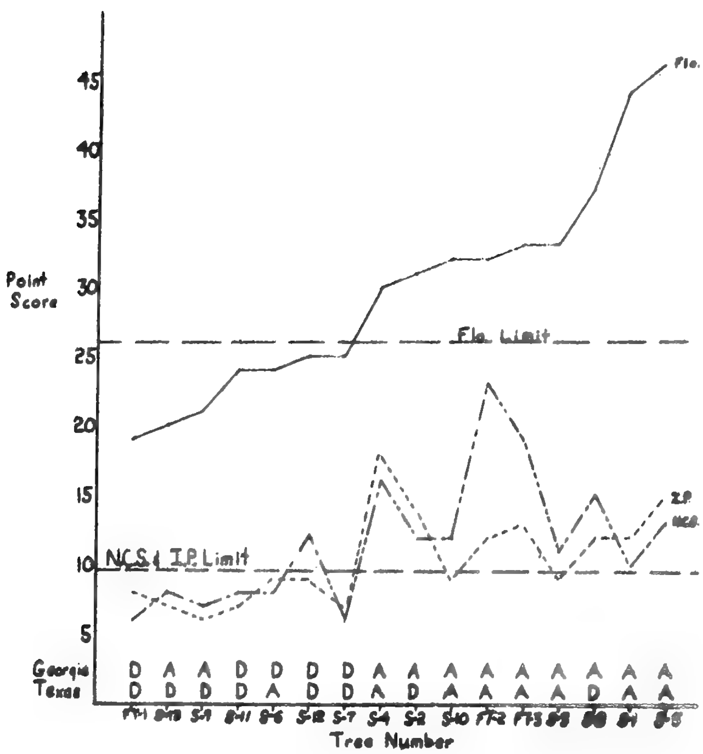


Figure 2.

Establishment and Management of Seed Orchards

George M. Ference [1]

It seems that there is very little that can be added to the theory of seed orchard establishment and management. A search of the literature during the past few years indicates that every possible angle has been covered and contradicted. Rather than rehash this information that is available and familiar to all of you, I will discuss our experience with seed orchards. Each organization dabbling in seed orchards has its peculiar problems and situations which must be met in their own way so that what works best for one may not be best for another. Such things as available labor, sites, money, foresters' ingenuity or lack of it, all influence what each organization has done and is doing.

I must interject here that we have worked with the University of Florida's Cooperative program and owe much to them for their guidance. If Drs. Perry and Wang take exception to some of my statements, I hope they will kindly do so.

The obvious place to begin is with the site. Ours is a 45 acre upland hardwood site completely surrounded with hardwood drains. These drains are invaluable as isolation strips as well as fire barriers. The nearest slash pine is over one half mile away. The site is nearly in the center of a 40,000 acre tract under fence and locked gates. There are some drawbacks to its' location but fire hazard and molesting by unauthorized persons are not among them. We first planned to place the orchard at our nursery, but we would have had to cut many acres of excellent young slash pine stands to get even a meager amount of isolation.

In order to clear the site, all merchantable wood was utilized and then the brush and stumps were cut with a K-G blade mounted on a D-8 tractor, the debris was piled and burned, and then the area was harrowed three times with a Rome offset harrow. After this treatment the area was nearly as clean as an old field. A fence 7 feet high was built in order to keep out deer as well as hogs. A soil analysis at this point indicated that the soil was low in all nutrients, at least by agricultural standards, and the PH slightly over 6. The soil is loamy sand 2-3 feet thick over sandy clay and moist but not wet. The site index for slash pine is about 90 and about 100 for loblolly pine.

Our first 200 potted grafted slash pine plants were planted in August of 1956 at a spacing of 30 feet by 30 feet. They were watered several times but in spite of an abnormally dry early winter no trees were lost until they started

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1/ Brunswick Pulp and Paper Company, Brunswick, Georgia

to grow the following spring. These trees averaged over 8 feet tall last winter and some were as high as 11 feet. An additional growth of 3 to 4 feet has been added this spring. Since then we have planted each spring about 400 potted grafted plants. Our orchard now contains grafts from 83 clones varying in quality from good to long-shots.

Mortality has come at two times; first when the plants were out-planted, then during the second growing season. The first type of dying usually involves only the scion. The second type of mortality is characterized by a hip shaped graft with the scion enlarging in diameter while the rootstock does not grow. The plants first lean over and then die soon after. Apparently water is going up to the scion while food is not getting down to the rootstock. Some have suggested leaving limbs on the rootstock for several years in order to nurse these trees along. According to our records as of March, 1959, 77% of the scions grafted lived and were outplanted and now 42% of the scions grafted are alive. Since 4 years of grafting are involved, we still lose some of the last plants so that we will probably have as live trees 35-40% of the scions grafted.

Insects have not given any trouble. Spraying has been done only once or twice a year with Malathion for red spider. We may get into trouble later, but I don't believe in spraying only as a precaution. There is too little known about the effects of insecticides to spray when it isn't known which insects might be killed or which might be caused to become epidemic.

So far no cover crops have been planted in the orchard and it has been allowed to grow up in weeds which are mowed every May and again in August. The first mowing is after the weeds reach about maximum size and the fall mowing is partly for fire protection and also an aid in moving around for control pollinating, etc. The weed cover works out well since it doesn't seem to compete with the trees as much as a grass cover would. Continued mowing will probably cause native grasses to take over, but these should not be troublesome if they aren't heavily fertilized. A 5' diameter area is scalped around each tree at the time of planting, but these haven't been maintained.

Fertilizer is being applied at the rate of 1 cup or about 1/2 lb. of 6-12-12 per tree for 1 year old trees and 2 cups for trees out-planted 2 or more years. With the cooperation of the University of Florida, a study has been installed to find the effects of N, P, & K in all combinations using two levels of N. After two years no differences in height growth can be noted as the result of the various fertilizer treatments. However, after the first year, only the trees receiving nitrogen had female flowers, but not all trees receiving nitrogen produced flowers. No such pattern developed this year. It is questionable whether faster growth than we are receiving would be desirable. The trees now have very long succulent leaders which are particularly subject to breaking by the wind and birds. In addition to the possible loss in height growth, it is very disheartening to lose young cones on the terminals in this manner.

Female flower production has increased from 10 in 1957, to 89 in 1958, and to over 200 in 1959. All cones were control pollinated in 1958 and 1959 in order to get started on progeny testing. About 45 cones will be picked this fall. The seed will be stored for a year or two until enough can be secured to make some plantings for comparative purposes. The progeny testing will be pushed as fast as possible in order to evaluate the tree selection program.

At this point, the first phase is over and another is about to begin. The University of Florida ended its large scale grafting program this past spring and from here on, it's up to us to do the propagation.

Our main effort will be with field grafting and in preparation 2,000 seedlings have been planted in groups of 3, spaced 30' x 30'. Grafting will be started during the spring of 1960. Although we haven't done any field grafting, it seems to be the only alternative to using pots which we don't like. Slash pine grows too fast to be confined to a 1 gallon pot for one year. The roots start circling the inside of the pot and the tap root seems to be permanently damaged. Some of our otherwise healthy three year old trees which were grafted in pots are wallowing holes in the soil around their trunks during wet and windy weather indicating root support may be faulty and these trees may become subject to windthrow as they get taller.

Our other attempt at propagation will be with airlayering. Last June 100 air layers were placed on 2 year old grafted stock in the seed orchard and of these, 25 rooted. These trees are now growing very well. The ages of the trees, from which the scions had originally come, were between 20 and 30 years of age. This is a convenient method of propagation and a very low percentage of success can be tolerated since the care and supervision is negligible. Only a weekly examination after installation is sufficient.

The present seed orchard is only a step to better things. When progeny tests give some results as to which clones are worthwhile keeping, another orchard will be established with these proven clones. Although the present orchard contains many clones that are only average, it is doubtful whether they will be destroyed. The present orchards are valuable in providing experience in orchard management, in providing easy access to trees to carry on control pollinating, and of course, to supply seed of better than average quality until it is possible to have a source of proven seed.

The Place Of Fertilizers In Forest Tree Improvement

by

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In various part of the silvicultural world, fertilizing is becoming recognized as a legitimate "tool" in some phases of professional forestry practice. Even in our own country serious exploration of its potentialities is getting underway. This development has been long in arriving, certainly overdue. Yet the lag in recognition of its possible utility is not strange, if we ponder a bit on the influence of tradition on our professional thought.

Traditionally, we foresters have been "anti-manurial" in our attitudes, and smugly proud that we are husbandmen for a crop considered capable of attaining economic size without benefit of fertilization or other intensive cultural measures. Indeed, we have been rather disdainful at the thought of stooping for, or leaning on, any agronomic aid in the lofty occupation of growing trees for timber. Quite early, and perhaps quite properly, we sensed that the rapidity and vigor of tree growth seemed to be largely associated with such physical factors as texture, structure and depth of soil horizons, aeration, and available moisture, and that the productive capacity of the land might be readily assessed from one or more of such factors. Soil fertility levels, more nebulous entities and difficult to measure at best, were relegated a subordinate place in the culture of forest trees and in the evaluation of the productive capacity of forest land. Occasionally, we seem to have even derived some comfort from noting that efforts to assess site quality from fertility levels have led, for the most part, to an impressive accumulation of negative results.

The development of this attitude and philosophy has been encouraged and abetted by our own observations and rationalizations, as well as by the elders at whose feet we may have osmosed much of our silvicultural wisdom. Only about three years ago, one of our outstanding silviculturists aptly expressed this philosophy when he wrote "Forestry . . . . deals mostly with natural plants . . . . . that through many centuries by natural selection have been able to utilize the available site to best advantage for survival and development. In forestry the demand is for the stem rather than the fruit. Seeds, branches, and roots, which contain the greater portion of mineral nutrients, are in almost all cases left in the woods. As decomposition of this residue proceeds, essential elements are released and re-used by future forest crops." So we have remained comfortably satisfied with the assurances that Nature's wonderful nutrient re-cycling takes care of all the fertility problems in forestry. We have confidently continued to rest in the knowledge that forest trees, growing on any given site over a long period, have time to integrate all the soil and site factors to the end that growth may be associated much more strongly with some one or more, readily-determined physical factor than with any particular level of available or total nutrient supply.

I do not wish to imply that any of our past rationalizations, reasonings and observations are wrong. But I submit that an unchallenged drift in this climate of complacency has culminated in failure to develop any solid understanding of the nutrient requirements of our commercial timber species, the fertilizer responsiveness of forest soils, the salt tolerance of seedlings, specific ion uptake and ion antagonisms, and a host of other important questions. In our pride of hard-headed practicality and our pre-occupation with the economic obstacles to employing fertilizers in silvicultural manipulations, we have overlooked the development of information on the physiological and biochemical aspects of forest tree nutrition. So now that forestry has become sufficiently intensified to require application of fertilizers in a number of common sense ways and situations, we find ourselves trapped, agronomically illiterate, and devoid of necessary experience, -- in effect like

> ". . . . . . an infant crying in the night,
> An infant crying for the light,
> And with no language but a cry."

These prefatory remarks, which represent a sizeable digression from the subject that was assigned to me, were provoked by my search of literature which proved quite un-rewarding for the purpose of this conference. I am mindful that much intensive study of fertilizing has been initiated in recent years by many agencies, industries, and individuals throughout the South, but scarcely any of this work has progressed far enough to yield definitive results. I shall now comment and make some observations, mainly in a speculative vein, on the place of fertilizers in the several areas of tree improvement programs where immediate use appears warranted.

In the Nursery

As yet, it is only in the nursery where we have attained a reasonable degree of sophistication in handling of fertilizers. And nurseries, unless direct seeding makes them obsolete in the future, should continue to play a very important part in forest tree improvement.

Fertilizers enter the program at this stage mostly through the soil management phases which also affect general nursery production. We know vaguely that fertilizers can greatly affect quality of planting stock, not just the size of seedlings. Tremendous advances have been made over the years in nursery practises, and quality control, in so far as morphological grades are concerned, is already quite good. However, much improvement is still needed in quality control of "physiological" grades. This improvement will come through basic study of seedling nutrition coupled with other soil management practises, and it is the responsibility of the researchers to supply the needed information to the nurseryman who still has to depend largely on the sometimes deceptive morphological grades as a guide.

At least in the early stages of tree improvement work, the select nursery stock will often be much more valuable than bed-run or run-of-the-woods seedlings. Improper fertilizer applications could easily reduce the drought hardiness of such select seedlings by a very substantial amount.

In Vegetative Propagation

Another important use of fertilizers is in connection with vegetative propagation. Until very recently, use of minerals has been confined mainly to treatment of cuttings, as, for example, in the complex concoctions employed by Mitchell, et al. (1942), in their early successful work on propagating slash and longleaf pines in Florida. However, use of fertilizers to envigorate the ortet prior to severing the twigs or branches, or prior to marcottage, appears to have been overlooked in theSouth until very recently. Enright (1959) shows convincingly that fertilizing of the parent plants prior to securing cuttings from them gave outstanding success with red pine, white pine and Norway spruce. For example, treating red pine cuttings with concentrations of 20 mg. per liter of indolebutyric acid yielded an average of only 1.3 percent successful strikes for all dates of treatments, but the same treatment applied to cuttings from fertilized seedlings averaged 84 percent successful strikes! It also is worthwhile noting that Enright found substantial differences in species response to fertilizing.

Fertilizing should also prove useful in grafting. It is already known that vigorous stock makes for better success in grafting, but the details of optimum timing and dosage for specific situations is largely unexplored. There is some evidence that fertilizing the ortet prior to collecting the scions will improve the number of successful grafts. It has long been known that fertilizing increases the rate and amount of callus formation, and this fact should prove useful wherever grafting is attempted.

In Seed Orchard Establishment

As already suggested above, seed orchards require vigorous growth of understock in advance of the grafting program, and subsequently there is need for getting the clones to attain meaningful seed-bearing size in the shortest safe time. In most instances, commonly available formulations may yield acceptable results at the start, since the main purpose is to promote vigorous growth within safe limits. When the soil requirements and character of specific orchards are more fully understood, the fertilizing practises can be sharpened and made more effective in the initial program of promoting vegetative growth. Since selections may actually involve edaphic or other strains which may respond differentially in a uniform orchard environment, the need could develop for selective fertilizing practises to meet specific clonal requirements.

In Stimulation of Flowering and Seeding

When the individual trees in seed orchards have attained sufficient crown size to bear operable crops of seed, fertilizer practises will undoubtedly play an even more important part than in initial seed orchard establishment. There is no question any more that fertilizing for stimulating flowering and subsequent seed production is effective and essential for these purposes. Since it achieves the stimulation by promoting the vigor of the tree, it is preferable to girdling, root-pruning, strangulation and the like which tend to reduce vigor. Undoubtedly fertilization will increase the disease hazard in some instances, for example, fusiform rust in loblolly and slash pines, but if the pathologists stay on the job, the disease problems should not prove insurmountable.

Perhaps the main questions in this phase of the fertilization program concern effective timing and amounts per application, or in other words, dates and dosages. Much work needs to be done through a variety of field experiments and related investigations before we can expect to formulate efficient and effective prescriptions for specific areas and situations. However, the question of effectiveness may not prove too difficult, if past work provides any indication. A rather wide variety of dosages and mixes have seemed to produce results. For example, Allen (1953) found varying amounts from 19 to 44 lb. per tree of a 5-15-5 mix effective on longleaf pine; Hoekstra and Mergen (1957) produced significant increases in 21-year-old slash pine flowering with 20 lb. of 7-7-7 and 40 lb. of 3-18-6 commercial mix per tree; Wenger (1953) stimulated cone production in loblolly pine with 25 lb. and 50 lb. of a 7-7-7 mix per tree; and Detwiler (1943) produced a tremendous crop of acorns in 23-inch white oak by applying a 10-5-4 mix at the rate of 14,000 lb. per acre. Some of the past work suggests that fertilizing is also effective in altering the proportion of total buds that differentiate into female flowers.

There has been some speculation in the past that nitrogen should be used sparingly in fertilizing for flower and seed stimulation. However, Chandler's (1938) study used nitrogenous materials to advantage on deciduous trees and in the study of Hoekstra and Mergen (1957) abundant nitrogen proved to be the key element for slash pine. Although it may have been assumed that pines are not very demanding on nitrogen or mineral elements, various analyses of seed have shown pine seed to contain more protein than are contained in a wide variety of fruit and nut trees, and they are also high in phosphorus and possibly other elements. It has also been observed that heavy seed crops are frequently associated with marked reduction in annual ring width; although such observations may be strongly confounded with other factors, they may possibly reflect the heavy drain on nutrient supplies when heavy seed crops are produced, suggesting that simply to maintain the tree at normal vigor under conditions of heavy seed bearing, mineral supplements are essential, and that to depend entirely on other measures of stimulation could eventually prove disastrous to the orchard.

There is fairly good evidence that manipulation of soil fertility improves seed quality as indicated by such studies as that of Chandler (1938) and Youngberg (1952). If this relationship is fully demonstrated under varying conditions, it provides simply another reason for developing an adequate program of fertilization in seed orchards.

No mention has been made of seed-production areas, but a number of the considerations which apply to seed orchards would also be applicable to the seed producing areas.

In Progeny Testing

Testing of progeny is obviously not a simple matter. Selections may involve strains of various sorts which may behave quite differently under one set of edaphic or other environmental conditions than another. It would seem that adequate testing programs should encompass not only several native fertility levels or site qualities, but within each level or quality, provision should be made for the assessment of several "sub-levels" produced through application of fertilizers. Only through such comprehensive testing will there be assurance that superior selections will be wisely employed in subsequent forest renewal.

If agronomic experience provides any guidelines, it seems likely that in forestry, also, the hereditary potential of new strains, particularly those involving rapid growth, cannot be realized to the fullest except on sites of the highest quality. Under some circumstances it may prove feasible, or at least be necessary, to employ fertilizers to salvage some of the hereditary potential.

In Conclusion

I have attempted in a very general way to sketch the major places of fertilizer use in forest tree improvement. It is clear that the use has passed the academic stage. Unfortunately, it will not be the most efficient or intelligent use until much more is learned concerning tree nutrition and fertilizer application for the specific purposes under consideration. Our late start in this field, without a doubt, is a big handicap, but we should not feel discouraged at this stage. Look at other phases of silviculture. Fore example, after fifty years of research on thinnings, we haven't found out much more than that thinnings may not increase total growth, but they may simply distribute the same amount of growth over different numbers of stems, and all this within a rather wide range of stand densities. If, in the past 50 years, we had spent even a fourth of the effort that has gone into thinning studies, in well-executed studies on tree nutrition (or fertilization), we might not have come up with any more earth-shaking conclusions than those gained from investigations of thinning. But I dare say we would have gained a better understanding of the intimate details of the organism with which we must now in our more intensive forestry practises deal in more than a general way.

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Results of Pollen Dispersal Studies

By:

Robert McElwee[1/]

Current research underway, and a review of pertinent portions of the literature, were presented in this paper. The final report will be published as a graduate thesis in the near future.

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The Establishment and Management of Seed Production Areas

Donald E. Cole [1/]

This discussion will concentrate on current methods in the establishment and management of seed production areas and will be confined to slash and loblolly pine.

A seed production area is defined as "a natural or planted stand or group of stands, set aside, periodically rogued, and treated to stimulate seed production. The genetic quality of the seed is not known (11)". The purpose of a seed production area is to provide, in quantity, seed of known origin from the best phenotypes available. The establishment of seed production areas is a stop-gap measure, designed to provide seed of the best possible quality until our seed orchards begin to bear.

While opinions differ as to the degree of improvement to be expected from seed from such areas it is of considerable benefit just to have seed of known origin and to have seed collection concentrated on specific areas. Perry and Wang present calculations to show that seed that is only one-half of one percent superior to the average would, under the conditions they have assumed, be worth an extra $4.52 per pound. They also say, in speaking of seed production areas, that "when racial variation is taken into consideration, it is highly conservative to assume genetic improvement of at least two percent over the use of wild type seed of unknown geographic origin and unknown parentage. A two percent genetic improvement, by the calculations of this example, permits an expenditure of $18.93 extra per pound of seed... (9)" This would seem to be ample justification for the trouble and expense involved in establishing these areas.

In Georgia the most important change in the establishment of seed production areas is in the greatly increased emphasis on the quality of the trees left for seed production. The purpose is to secure, through the selection of good seed trees, all the improvement in genetic quality that is consistent with quality seed production. Only the best trees are left, their quality being judged by their bole form and crown characteristics, freedom from disease, and vigor. The change has been caused by the adoption by the Georgia Crop Improvement Association of standards for the certification of forest tree seed; this has focused our attention on seed quality and has provided a set of standards for choosing the seed trees.

This emphasis on quality is important since the selection of the original stand and of the trees to be left on the area and its isolation zone determine

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1/ Gair Woodlands Corporation, Savannah, Georgia

the degree of improvement in genetic quality that will be obtained. We can't be positive that any improvement in genetic quality has been effected until these areas have been progeny-tested; but surely this will counter the dysgenic effect of using seed collected without regard to its parentage or origin. We are confident enough of the benefits that we plan to continue until we are securing all of our seed from certified seed production areas.

What sort of stand, then, makes a good seed production area and how is it established? In selecting a stand for this purpose, the most important requirements are that it be a well-stocked stand of good quality that has not suffered any sort of highgrading and that it be so located that an isolation zone of the proper width can be established on all sides (Georgia Crop Improvement Association Standards specify a 400 foot isolation zone). In addition, the trees should be large enough to produce fair cone crops (12" dbh or more), the stand should be on a soil type and topography that is fairly typical of the area to be served, it should be as accessible as possible, and finally, it shouldn't be too small a stand as this would tie up a disproportionate area in the isolation zone.

The next stop is to mark the area and its isolation zone; the same criteria are used on the isolation zone as on the seed production area. This is a very important step, of course; our practice is to follow the Georgia Crop Improvement Association standards rigidly in selecting seed trees and then to leave every tree that meets the standards, regardless of spacing. This has given us about fifteen trees per acre in twenty-five to thirty year old slash stands; older stands would probably have fewer trees. The distribution is somewhat patchy but not excessively so if the original stand is well stocked and of good quality. It has been suggested that preparation and management would be simplified if the isolation zone was clearcut and planted with a species that won't cross readily with the species on the area but we feel it is important to leave as many trees as possible there to improve the pollination of the trees on the edges of the area. The first crop pollinated by the marked tree is ready two years after release and the crop should increase to a maximum about the fifth year after release; it may level off or decline after that (13).

Once a seed production area has been established, a number of practices can be used to increase seed yields and facilitate operations. Probably the most promising is the application of fertilizers. A number of reports show that fertilizer applications will increase seed yields (1, 6, and 12).

Considerable research is underway on the techniques of fertilizing seed production areas (and seed orchards) but little of it has been reported yet. The best procedure is to have a soil analysis made, submit the results to a qualified soils specialist, and follow his recommendations.

It is also known that girdling, root pruning, strangulation, etc. may be effective in stimulating seed yields (6, 8, and 12). However, there are also reports that these treatments may reduce the vitality of the trees and even result in the production of fewer cones, in the long run, than no treatments (2 and 7). The loss in vitality is probably the result of too severe root pruning and girdling and it is likely that methods of light root pruning and partial girdling can be worked out that will stimulate seed production without much loss in vitality. But until we have a better idea of the long term effect of these practices we shouldn't apply them on a large scale.

Cone losses to various insects (and in some parts of the South, to disease) are serious but other papers are being given on these subjects. However, I will say that we badly need an effective chemical with greater residual effect); perhaps one of the systemics now being tested will prove to be satisfactory.

Understory vegetation will have to be controlled on these areas in order to reduce competition and facilitate operations; pine reproduction, hardwoods and shrubs should all be treated. The methods adopted to do this will vary with conditions but will probably involve regular prescribed burning and/or cleaning with a rotary mower.

Finally, we come to the most difficult problem involved - harvesting the cones. Some of the harvesting from seed production areas, especially loblolly areas, has been done by cutting the trees and collecting the cones from the felled trees (3). However, the difficulty of finding a succession of stands good enough to make seed production areas is forcing many companies to collect from the standing trees so that the same areas can be kept in production for several years. L. T. Easley, of the West Virginia Pulp and Paper Company, reports a cost of $3.16 per pound (or about $3.35 per bushel) when his crews collected from standing slash pines four years after release; the average yield per tree was about 0.9 bushels. 2/ Our company had had no experience with collecting cones this way so we had it done by the Davey Tree Expert Company; results were satisfactory and costs, the final week of operations, were $4.50 per bushel on a slash seed production area three years after release; the average yield per tree was 1.1 bushels. Goddard reports a collection cost of $4.77 per bushel on a loblolly seed production area three years after release; the average yield per tree was about 1.5 bushels (4). In all three cases, the climbing was by means of ladders and ropes and a considerable amount of time was spent in climbing and moving ladders. Climbing with spurs and ropes has been reported as the most efficient means of cone collection (7); this would eliminate the need for labor to move the ladders, speed the actual climbing and since the climbers would decend from the trees on their ropes, the spurs probably wouldn't damage the trees too much. This method shows enough promise in reducing costs to be worth investigation. Cones have also been collected from the bucket of a dragline and it has been

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2/ Personal communication.

suggested that cones might be collected by an operator suspended from one or more balloons tied to a vehicle that could move the balloons about as needed; other methods have been suggested and will undoubtedly be tried in an effort to reduce cone collection costs.

Yields from seed production areas vary in bushels per tree and seed per bushel and also from year to year on the same tree or area. Such factors as spacing, diameter, crown length, period of time since release, inherent fruitfulness, insects, and disease and climatic conditions all have significant effects. The number of cones that is set as the minimum that will be climbed for also has a marked effect on costs and yields; 300-400 cones per tree has been suggested as the minimum for loblolly (4); probably 300 cones per tree would be a good minimum for slash. Since a minimum has to be set, it is apparent that some trees are not producing very heavily, at least in the first years after release. The general opinion seems to be that most of these trees will improve as producers as release and fertilization continue to have their effect. The reported yields per individual tree range up to 3 bushels (4) (commercial collectors have stated that they have collected as much as fifteen bushels of cones from a single open grown slash pine); it would appear that we should be able to average two bushels or more of cones per tree if the trees are large enough, if the proper fertilizers are applied, if steps are taken to control cone insects and diseases, and if enough time has passed for release and fertilization to have full effect.

In summary, then we can say that seed production areas can provide us with seed of the best quality that will be available until our seed orchards begin to bear, although we don't know the degree of genetic improvement to be expected from such seed, the evidence available indicates that the results will justify the costs involved. Collecting cones from the standing trees, although more expensive than collecting from felled trees, is not too expensive considering seed quality, particularly if climbing is restricted to trees with a bushel or more of cones, and it permits collection from the same area for a number of years. Fertilization and the control of cone insects are two promising methods of increasing seed production but more research is needed on both methods. Finally, we need to test the progeny from these areas so that we will have an indication of their genetic worth.

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Variation in Nursery Grown Seedlings From Individual Mother Trees in a Seed Production Area

By C. L. Brown and R. E. Goddard 1/

In 1955, the Texas Forest Service established a seed production area on the I. D. Fairchild State Forest near Maydelle, Cherokee County, Texas. The area consists of six acres of loblolly-shortleaf pine, with loblolly pine predominating. It is an even-aged stand which averaged 44 years of age at time of establishment, and before thinning supported over 14,000 bd. ft. (Scribner) per acre. Presently the stand has an average of 18 trees per acre, with a volume of approcimately 4,000 bd. ft.

The primary objectives underlying the establishment of this area were: (1) to determine what degree of genetic improvement in quality and growth might be expected in the progeny from such areas, (2) to study methods of increasing cone production on large trees, and (3) to determine the economic feasibility of permanent seed producing areas where individual trees must be climbed for cone collections. This last objective has been realized and has been previously published upon by Zobel et al (1956) and Goddard (1958). The second objective, that of increased flower stimulation and cone production, is still under investigation.

For deriving objective (1), that of determining the genetic validity of seed production areas, several long range studies are currently in progress. These consist of established replicated field plantings of open pollinated progeny from: (a) individual mother trees in the seed production area before the area was rogued, (b) the same individual mother trees after roguing, (c) extremely poor phenotypes from an adjacent area (large crowned, poorly pruned trees of the type many cone collectors prefer) and (d) commercial seedlings, i.e., average nursery run seedlings from the Texas Forest Service Indian Mound Nursery near Alto, Texas. During the 1958 growing season seedlings from these four sources were grown under standard nursery practices and outplanted to the field for future observations and measurements on growth and form.

Because so little is presently known about juvenile characteristics of pine seedlings and their expression of growth and form in later years, it seemed pertinent to make rather detailed observations on the one-year-old seedlings from these different sources at the time of lifting. Such information would provide a basis for making comparisons of the same seedlings as they

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became older under uniform spacing on a given site. Secondly, every nurseryman in the South that has produced loblolly pine seedlings in commercial quantities recognizes the wide variations in size and grade common to this species, and the factors contributing to this variation is of primary importance.

The purpose of the present paper is to point out some of the observed variations in growth and form of the progeny from different mother trees and to compare the variation in height growth of seed production area seedlings with commercial seedlings produced from local seed obtained from cone collectors in East Texas. The data reported here were obtained from detailed measurements on 14,000 one-year-old seedlings and included approximately 140,000 recorded observations.

Experimental Procedures

Seed from 75 individual loblolly pine mother trees in the Fairchild Seed Production Area were machine graded, by the use of sieves, into large, medium, and small size classes and stratified for 30 days at 5°C prior to planting. The seed from each mother tree were sown separately by the three size classes in standard nursery beds. Each seed source was replicated twice in adjacent nursery beds. Records of germination rates were kept for each tree by seed size for a 4 week period after planting. At this time all seedlings were thinned, by hand, to 30 seedlings per square foot which corresponded to the average density of commercial loblolly pine seedlings growing in the same nursery. Throughout the growing season the experimental seedlings received the same care and irrigation schedules as the adjacent commercial seedlings.

During late December the seed production area seedlings and the related check seedlings were lifted for grading and planting. A sample of 30 seedlings were taken from each seed size class for each mother tree, in both replications, giving a total of 180 seedlings from each source for detailed measurements. In addition, twenty random samples of commercial seedlings, totaling 30 seedlings each, were also measured and outplanted for comparison. The following measurements and observations were recorded" (1) stem diameter at ground line by 4 sizes in ,1, .2, .3, and .4 inche classes, (2) total seedling height to the nearest inch, (3) length of first flush (juvenile growth) to nearest inch, (4) total number of flushes (shoot extensions), (5) number of lateral buds or branches at distal end of each flush, (6) the presence or absence of a distinct terminal bud, and (7) the number of adventitous branches on the basal portion of the stem near the ground line.

Results

During the initial separation of seed into small, medium, and large size classes by the use of round-hole sieves graduated in successive units of 1/64 inch in diameter, it immediately became apparent that the average size of seed from different mother trees was highly variable. Because of this it was impossible to adopt two standard sieve sizes for all trees, therefore, it was necessary to shift the size of the sieves used for different mother trees. To standardize the relative grading process for each tree, sieve sizes one unit above and below the mean seed size were consistently used to separate the largest and smallest seed, e.g., if the bulk of the seed from any one tree passed through a #12 sieve (12/64 inch) then a #13 and #11 sieve were used to collect the large and small seed respectively. A frequency distribution of average seed size among the 75 mother trees is shown in Figure 1. From such a distribution it appears likely that the common process of grading bulk commercial seed collected from numerous trees into small, medium, and large seed sizes, to some extent, separates trees as well as seed of varying size within the same tree.

The primary purpose of grading seed by size classes is, of course, to reduce variation in seedling size or yields because seedling size is known to be related to size of seed, as has been previously shown by several workers (Spurr, 1944: Righter, 1945; Fowells, 1953; and Mitchell, 1939). In the present study, an analysis of variance of the mean heights of all seedlings from the seed production area showed that the mean heights of seedlings from the large and medium sized seed were significantly greater at the 1% level than the mean heights of seedlings produced from small seed (Table 1). There was no significant difference in mean seedling heights between large and medium size seed.

A further interpretation of the data is made possible by grouping all mother trees together which possess the same average seed size, and comparing the mean seedling heights of each group. When this is done as shown in Figure 2, there is no strong correlation between absolute seed size and seedling heights. Stated somewhat differently, the greatest influence of seed size on seedling size is found within and not between individual mother trees.

With regard to other measurable characteristics of seedlings as related to seed size the following statements hold true for this study:

(1) There is a slight trend toward smaller stem diameters with seedlings from small seed as indicated by the greater proportion of seedlings in the .1 inch diameter class as shown in Table 2. This data was not statistically analyzed.

(2) There is no significant difference in length of first flush (juvenile growth) in seedlings from different seed sizes; however, there is a trend in this direction. The average length of the first flush was 7.1, 7.3, and 7.4 inches for small, medium, and large seed sizes respectively. There is, nevertheless, a strong correlation between mean total height of seedlings and mean length of the first flush regardless of seed size. A correlation analysis of these data show a correlation coefficient of .85 which is highly

significant. This obviously indicates that the variation in length of the first flush accounts for most of the variation in total height.

(3) A close review of the data indicates that no real differences exist between seedlings from different seed sizes in the number of successive growth flushes.

(4) There was a slight trend toward more rapid germination with an increase in seed size, e.g., at the end of the third week the germination percentage was 42, 45, and 47 per cent for small, medium, and large seed respectively. After these considerations on the influence of seed size on seedling growth and development, it is now possible to discuss seedling variations of an apparent inherent nature.

Because one-year-old nursery grown loblolly pine seedlings from graded seed usually show considerable variation in total height, it becomes of primary interest to compare the mean heights and range of variation in seedlings from the seed production area with standard nursery seedlings from local seed sources in East Texas (Table 3). A modified chi-square test 2/ for homogeneity of variance of heights indicates that the variances are heterogeneous, i.e., the variance of standard nursery seedlings is significantly higher than that of seedlings from the seed production area. These data are not at all surprising, however, when one stops to consider that one-half of the total heritable variation in each progeny group from the seed production area was contributed by individual mother trees, in contrast to the sample groups of nursery seedlings coming from an undetermined number of mother trees. Therefore it is not inferred, in any sense, that the total variation in height of the progeny from all 75 trees in the seed production area would be any less than that encountered among 75 other trees randomly selected in any local area.

There are also real differences between progeny from different mother trees in the following characteristics: (1) total height, (2) length of first flush (juvenile growth), (3) number of growth flushes per seedling, and (4) formation of terminal buds.

Seedlings from some mother trees tend to be short regardless of seed size, while others are consistently tall. The same was true for total length of the first growth flush as shown in Figure 3.

The progeny from some of the 75 mother trees possessed almost 100% well-formed, terminal buds at lifting time (late December) whereas the majority of seedlings from other trees were caught in various stages

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2/ Bartlet's test of homogeneity of variance. Snedecor, G. W. Statistical Methods. Fifth ed. pp. 285-289. Iowa State College Press, Ames. 1956.

of shoot elongation late in the fall season (Figure 4).

Although the majority of all seedlings produced by each of the 75 mother trees possessed two flushes of growth, there were also certain trees that produced a higher percentage of seedlings with three, or even four growth flushes, while other trees consistently produced seedlings with only one and two flushes.

There were no consistent differences in the number of lateral buds produced at the top of each successive growth flush by the progeny from different sources; neither did the number of adventitious branches at the base of the stems conform to any set pattern within or between progeny groups.

Conclusions and Summary

The observations reported here are of practical as well as theoretical importance. In essence, the study confirms some of the same conclusions reached by Righter (1945) on the relationship of seed size and seedling size to inherent vigor, and in addition it points out that one-year-old progenies from different trees possess inherent differences in patterns of growth and development.

These findings may be summarized as follows:

(1) Seed size is positively correlated with seedling size within the progeny of individual trees, but not between progenies from different trees.

(2) The variation in seed size within a progeny is non-heritable, and accounts for part of the total height variation in one-year-old loblolly pine seedlings. This indicates that subjective selection of seedlings for inherent vigor within any progeny group will not necessarily result in genetic improvement. If, however, the seed of any one progeny are graded and sown at wide spacing in a uniform environment, followed by statistical selection above the mean in each seed size-class, then one should expect to select inherently vigorous seedlings with more than 50 per cent accuracy. Furthermore, it seems valid to say that a comparison of different mother tree progenies on a similar basis could assist one in the early "weeding out" of undersirable "strains" in a program of controlled breeding designed toward strain building.

(3) A large part of the variation in seed size between progenies from different trees is heritable, but these inherent differences in seed size _per se_ do not form a genetic basis for selecting inherently vigorous seedlings.

(4) In nursery practice the grading of bulked seed into size classes results in the production of more uniform seedlings because it separates seeds within progenies thereby reducing the non-heritable variation. At the same time, and to a greater extent than one might think, it separates individual

trees possessing inherent differences in seed size which reduces the number of trees and possibly seedling variation. Grading bulked seed is, therefore, a desirable cultural practice, but is of no consequence genetically in either direction.

(5) There are inherent physiological differences in the rates and duration of growth between progenies from different trees which result in marked differences in growth patterns and morphological expression of several seedling characteristics. The most obvious of these were the average length of the juvenile growth flush, the number of successive shoot extensions, and terminal bud formation. Although these differences were clearly distinct, nothing is virtually known about the degree of heritability of these traits, or even of more importance from the practical standpoint, whether these early differences are strongly correlated with later growth, form, and quality.

The greatest value of this study will come several years hence when these same progeny can be compared with their seedling characteristics. Until this is done, we will not know what extent or what degree of genetic improvement may be expected quality-wise in seedlings from seed production areas as compared to other local sources. It must be kept in mind that we are working with selected phenotypes whose genetic value is presently unassesed, and for this reason there is no real evidence upon which to draw generalizations.

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Table I. Mean Height of Seedlings Grown From Three Size Classes of Seed

Seed Size	Height (inches)
Small	10.7 ± .42 *
Medium	11.1 ± .40
Large	11.2 ± .33

* Significant at the 1% level.

Table II. Percent Seedlings in Each Stem Diameter Class Grown From Seed of Three Size Classes.

Seed Size	Stem Diameter Class (tenths of inches)			
	.1	.2	.3	.4
Small	25.6	70.3	4.0	.7
Medium	17.1	76.2	5.5	1.2
Large	16.5	75.7	6.8	1.0

Table III. Comparison of Variance of Seed Production Area Seedlings With Ordinary Nursery Seedlings Grown From Seed of the Same Size Class.

Source	Total Height (inches)	Mean Variance $\bar{s}^2$	Range in $\bar{s}$
Seed Production Area	10.7	5.36	1.0 - 3.2
Nursery	10.4	11.87*	2.7 - 4.2

* Highly significant.

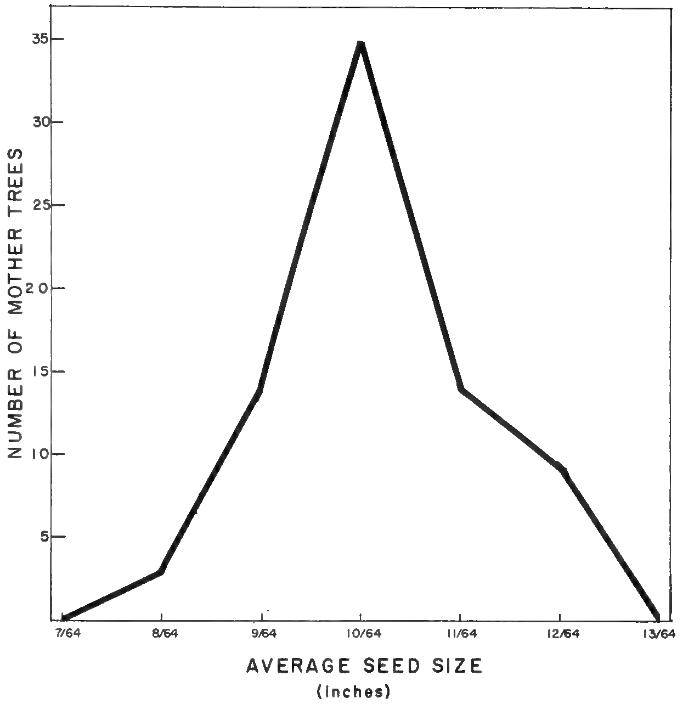

Figure 1. Frequency distribution of average seed size among the 75 loblolly pine mother trees in the seed production area.

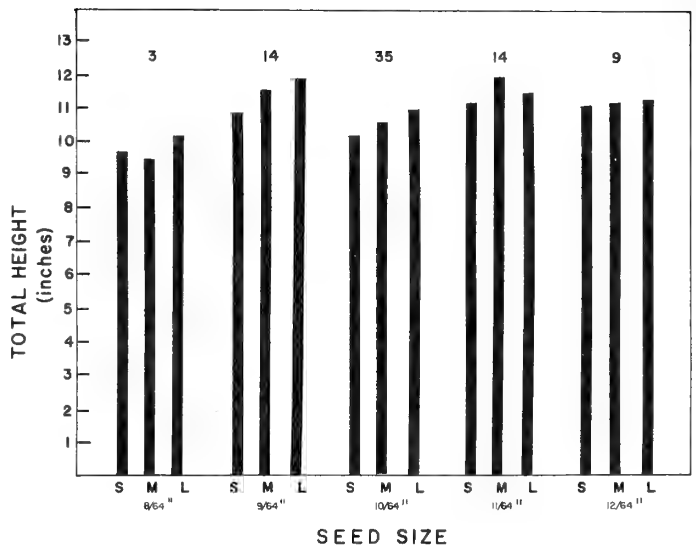

Figure 2. Total heights of one-year-old seedlings grouped by mother trees possessing the same mean seed size. (S M L denotes small, medium, and large seed within each group. Figures at top denote number of mother trees in each group).

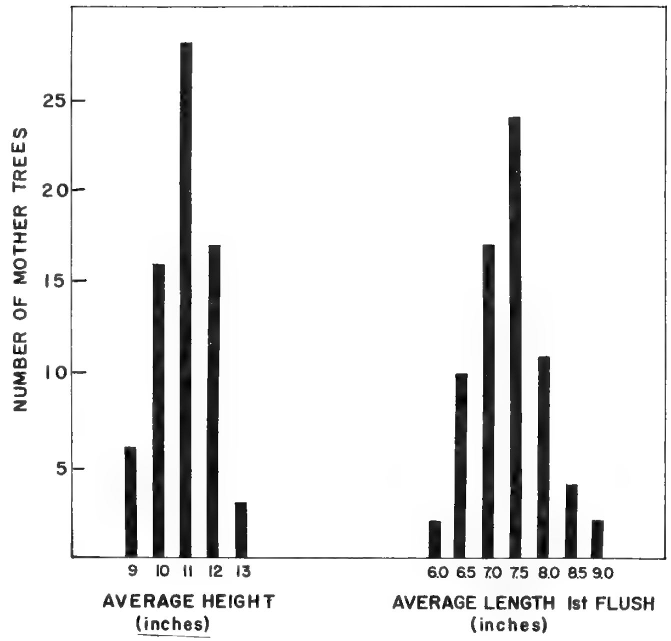

Figure 3. Frequency distribution of average seedling heights (left) and average length of first flush (right) of the progenies from each of the 75 mother trees in the seed production area.

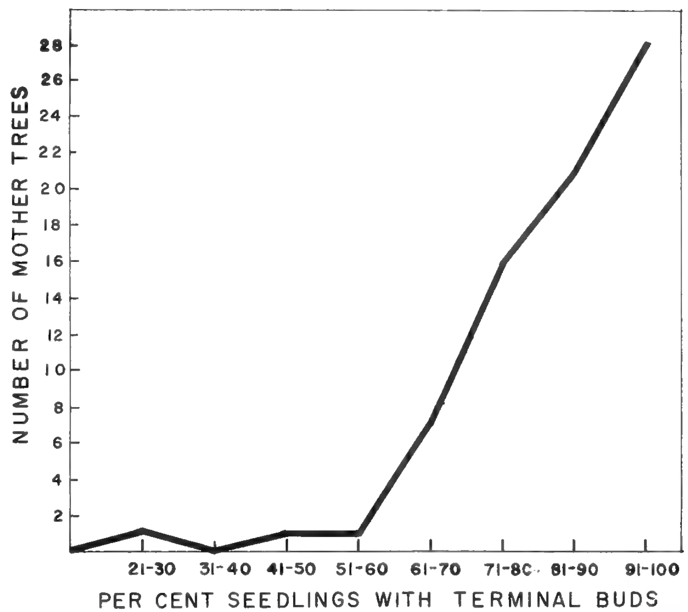

Figure 4. Frequency of terminal bud formation in the progenies from 75 mother trees in the seed production area.

Problems Involved in the Control of Cone Insects by Aerial Spraying

By:

E.P. Merkel [1], W. L. Beers [2], and P. E. Hoekstra [3]

Entomologists at the Southeastern and Southern Forest Experiment Stations are currently engaged in research aimed at developing methods for the control of insects destructive to pine flowers, cones and seeds. In order to attain the goals of entomological soundness and economical practicability in control methods, we are striving to obtain essential information on the identification, life histories, habits, and ecological relationships of the major cone-and seed-insect pests. This basic knowledge is the prerequisite to any biological, chemical, or silvicultural control method.

We naturally look to chemical control as our immediate line of defense. This is to be expected when one observes the spectacular insect control which has been obtained with the great variety of new insecticides developed since 1946.

Several authors have already published on the chemical control of southern cone and seed insects. Allen and Coyne (1) have reported satisfactory protection of longleaf and slash pine cones with hydraulic-spray applications of a 0.5-percent gamma BHC (Benzene hexachloride) water emulsion applied in April, June, August, and October. Coyne (3) also reported that pines in southern Mississippi, in preliminary trials, were successfully and economically protected from cone-insect attack with a 0.5-percent gamma BHC water emulsion applied by means of a turbine mist blower. Cole (2) used an airplane to apply 12 ounces of 36-percent gamma BHC per gallon of fuel oil at the rate of 1 gallon per acre to a slash pine seed production area in Long County, Georgia. Differences in the protection of 1-year-old and new cones on sprayed and check trees were not statistically significant when sprays were applied on February 25 and June 15, 1957. However, mortality of new cones was significantly reduced in 1958 when sprays were applied earlier; i.e., on February 17 and May 10.

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Although these references to chemical control are encouraging, there are still many obstacles to be overcome. Despite the fact that benzene hexachloride is very toxic to Dioryctria "coneworms" in laboratory and field tests, we should not rely on this single chemical to solve all our control problems. Entomologists at the Gulfport, Mississippi, and Lake City, Florida, laboratories are continuing the search for chemicals that are cheaper and less phytotoxic than BHC. Laboratory insecticide-screening tests, conducted at Lake City during the past year, indicate that aldrin, DDT, and Sevin are potentially effective chemicals when tested against half- to fully-grown Dioryctria abietella (D. & S.) larvae. Considerable testing of these and other promising insecticides under field conditions is needed; and studies of the effects of weathering on the residual longevity of insecticide deposits on flowers and cones should be undertaken.

Because of the scarcity of available information on the life histories and habits of major southern cone and seed insects, most of the field applications of insecticides, to date, have been made largely on an arbitrary timing basis or by guesswork. Although this approach has yielded some promising results, there is much to be gained by determining the optimum time for insecticide applications. If we know the insects we want to control, considerable time, effort, and money can be saved when insecticides are applied to correspond with the most vulnerable stage of insect development or with a period when the insect is most likely to contact, or be contacted by, the chemical.

Other problems arise when we consider where chemical control is to be applied" i.e., in seed production stands, in seed orchards, or on individual trees or single branches of trees of high genetic value. Seed production areas usually contain very tall trees and generally are not accessible to heavy, ground spray equipment. In such areas, fixed-wing and helicopter aircraft, or specially designed ground equipment, will probably be the most feasible means of spray application. On the other hand, in seed orchards, similar in appearance and accessibility to commercial fruit and nut orchards, insecticides could be applied readily by conventional hydraulic sprayers and mist blowers. When we consider the protection of individual trees or parts of trees, as in special tree-improvement studies, the cost of chemical application may not be a critical factor; but special equipment or application techniques may be required to obtain the desired control.

With this background discussion, we will consider next an exploratory, aerial-spray study conducted near Perry, Florida, in 1958 by the Buckeye Cellulose Corporation, with technical assistance from the Lake City Research Center.

A field test was instituted in three Buckeye Cellulose Corporation seed production areas to determine the effect of one and two applications of BHC upon survival of slash pine conelets. Stands (25, 38, and 56 acres in size) were chosen on the basis of similarity of site, age class, and thinning history. Consistent with the gross nature of the test, a simple experimental design was used whereby each seed production area was set up as a block containing three plots. Spray treatments were one application, two applications, and the check. Five trees were marked in each plot to serve as sampling units for later statistical evaluation.

Insecticide sprays consisting of 3-percent gamma isomer of BHC in 1 gallon of diesel oil per acre were applied on March 13 and July 1, 1957 by Scott Air Service of Savannah, Goergia, using a Piper Cub aircraft. Dye card analysis of the spray deposit made during the March treatments indicated an average application rate at the forest floor of 0.54 gallons per acre with a coefficient of variability of 67 percent.

Binocular counts were made of the conelet crops of sample trees during the period of rapid shoot elongation in late April and early May 1957. All visible conelets were counted by two observers using 7 x 35 mm. binoculars while standing at a fixed point approximately 2 chains from each tree. Deductions were made at the time of counting for rusted conelets, which in this instance amounted to 18 percent of the observed crop.

A followup binocular inventory of mature cones on sample trees was carried out in September 1958, after which cone and conelet data were adjusted for full crop by the use of regression equations developed by P. E. Hoekstra. Subsequent statistical analysis of corrected data failed to show significant differences between treatments.

Although the results of the Buckeye aerial-spray study were not conclusive, valuable experience was obtained which would serve as a guide in the planning, design, and conduct of future aerial-spray tests. What are some of the factors to be considered in the design and evaluation of aerial-spray tests for the control of cone and seed insects?

First, it should be re-emphasized that all available information on the biology of the insect or insects should be utilized. This may be important particularly with reference to timing of spray applications.

The statistical design of the experiment should be kept as simple as possible; i.e., the number of variables introduced into the test should be held to a minimum. This is particularly necessary because aerially sprayed stands are not sufficiently large generally to permit treatment replications within each forest stand. Each treatment replication must consist of a full-area-treatment; and each treated area should be preferably at least 1/4 mile from the next nearest area to prevent contamination from spray drift.

Every effort should be made to secure the services of reliable aerial contractors with experienced pilots. Contracts that are carefully prepared and rigidly adhered to will reduce the chances of test failures due to poor insecticide application. Contracts should state the insecticide and formulation, type of aircraft, rate of application, time, pattern, and altitude of flight, minimum acceptable dosage, etc. The type of aircraft to be used for the test will frequently determine the details of the contract specifications.

It is of paramount importance that the pilot fly over the test areas prior to spraying in order to avoid possible safety hazards and to become familiar with the plot locations. Spray areas should be clearly delineated on the ground by means of balloons, flags, tree markers, or other devices so that they may be seen readily by the pilot as he maneuvers his plane into position for the spray runs.

When oil-base sprays are used provisions should be made to assess the distribution and dosage of the spray deposit. Davis and Elliott (4) have described a rapid method of estimating aerial-spray deposits by means of oil-sensitive dye-cards. With this technique, however, you must have sufficient time and manpower to adequately distribute the dye-cards just prior to spraying.

Finally we come to the most difficult and time-consuming task of evaluating the effects of the treatments. Flower or conelet and second-year cone counts must be made on sample trees before the first spray is applied and again after the last spray in order to obtain cone-survival data. The actual tagging of sample flower-and cone-clusters is the most accurate method of making counts because it permits the examination of the cones to determine the cause of insect damage. This procedure is very slow and costly. Another method is to make binocular counts and estimates of the numbers of conelets and cones on sample trees. Although this technique is fast and can be quite accurate, it does not permit the close examination of the flowers and cones. The solution to the problem of evaluating treatment effects may be a combination of binocular cone-counts on sample trees supplemented by periodic examinations of actual flowers and cones on additional sample trees.

In order to appraise the effects of aerial sprays in protecting cones during a complete cycle of development, the study areas should be sprayed during two consecutive seasons. Such experiments should indicate plans for evaluating the insect-caused mortality of overwintering conelets.

The evaluation of aerial or ground spray tests are further complicated when more than one spray application is made in a given season. Theoretically, direct or indirect measures of the insect populations should be made prior to and following each spray application so that the effect of each spray can be determined. Such an evaluation is not possible when simple cone-counts are made at the beginning and end of the season. Availability of time and manpower will, of course, determine the feasibility of making frequent pre-and post-spray appraisals of the insect damage.

In the preceding discussions we have shown that progress is being made toward developing chemical control methods for cone and seed insects in the South. Aerial spraying of seed production areas, and possibly seed orchards, would appear to be the most practical control method for such areas. The difficulties involved in conducting and evaluating aerial spray tests have been described, but the problems are not insurmountable.

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Cone Rust Control

By:

Fred R. Matthews[1]

This paper was a progress report of studies underway. Results will be published at a later date.

Southeastern Forest Experiment Station

1/ Lake City Research Center, Lake City, Florida

Results To Date Of A Seed Source Study In Yellow Poplar

By:

Earl R. Sluder [1/]

Mr. Sluder reported results of a portion of a study made for his graduate thesis at the School of Forestry, North Carolina State College. His thesis will be completed soon.

[1/] Southeastern Forest Experiment Station, Bent Creek Experimental Forest, Asheville, North Carolina

The Georgia Seed Certification Program

By:
John C. Barber 1/

Seed Certification has long been discussed by foresters in this country, but until recently little action has been taken. There has been interest in knowing more of the origin and genetic quality of tree seed and several articles have pointed out their importance. One of the more recent discussions of the problem is that of Baldwin (1954). You have heard many papers at this conference and those of previous years which provide facts and figures to show the importance of using seed of known genetic constitution. Data showing racial differences have been available many years (Wakeley, 1954; Engler, 1913). Recently, information on inheritance of individual characteristics has pointed up the importance of the individual trees from which we collect our seed (McWilliam & Florence, 1955; Echols, 1955; Mergen, Hoekstra & Echols, 1955). Such characteristics as specific gravity and straightness may rank with growth rate in importance.

In order to provide the seed buyer with some reasonable assurance of the genetic quality of the tree seed he uses, the State of Georgia has begun a program aimed at making Certified Seed the source of every seedling grown in nurseries and from direct seeding.

Let me distinguish now between labeling and Certification. The Federal Seed Act (August 9, 1939-53 Stat. 1275) defines Certified Seed as "seed that has been produced and labeled in accordance with the procedures and in compliance with the rules and regulations of an officially recognized seed-certifying agency". In Georgia, as in most states, the Crop Improvement Association or College of Agriculture is that agency. Georgia law already requires the labeling of all seed sold or offered for sale as to origin and germination. Certification provides for additional information about the genetic quality of the seed. It is a guarantee, to the extent of our knowledge, of inheritance and the integrity of the producer. The responsibility for choosing the correct species, variety, strain, or geographic source of seed still lies with the purchaser. It is the objective of selection, hybridization, and racial variation studies over the South to develop or isolate strains with special characteristics for use in various regions.

Georgia's standards were prepared by a committee of the Georgia Chapter of the Society of American Foresters. The first draft was made in 1956 and in February 1958 the Standards were adopted by the Georgia Crop Improvement Association. This Society committee continues and also serves as a Commodity Committee of the Association with the same rank as those for corn, small grain, cotton, etc. Forestry is represented on the Board of Directors and other committees of the Crop Improvement Association.

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The standards provide the three classes of Certified Seed and an additional classification, Approved Seed. Class I Certified Seed will be produced only from progeny-tested parents. Class II Certified Seed will be from seed orchards prior to the completion of progeny tests. This classification denotes that the parents are the result of intensive selection and are under test. Class III Certified Seed are produced from seed production areas where selection of the parents is more restricted and progeny tests are not made. All classes of Certified Seed provide for minimum isolation strips of 400 feet to reduce pollen contamination.

Approved Seed is an interim category which provides for the selection of the trees from which cones are collected but has no provision for controlling the pollen source. An area set up to produce Approved Seed could be developed into a seed production area for Class III Certified Seed by roguing the stand and providing an isolation strip. It is hoped that Approved Seed will serve as a "stepping stone" for the establishment of certified seed producing areas.

As seed of better quality become available, the lower classes will be dropped, with the ultimate goal being all seed Certified Class I. Varieties may be established for such characteristics as high gum-yield, high or low specific gravity, figured grain, etc. The varietal name or number will be shown on the seed labels in addition to the Class number.

All progeny tests must be maintained until accepted by the Crop Improvement Association. The Association has the right to examine these tests and refer the data to other authorities for evaluation.

The administrative procedures are quite simple. A person or company wishing to produce Certified Seed prepares his area according to the Standards and then makes application to the Association for inspection. He also pays his inspection fee in advance. The Association inspector, a specially trained forester, makes the inspection and approves or rejects the area. Trees which do not measure up to the standards must be cut while he is on the area, or a reinspection is required.

The initial inspection must be made at least 21 months prior to cone collection with subsequent annual inspections in years in which cones are collected. The Association, of course, has the right to inspect at any time to insure compliance with the Standards. To minimize mixing or contamination of lots of seed or cones, the plant facilities used must also be approved.

There are now 53 acres of Seed Production Areas in Georgia which have been approved for Class III Certified Seed for the 1960 crop. Most of the area is slash pine, but there is one seed production area each of loblolly and longleaf.

The success of this program, like any other cooperative venture, rests upon the integrity of the people involved. Certainly any control over the genetic quality of tree seed will be an improvement and the sooner we can supply seed which meet certain minimum standards the sooner we can achieve the higher production goals we seek.

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Specific Gravity Variation In Mississippi Pines[1]

By

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and

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Forest Service
U. S. Department of Agriculture

Specific gravity variation--in which inheritance plays a part--is an important concern in the field of forest tree improvement. Dense wood is valued for some purposes, less dense wood for others. For most products normally made from southern pine, high density is desirable. Accordingly, new data here presented on some of the factors that affect specific gravity in southern pines are of special interest to researchers concerned with the improvement of these species.

Work on the specific gravity of southern pines was started by the Forest Survey at the Southern Forest Experiment Station primarily to obtain a better measure of pulpwood quality, since kraft pulp yield is known to increase directly with wood density. The strength of pine lumber, poles, and other products is also related to specific gravity. Such Statewide studies also show promise of yielding considerable fundamental information of value in forest management and other related fields.

In the recent cooperative Forest Survey in Mississippi, some 8,000 increment cores were obtained to the heart center of each pine point-sampled on a 3- by 3-mile grid. The Forest Products Laboratory determined specific gravity, by the calibrated increment borer technique (2),[3] and also tree age at breast height. These data were correlated with other tree and stand characteristics for analysis. Preliminary results are discussed in a recent

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1/ Paper presented at Fifth Southern Forest Tree Improvement Conference, Raleigh, N. C., June 11-12, 1959.

2/ Maintained at Madison, Wis., in cooperation with the University of Wis.

3/ Underlined numbers in parantheses refer to Literature Cited at the end of the article.

Forest Products Laboratory Report (3) and elsewhere.

In a companion study of 100 trees each of the four principal southern pines, the Forest Products Laboratory and the Southern Station, in cooperation with the International Paper Company, have related core gravity to tree gravity (4). This relationship is needed to combine the effect of volume growth with that of specific gravity to present the total effect of tree weight increase with age. The geneticist, however, is often more concerned with the variation to be expected in the individual core samples he obtains.

The Mississippi Survey core gravity data were analyzed with the Southern Station IBM 704 regression program developed by Grosenbaugh (1). Following are the nine independent variables included in the regression analysis:

Tree age at breast height (A)
Reciprocal of age (1/Age)
Tree DBH, inches (D)
DBH/Age (D/A)
Tree volume in cubic feet, i.b., to 4-inch top (V)
Stand basal area, square feet per acre (BA)
Latitude, 3-mile units, North to South (Lat)
Longitude, 3-mile units, East to West (long)
Latitude X longitude (LXL)

Table 1 includes the means for each of the variables and the number of observations on which they were based for each of the four species.

The four species of southern pines are affected similarly by the nine variables (table 2). As we have long known, longleaf and slash pine are closely related. They have higher average core specific gravities than the less closely related loblolly and shortleaf pines. The difference between mean core specific gravity of the two groups, however, is somewhat exaggerated by species distribution in Mississippi. Loblolly and shortleaf grow over most of the State. Longleaf and slash occur only in south Mississippi where the warm-season rainfall is highest and more frost-free days occur. Ample soil moisture is known to favor summerwood formation, and thus affect specific gravity.

By far the most important single variable tested to predict core specific gravity was 1/Age (table 2 and figure 1). For the four species tested, this variable makes up from 63 to 81 percent of the total variation explained by the nine variables. Each of the other five tree and stand variables reflect the effect of age when used as a single variable in estimating equations. However, when nine-variable regressions were computed for each species, volume, d.b.h., and stand basal area (the latter with the exception of slash pine) did not significantly contribute to the estimating equations. Basal area probably has an effect on slash pine because, if not properly thinned, stands of this species become stagnant. Diameter is not significant when used with D/A and age, because the product of these variables equals diameter.

Because core specific gravity is so strongly correlated with age (figure 2 and table 2), the geneticist must consider the age of each tree studied. In plantation studies, where age is constant, this is not a problem. But in the selection and rating of plus trees in mixed age stands, the age factor must be taken into account when comparing an individual with its neighbors. A procedure for making such comparisons, using curves of average core gravity over age for the species and the same general geographic location, is discussed in another publication (2).

Probably an even better way to rate plus trees, especially for gross pulp yield potential, is on the basis of merchantable dry weight attained by an individual at a given age, as compared with the average for the species in the same general area. Preliminary curves of this nature are now available for Mississippi pines (fig. 3). Merchantable dry weight per tree (in pounds) is the product of net volume (in cubic feet) X tree density (in pounds per cubic foot). Tree densities are estimated from core densities with the regression equations given in figure 10 of the Wahlgren-Fassnacht report (4).

Holding constant the six variables other than latitude, longitude, and latitude times longitude, enables calculation of the effect of geographic location. It is true that geographic location includes the effects of rainfall, soil, heredity, and other factors. However, if comparison of specific gravity isograms with the warm-season rainfall chart shown in figure 4 is reasonably indicative, rainfall seems to have an effect on the specific gravity. It is most pronounced in loblolly pine (fig. 5); shortleaf (fig. 6) and longleaf (fig. 7) are less affected. If there is any effect of rainfall on slash pine, it seems to be overshadowed by what may be a hereditary trend as the species approaches the western limit of its natural range (fig. 7). Soil differences within Mississippi must also have their effect--what we do not know. We will obtain information on soil effects in the current Arkansas Forest Survey.

As shown by the isograms, core specific gravity of loblolly and shortleaf pine increases from northwest to southeast Mississippi. Therefore a superior loblolly or shortleaf tree in the northwest part of the State may have the same or only slightly higher core specific gravity than that of an average tree in the southeast.

Because age so greatly affects core specific gravity, tests for mean age differences between stands in various regions of the State were made. No significant difference was found. It seems reasonable, therefore, that isograms of core specific gravity reflect true variation.

Specific gravity also varies within the individual tree. If the exact relationship between the specific gravity of a core and the tree from which it was extracted were known, the true difference between trees might be predicted more accurately. When the variation attributable to significant variables is known, the remainder may be due to genetic factors. Some clue to the remaining unexplained variation was obtained by applying the specific gravity relationship between core and disk (found by the Wahlgren-Fassnacht study) to the variation explained by the nine variables used in the Mississippi Forest Survey regression analysis. Total inferred explained variation of the four species ranged from 69 to 73 percent. The implication is that almost one-third of the variation in tree specific gravity may be due to genetic factors.

While these estimates are only indicative, they do point out that forest geneticists have a considerable range within which to work. Further study by plant physiologists and soils scientists may narrow this range somewhat. It is certain, however, that as more variables can be studies and more data obtained for analysis, we shall all be further along toward tailoring trees to profitable products.

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Table 1. Means of variables, specific gravity study, Mississippi Survey, 1957 1/

Variable		Longleaf	Slash	Loblolly	Shortleaf
Core gravity Y		0.5525	0.5595	0.4877	0.5125
Long.	X_1	21.2004	16.5405	30.1778	24.5205
Lat.	X_2	90.8386	100.0991	69.2128	49.1391
LXL	X_3	1,923.5344	1,667.6901	2,254.4514	1,366.4969
BA	X_4	57.4101	82.1622	87.7081	80.8152
Vol.	X_5	10.5320	11.7953	15.5727	8.5726
Dbh	X_6	9.6356	9.1586	9.9452	8.3524
Age	X_7	31.1202	33.1892	26.0409	32.3829
$\frac{1}{A}$	X_8	0.0406	0.0396	0.0532	0.0420
$\frac{D}{A}$	X_9	0.3525	0.3137	0.4352	0.3014

1/ Number of observations: longleaf 973, slash 555, loblolly 3,713, and shortleaf 2,711.

Table 2. Simple regressions of nine individual variables with core specific gravity for four species, with coefficient of correlation and standard error of estimate, Mississippi Survey, 1957.

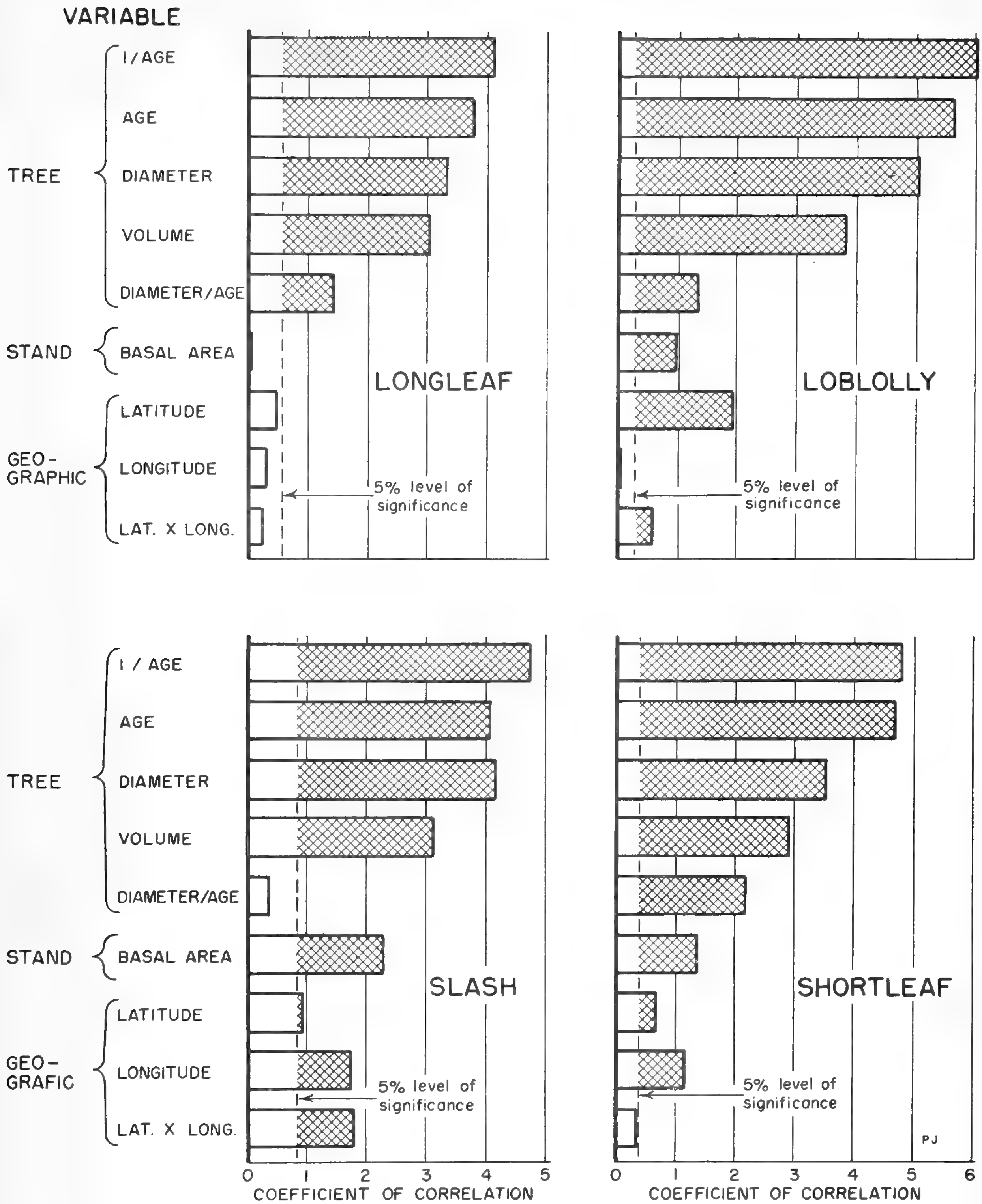
Species	Variable	Simple regression 1/ Constant	Simple regression 1/ Coefficient	Coefficient of Correlation	Standard error of estimate
Longleaf	Reciprocal of age	0.6019	-1.2162	-0.4124	0.0520
	Age	.5148	+0.001211	.3784	.0529
	Diameter	.4991	+ .005537	.3333	.0539
	Volume	.5344	+ .0017180	.3023	.0545
	Diameter/Age	.5743	- .06185	- .1449	.0565
	Basal area	.5522	+ .000005061	.00316	.0571
	Latitude	.5250	+ .0003025	.0500	.0571
	Longitude	.5566	- .0001931	- .0316	.0571
	Lat. X Long.	.5557	-.000001662	- .0245	.0571

(continued)

Table 2: (continued)

Species	Variable	Simple regression 1/ Constant	Coefficient	Coefficient of Correlation	Standard error of estimate
Loblolly	Reciprocal of age	.5561	-1.2860	- .6013	.0512
	Age	.4265	+ .002349	.5634	.0529
	Diameter	.4257	+ .006226	.5033	.0553
	Volume	.4723	+ .0009886	.3824	.0592
	Diameter/Age	.5059	- .04189	- .1338	.0635
	Basal area	.4747	+ .0001473	.0964	.0637
	Latitude	.4467	+ .0005922	.1924	.0629
	Longitude	.4871	+ .00001899	.00547	.0641
	Lat. X Long.	.4821	+ .000002457	.0600	.0639
Slash	Reciprocal of age	.6062	-1.1802	- .4754	.0493
	Age	.5164	+ .001297	.4098	.0511
	Diameter	.5054	+ .005902	.4176	.0509
	Volume	.5449	+ .001235	.3118	.0532
	Diameter/Age	.5642	- .01513	- .0387	.0559
	Basal area	.5368	+ .0002757	.2298	.0545
	Latitude	.6284	- .0006886	- .0943	.0557
	Longitude	.5834	- .001446	- .1742	.0551
	Lat. X Long.	.5829	- .00001408	- .1803	.0551
Shortleaf	Reciprocal of age	0.5636	-1.2148	-0.4799	0.0562
	Age	.4587	+0.001661	.4601	.0569
	Diameter	.4615	+ .006113	.3544	.0600
	Volume	.4999	+ .001474	.2914	.0613
	Diameter/Age	.5412	- .09507	- .2170	.0626
	Basal area	.4948	+ .0002189	.1375	.0635
	Latitude	.5047	+ .0001599	.0663	.0640
	Longitude	.5261	- .0005543	- .1166	.0637
	Lat. X Long.	.5150	- .000001845	- .0374	.0641

1/ Core specific gravity = a + bX.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LAT. X LONG.
LONGLEAF
LOBLOLLY
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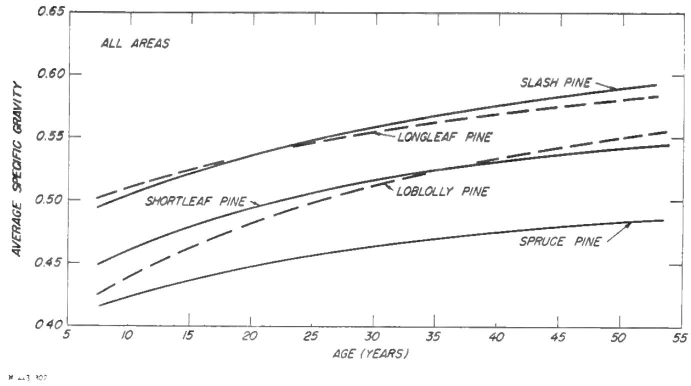

Figure 2. Relationship between age at breast height and core specific gravity for five species of pine in Mississippi.

(M113 302)

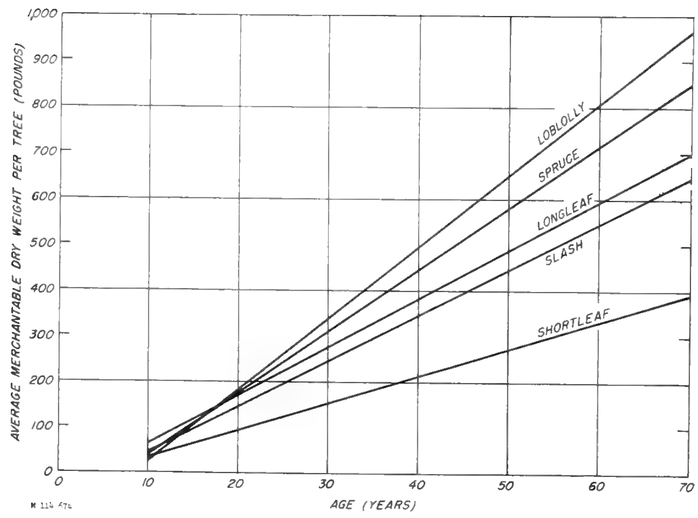

Figure 3. Relationship between age at breast height and average merchantable dry weight per tree (in pounds) for five species of pine in Mississippi.

(M 114 674)

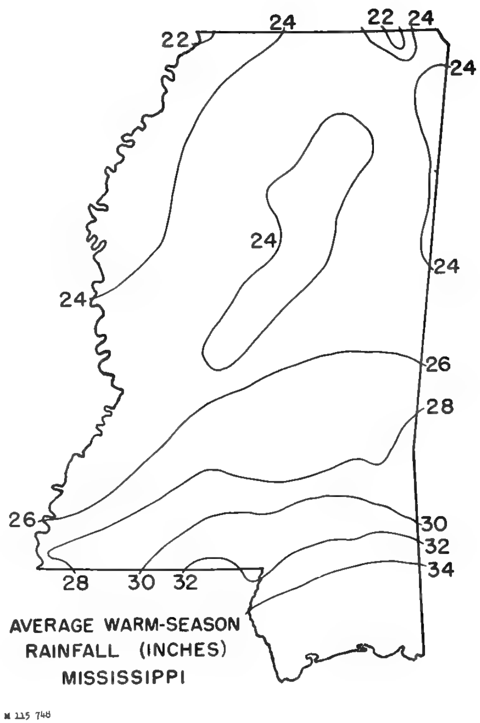

Figure 4. Average warm-season rainfall (inches) in Mississippi.

(M 115 748)

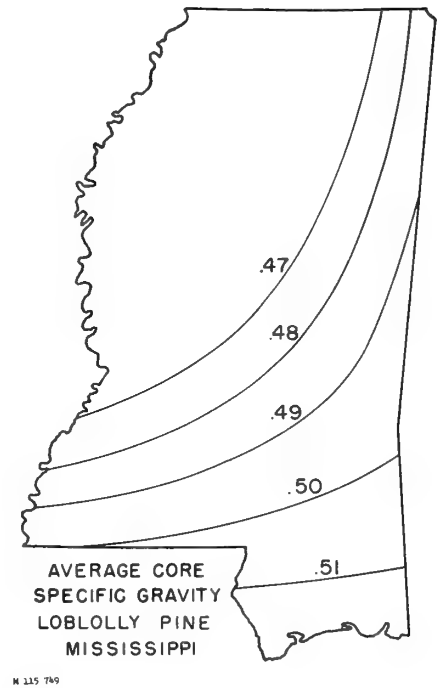

Figure 5. Isograms of average core specific gravity for loblolly pine in Mississippi.

(M 115 749)

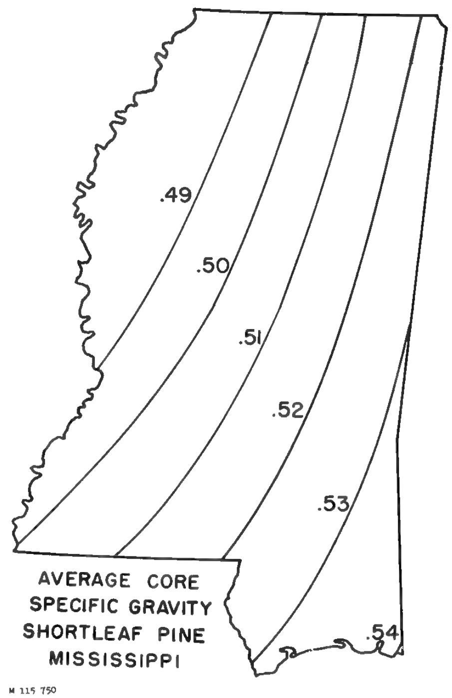

Figure 6. Isograms of average core specific gravity for shortleaf pine in Mississippi.

(M 115 750)

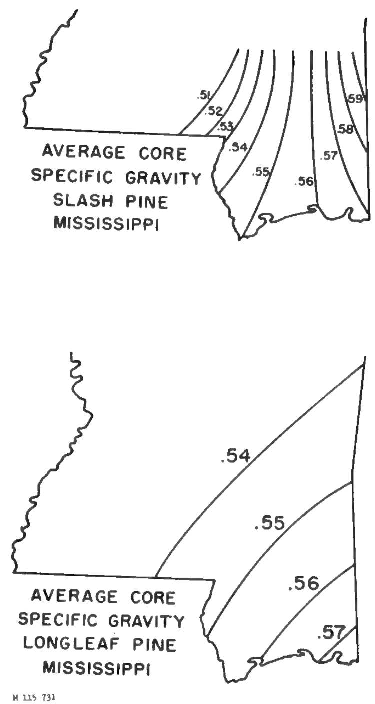

Figure 7. Isograms of average core specific gravity for slash pine (upper) and longleaf (lower) in Mississippi.

(M 115 731)

Variation in Inherent Wood Characteristics in Slash Pine

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The paper you have just heard on specific gravity variations for several species over an entire state introduces rather nicely my subject, entitled "Variation in Inherent Wood Characteristics in Slash Pine." Specific gravity is the major inherent characteristic I am involved with here, along with moisture content and proportion of summerwood as they are related to specific gravity. Instead of covering a major geographic area such as the state of Mississippi, however, this study deals with variations between and within just a few carefully-selected trees. Let me outline how we got into this work and what we learned from it.

Several years ago, in 1955, we initiated a sizeable study concerning determinations of weight-volume relationships in slash pine and how these could be used operationally in our land management and wood procurement work. Our increasing emphasis upon weight measure of pulpwood prompted this study. We felt that we should know more about the factors that affect wood weight in order to use this method of measurement intelligently and accurately. For example, we hoped to obtain information aimed at eventually cruising timber in terms of weight rather than volume.

The study grew in scope as it progressed until finally we had data on many parts of the weight-volume picture. As a result, it was possible to go deeper into the matter than had previously been planned. We ended up with information on specific gravity, moisture content, and percent summerwood, plus additional information on density, bark content, etc. for a phenotypically homogeneous sample of slash pine trees over a restricted area. It is from these data that I intend to draw the text for my presentation here today.

First of all, I would like to explain briefly the study areas and procedures we used for obtaining these data since they have a bearing upon the application of the results. The areas we used were four different sites on our Experimental Forest about 20 miles northwest of Savannah. These can be described as:

1. Upland ridge or Hill site characterized by a deep, sandy soil and low water table.

2. Run or Hammock site, characterized by a layer of undecomposed hardwood litter on top of incorporated humus and fine sand, with abundant or over-abundant moisture but generally good drainage.

3. Flat site, characterized by its low, level topography, palmetto-gallberry understory, and seasonal flooding.

4. Pond site, characterized by its bowl-like topography, with standing water present for long periods of the year.

Within each of these sites, 24 slash pine trees were selected--8 in the 7-inch d.b.h. class, 8 in the 9-inch d.b.h. class, and 8 in the 11-inch d.b.h. class. These d.b.h. classes were chosen because we felt that they covered the normal range of pulpwood sizes. In selecting the trees, other variables such as age, height, live crown ratio, and amount of adjacent competition were required to fall within fairly narrow limits in order to minimize outside effects and give a homogeneous sample for each site and size class.

A cutting schedule was set up whereby two trees in each d.b.h. class on each site were selected to be cut, measured, weighed, and sampled at a specified time during the year. Four such equally spaced cutting dates or seasons--Spring, Summer, Fall, and Winter--were used. Thus, we had three major variables consisting of site, season of cutting, and d.b.h. class.

As each tree was cut, it was marked into five foot bolts up to a minimum top diameter inside bark of four inches. Each bolt, starting with the butt bolt, was cut from the stem, weighed rough to the nearest one-half pound, measured for rough diameter at both ends and in the middle, weighed peeled, and measured peeled for diameters. A one- to two-inch sectional disk was then cut out of each peeled bolt at the midpoint. Two diametrically opposite wedges of about 30 degrees were cut from each disk, and these wedges were immediately labelled and weighed to the nearest 0.1 gram. This essentially completed the field work.

The volume--by the water-displacement method--and moisture content of each wedge was determined soon after it was cut. Percent summerwood for each bolt was calculated for the two wedge samples using a technique that allows an accurate and fairly rapid determination of the proportion of summerwood in the round tree. This technique, incidentally, was described by myself and Barry F. Malac in the November 1956 Journal of Forestry. Our use of wedges for determinations of specific gravity and moisture content and this technique for summewood percent determinations gave us measurements of these three characteristics on a common basis representing round timber such as a tree or a stick of pulpwood.

As we determined it, specific gravity represents the dry weight of wood per unit of green volume using the metric system of measure; moisture content percent represents the amount of moisture in terms of weight in comparison to the oven-dry weight of the sample; and percent summerwood represents the amount of summerwood area as compared to the amount of total cross-sectional area in the sample. Wood characteristics presented on a tree basis are properly weighted so that the figures represent weighted combinations of the bolts making up the tree. Needless to say, we found substantial differences in these characteristics both between and within trees.

Now with the experimental procedure out of the way, let's get down to the meat of the study--the results. First of all, I want to cover the effects of the three main variables--site, season of cutting, and tree size--upon tree specific gravity and moisture content. These were tested employing the analysis-of-variance approach and using a 5% level of significance for accepting or rejecting the hypothesis that no effect exists. D.b.h. was eliminated as an influencing factor on specific gravity and moisture content early in the game; soon after came the effect of Season of Cutting, although this variable tested very close to the 5% level. Actually, it was close enough so that its effect upon moisture content and specific gravity became a matter of discussion for some time. It was not too difficult to accept the possibility of Season affecting moisture content, but any effect of Season upon specific gravity was rather difficult to visualize. A survey of available literature plus various inquiries into the matter failed to shed any further light upon the question. Consequently, we presently hold to the feeling that Season of Cutting has no real effect upon either moisture content or specific gravity. I may be opening up an old controversy by even mentioning this subject here today, but there it is for what it is worth.

Site alone was not a significant factor in specific gravity or moisture content, but a sizeable interaction existed between Site and D.b.h. A careful examination of the data indicated that Site consistently influenced specific gravity and moisture content in the larger two d.b.h. classes but the consistency and degree broke down in the lower d.b.h. class. At first we thought we had something that we could put our finger on, but a closer look at the basic data showed that there was a sizeable difference in average age between Sites. An array of the average ages indicated that Site and Age could easily be used interchangeably as variables. Various publications list Age as having an influence upon specific gravity, so we are not sure if Site is the real factor in the interaction. All I will venture to say is that some element, probably age, plus d.b.h. measurably affects the specific gravity of living trees.

After dispensing with the three main variables, various regressions and mean values were determined for a number of different wood characteristics. Curvilinear regressions were tested and retained where significant. Figure 1 presents the curvilinear correlation between specific gravity as the dependent variable and moisture content as the independent variable. I will not go into the equation itself but merely want to point out the high multiple correlation index of about 0.92. This regression and most of the ones to follow were calculated using 855 individual measurements from that many bolts. By the way, the two sets of measurements obtained from the two wedges cut from each bolt were averaged resulting in one set of figures for each bolt. Although the strong relationship between specific gravity and moisture content is nothing new, we think the method of obtaining the data and the way of presenting it resulted in an improved measure of that relationship as evidenced by the very high correlation index.

Figure 2 summarizes the relationship found between specific gravity and percent summerwood; in this case, however, a test for curvilinearity indicated that a straight line was adequate and this was used. Although the correlation coefficient is not quite as high as between specific gravity and moisture content, still the highly significant coefficient of about 0.78 indicates a strong relationship between the two variables.

Figure 3 presents the relationship of moisture content to percent summerwood and in this case a curvilinear regression again proved worthwhile. The correlation index is about the same as that for specific gravity and percent summerwood. This was expected due to the strong tie-in between specific gravity and moisture content.

A slightly different approach to the problem is presented in Figure 4. In this instance we were trying to find if it would be possible to determine the weighted average specific gravity of the merchantable portion of a tree by just measuring the specific gravity at the midpoint of the first bolt. As you can see by the high correlation coefficient of about 0.86, this seems to be a real possibility. This relationship could possibly be the most useful one of those discussed thus far.

The most important factor yet to be considered is the matter of bolt number or position in the tree. Bolts were numbered consecutively starting with the butt bolt as Bolt Number 1. The literature is sprinkled with information on the variation of moisture content and specific gravity relative to position in the tree, and Figure 5 emphasizes the degree and consistency of this effect as we found it for moisture content. No effort has been made to smooth out the results; each point represents an average figure for that position in the tree. I might point out to you that beyond Bolt #8 the number of samples starts falling off rapidly. Hence the more erratic path of the points. Figure 6 shows the effect of bolt number upon specific gravity. Note that in this case the dependent variable decreased with increasing height in the tree, whereas moisture content increased with increasing height in the tree.

Figures 7 and 8 summarize some of the results concerning other relatively minor aspects. First of all, in Figure 7, it is interesting to note the lack of change in green wood density with increasing height in the tree. As we used it, wood density represents green weight in pounds per green cubic foot. The theory is that the reduction in specific gravity, which deals with dry weight, is offset by an increase in absolute moisture content resulting in a stable green density up the tree. This points up the fact that moisture content percent as such is often concealing. Percent moisture can actually vary

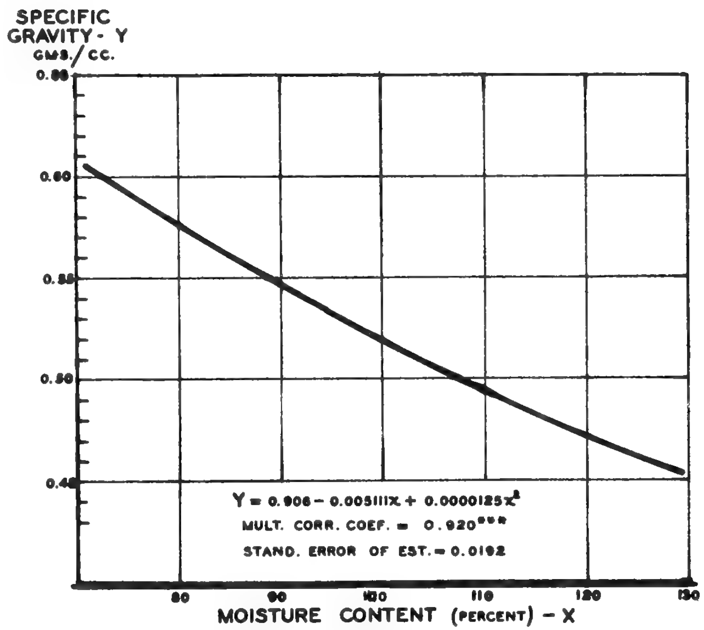

Figure 1. Relationship between specific gravity and percent moisture content for slash pine (855 samples from 96 trees).

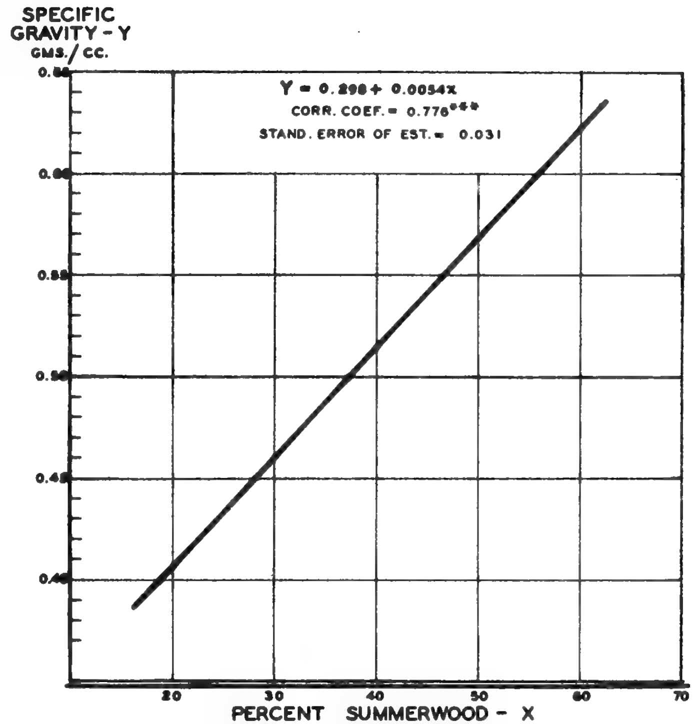

Figure 2. Relationship between specific gravity and percent summerwood for slash pine (855 samples from 96 trees).

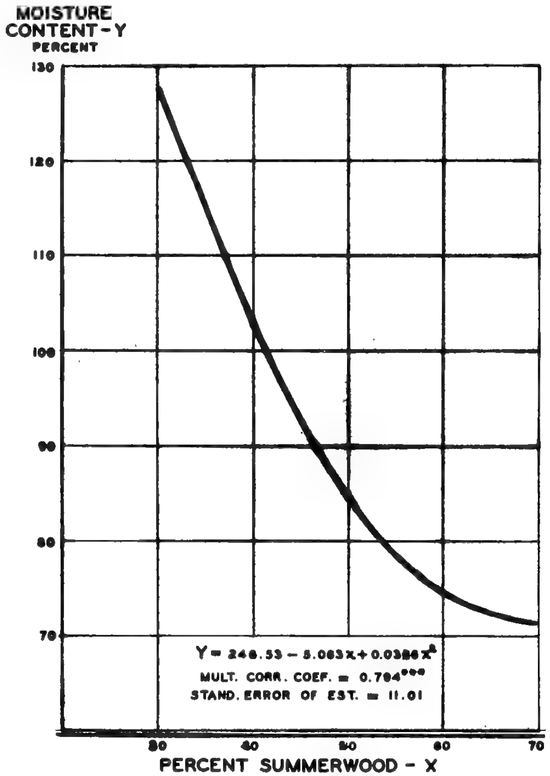

Figure 3. Relationship between percent moisture content and percent summerwood for slash pine (855 samples from 96 trees).

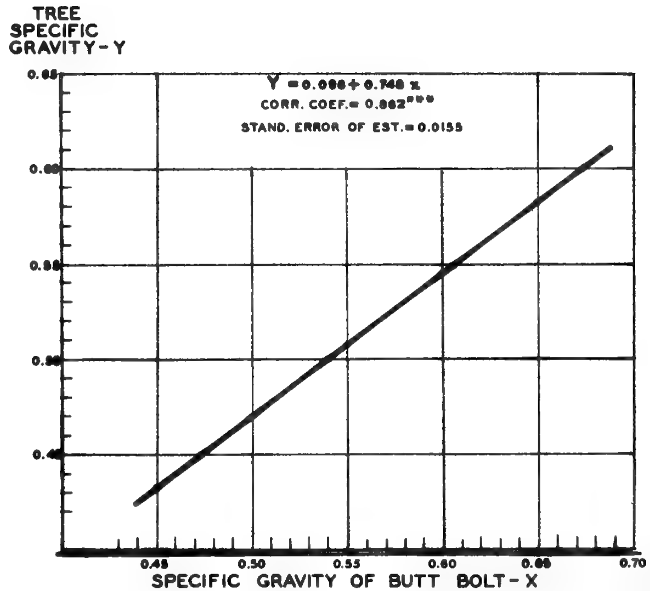

Figure 4. Relationship between specific gravity of entire merchantable stem and specific gravity of butt bolt for slash pine (96 paired measurements from 96 trees).

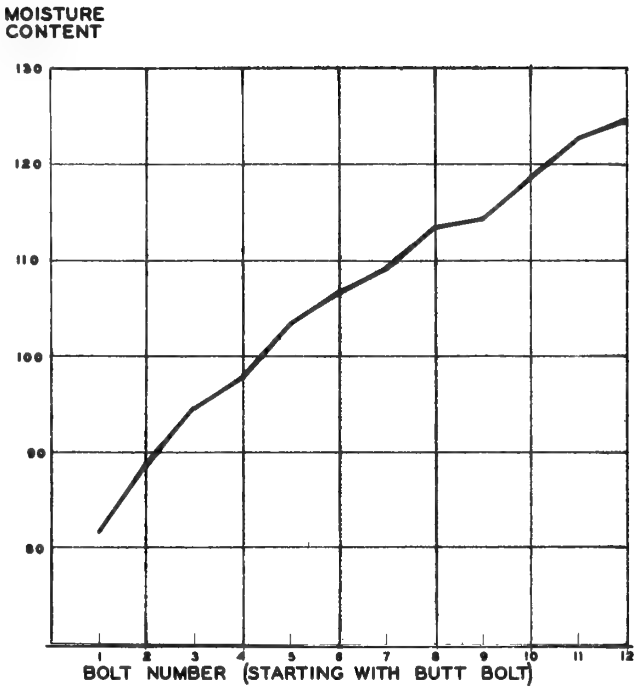

Figure 5. Relationship between percent moisture content and position in the tree for slash pine (855 samples from 96 trees).

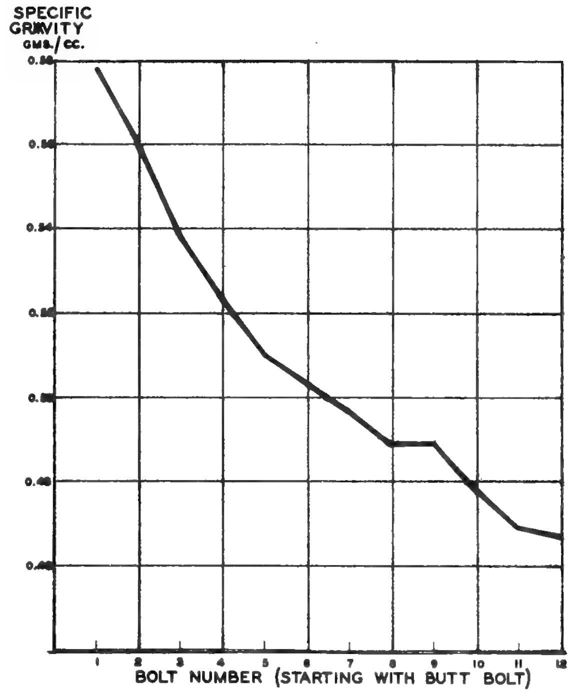

Figure 6. Relationship between specific gravity and position in the tree for slash pine (855 samples from 96 trees).

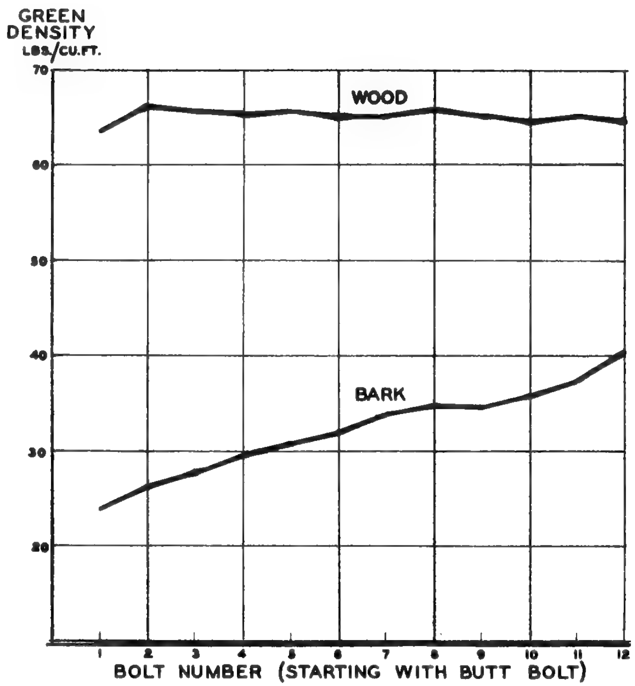

Figure 7. Relationship between green wood and green bark density and position in the tree for slash pine (855 samples from 96 trees).

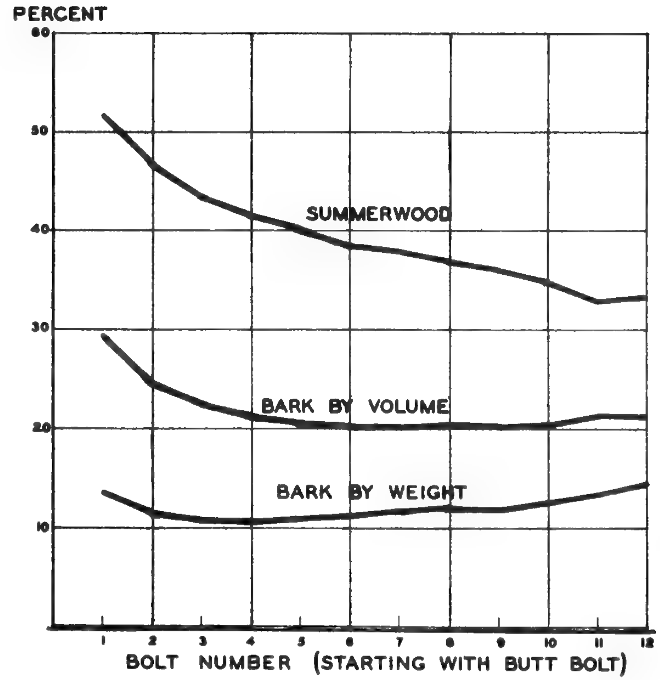

Figure 8. Relationship of percent summerwood, bark by volume, and bark by weight to position in the tree for slash pine (855 samples from 96 trees).

without any difference in the absolute amount of water per given volume. Green density does not give a clear picture of the amount of wood substance present, and the latter is often the most important factor. Note also in Figure 7 that bark density appears to increase with increasing height in the tree.

The bark information presented in Figure 8 is interesting and may be useful in the future. It should be emphasized, however, that bark volume represents gross volume including air space in fissures. Percent bark tends to decrease rapidly at first, levels out, and then gradually curves upward. This must reflect tree form to some degree plus other factors. Percent summerwood, shown also in Figure 8, falls off with increasing height in the tree the same as specific gravity.

Table 1 gives you a brief summary covering nearly all of our results. All the many values determined are broken down in different ways to give you an idea of the magnitude and direction of differences. I included only the results for three different positions in the tree since I wanted to keep the table compact. Overall average figures presented at the bottom of the large table may be more meaningful to you than any of the other things I have presented today. From the literature I have seen, most of these values agree reasonably well with other results; there is quite a bit of variation in specific gravity results over the range of slash pine, however. Our main point is that our results represent properly weighted averages for the entire merchantable stem of trees and are representative of round timbers.

Height and age values are presented by Sites, in Table 2, to illustrate the possibility of several factors causing the variation in specific gravity. This variation was at first attributed to an interaction of Site and D. b. h.

In closing, I would like to say that we feel we have profited by this work in many ways. First and most important of all, we have gained a more intimate knowledge of the quantitative and qualitative aspects of individual inherent tree characteristics. As far as tree improvement work is concerned, we now have a better understanding of what we want, what we have, and how we can deal with it.

Table 1. Summary of wood and bark results by four major variables for slash pine.

Item	Bark % by wt.	Bark % by vol.	Green bark density lbs/cu. ft.	Green wood density lbs/cu. ft.	Specific gravity gms/cc.	Moist. cont. %	Summer-wood %
Bolt #1	13.6	29.5	23.9	63.4	.578	81.6	51.7
Bolt #4	10.8	21.1	29.5	65.4	.523	97.8	41.6
Bolt #8	12.0	20.5	34.8	65.9	.489	113.4	37.0
Hill site	11.9	25.2	25.9	64.9	.507	104.3	41.2
Hammock site	11.7	22.5	29.8	64.9	.538	94.6	44.9
Pond site	11.7	22.7	29.5	65.3	.523	101.7	41.8
Flat site	11.6	22.8	29.0	65.4	.544	92.5	43.3
7" d.b.h.	12.9	25.3	28.4	64.7	.527	98.1	41.9
9" d.b.h.	11.9	23.5	28.7	65.0	.534	96.3	43.3
11" d.b.h.	11.2	22.4	28.7	65.4	.527	98.9	42.9
Spring	12.1	24.2	28.3	65.7	.526	98.9	43.2
Summer	11.8	22.1	29.9	63.2	.527	97.4	43.0
Fall	11.9	23.4	29.2	65.7	.540	93.5	42.6
Winter	11.0	23.2	27.0	66.1	.525	102.1	42.7
Overall average*	11.7	23.2	28.6	65.1	.529	97.9	42.9

* Combined results for all bolts, all sites, all d.b.h. classes, and all seasons.

Table 2. Average age, total height, and specific gravity figures by sites.

Item	Average height	Average age at breast ht.	Specific gravity
Hill Site	53'	22 yrs.	.507
Hammock Site	71'	39 yrs.	.538
Pond Site	65'	30 yrs.	.523
Flat Site	63'	36 yrs.	.544

(Note similarity in effect of site and age upon specific gravity.)

Results of Pulping Tests of Slash Pine of Varying Density

By:

Louis A. Hiett[1/] and Walter L. Beers, Jr.[2/]

This paper was similar to one given at the meeting of the Biology Committee of TAPPI in February, 1959. This paper will appear in TAPPI magazine sometime late in 1959.

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Tree Improvement Activities in the Pacific Northwest

By:

John W. Duffield [1]

I am taking the liberty of attempting to combine an account of tree improvement activities in the Pacific Northwest with a summary of the present conference. This is possible, I believe for two reasons. First because the basic tree improvement problems are similar in all regions, and second because the program of this conference has covered the tree improvement field so well.

I. Historical Background.

Tree improvement work in the Pacific Northwest dates from the Douglas fir seed source study set up at the Wind River Experimental Forest in southern Washington in 1912 by Dr. J. V. Hoffman, who is here today, and some other notable collaborators. Although this pioneer American seed source study did not have the wide geographic basis, nor the systematic hypothetical structure of the southwide study reported in the papers by Wakeley and Henry, it did sample Douglas fir in the Pacific Northwest rather extensively. Seed was collected in 13 localities in Washington and Oregon, from marked and recorded trees, and individual lots were kept distinct in propagation. Five outplantings were made in Washington and Oregon, two of them covering an altitudinal range from 2800 to 4600 feet on the slopes of Mt. Hood. Four of the original five plantations survive today, and the data from their most recent remeasurement are being analyzed at present by Roy Silen of the U.S. Forest Service. Perhaps the most interesting outcome of this study is that it indicates that certain collections - the Darrington and Granite Falls - were uniformly good in all outplantings, and in some cases were better than local collections. This study has given great impetus to tree improvement work in our region.

In 1927 a second study, this one involving ponderosa pine, was established by T. T. Munger. This has been especially interesting because it included localities which were represented also in similar studies established at about the same time in north Idaho and New Zealand. The Pacific Northwest study was based on collection localities, outplanted in six localities in Washington and Oregon. Four of these plantations survive, and the most recent remeasurements have just been jointly analyzed by Roy Silen and Tony Squillace. In this study also, certain collection localities have proven outstanding, for example, the El Dorado County, California source, which has also been a leader in the New Zealand tests.

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II. Current Activities.

The Forest Genetics Research Foundation has recently published a summary of tree improvement activities in the western United States. Therefore I shall not attempt a systematic survey, but rather comment on some of our problems and activities in comparison with those which have been discussed at this Conference.

First, I believe I should give a bit of the seed supply, planting, and direct seeding picture in the Northwest as background to our tree improvement activities. Douglas fir dominates our artificial regeneration programs; perhaps 95% of artificial regeneration is with Douglas fir in western Washington and Oregon. Very few cones are collected from the tops on logging operations; small cones and rough terrain make this uneconomic. The Douglas squirrel collects and hoards cones, and his caches furnish a large proportion of the cones harvested. In addition, because fairly small trees produce good crops on occasion, a large crop is collected by climbing. This does not, usually, require the skill and involve the hazard connected with climbing southern pines, so that we do not need to hire the tree experts mentioned by Don Cole in his paper. Often a light extension ladder can be leaned into the crown of cone-bearing trees; in other cases, sound limbs are within easy reach from the ground. Relatively few cones are picked by the ultimate user; the bulk of our cones are bought from local collectors. This often leaves a substantial margin of uncertainty as to exact origin, especially in years of localized and spotty cone production.

Logging in the Douglas fir region is moving up into the mountains; much of the land cutover at lower elevations has been regenerated for fifty years or longer and, in some cases is starting to produce its second harvest. Thus the bulk of our current regeneration job is at higher elevations. Inasmuch as we have little knowledge of elevational races of Douglas fir, we are being conservative and attempting to use seed no more than 500 feet above or below its source. We find that seed production is less frequent at the higher elevations - above 2000 feet - than at lower elevations. Moreover, there is little young growth at high elevations from which seed can be readily collected. Therefore, high elevation seed is usually a rather scarce commodity.

Cone and seed insects further complicate our seed supply problems. 1958 started out with the promise of fair to good seed crops in many parts of the region. We ended the season with an unusually poor crop, largely as a result of insect attacks. Douglas fir has an impressive list of cone and seed destroying insects, the four principal ones being *Dioryctria* and *Barbara*, cone feeding lepidoptera, *Megastigmus*, a seed chalcid, and finally a gall midge, family *Itonididae*, which has only recently been recognized as a major threat. We have not yet developed sufficient life history information to go very far into aerial spray programs as described by Merkel in his paper.

However, we have learned enough to know that sprays to control the gall midge may have to be applied at about the time of pollination, and are therefore confronted with the pollen and conelet toxicity problems discussed by Matthews.

In years when seed supply is adequate, we use a much larger proportion of our seed supply for direct sowing than you do in the southeast. This is because of our rough terrain on the one hand and the fact that neither our nursery capacity or planting labor supply can keep pace with demands. Moreover, development of seed protectants and brush control chemicals have made direct sowing at least a satisfactory interim measure of regeneration.

Nursery capacity in our region totals at present approximately 100 million a year, but is being increased about 10 percent per year. Most of this stock is 2+0 Douglas fir. However, there are two noticeable trends in stock production. One is toward 2+1 transplants; the other toward an increasing percentage of true firs, especially noble fir and grand fir. These trends are largely the result of the very heavy damage inflicted on young Douglas fir seedlings by rabbits, field mice, mountain beaver, and deer. Most of our nurseries are quite complex in terms of number of species grown and in terms of numbers of seed lots within a given species. We grow appreciable amounts of noble fir, grand fir, western hemlock, sitka spruce, and Port Orford Cedar in addition to Douglas fir.

Seed certification in our region is in the active discussion stage. The Georgia Seed Certification Program, as outlined by John Barber, has been the focus of much interest in our region. A sub-committee on forest tree seed certification ultimately responsible to the Western Forestry and Conservation Association has started work. Its approach, so far, has been to work for an international program including British Columbia, Washington, Oregon and California, emphasizing the problems of "wild" seed certification for origin, and stressing industry self-regulation. As "cultured" seed becomes more important in our region, something resembling the Georgia program may be adopted.

Specific tree improvement activities in our region resemble those in the Southeast in general, but are as yet much more limited in extent. We are making a start with seed production areas, although the scarcity of young growth stands at the higher elevations for which we want seed limits this program. We are choosing stands in the 10 to 25 year age class, as these give us more scope for selection and tree-shaping than older stands. Moreover, we find that Douglas fir in this age class can be brought into fair cone production by heavy applications of nitrogen and phosphate fertilizers. Our first fertilizer study on a seed production area was established in 1955 cooperatively by the Industrial Forestry Association and the Weyerhaeuser Timber Co. Five-fold increases in cone production over controls encouraged us to go ahead with more extensive studies. At present, about 12 seed production areas up to 10 acres in size are being developed throughout the region.

We are thinking in terms of 40 to 80 trees per acre in these stands. On the basis of results so far, and under optimum conditions, we are expecting about 2 bushels of cones per 20-year old tree. This converts to about 60,000 seed per tree per year.

We are learning, from the individual tree performance on our first seed production area, that there are wide variations in flower and cone production from tree to tree, and that these remain relatively constant year after year. This will have an important bearing not only on the development of these areas, but ultimately on the selection of clones for our seed orchards. We are learning also that fertilizer applications tend to iron out the year-to-year fluctuations in flower crops.

Seed orchard programs in the Northwest resemble yours in general. However, it is probably fair to say that our grading of selected trees is, so far, less rigorous. To date we have had a relatively small number of people actively hunting for select trees. In several instances, a quota of 15 or 25 has been set for a given seed orchard, and this number of good-looking trees has been selected in a relatively short period in the appropriate area. We adhere to the usual criteria of form, branch habit, and growth attributes. However, the major emphasis has been placed on selecting generally good-looking trees from high elevation stands for development of seed orchards at lower elevations. Thus, our seed orchards are, to date, primarily intended to produce seed from good phenotypes for high elevation sites.

The industrial basis for tree improvement in our two regions differs somewhat. Much of our pulp is produced from by-product chips. The primary products are still lumber and plywood, and we believe that this will continue to be the case. This means that although we are very much interested in wood quality objectives as they affect the pulping uses of wood, we cannot be influenced by them to the exclusion of wood properties affecting quality of lumber and plywood. Indeed, it would seem that our quality objectives should be so selected as to ease as much as possible the shift from old growth to young growth timber supplies on the part of the lumber and plywood industries. We are, accordingly, in British Columbia, Washington, and Oregon, studying variations in specific gravity, which influences lumber and plywood utilization as well as pulping. We may not be quite as interested in cellulose content as you are in this region, but, at any rate, we are going slow in committing ourselves to very specific wood quality standards at present.

Approximately 15 seed orchards have been established so far in British Columbia, Washington, and Oregon. All but one are composed of Douglas fir; the exception is a small noble fir seed orchard. The largest of the orchards covers 20 acres, and was established in 1958 by the Olympic National Forest. Most of the seed orchards are 5 acres or less in extent. Several establishment procedures have been used. Natural regeneration stands have been top-worked as in the Olympic National Forest, planted seedlings have been field grafted, and bare-rooted seedlings have been bench grafted, lined out, and outplanted after a year in the nursery. Field grafting without covering is generally successful with Douglas fir, and can be done from April to July.

Individual clones of Douglas fir show wide variations in graftability, and we are accumulating evidence of stock-scion incompatibilities. Developing flowers on Douglas fir scions strongly inhibit growth of vegetative buds, and are usually removed from new grafts. Many types of grafts work on Douglas fir, the choice of type often being a matter of personal preference.

Isolation of Douglas fir seed orchards is not likely to be readily accomplished; the Douglas fir region is full of Douglas fir, and west coast Douglas fir is not hardy east of the Cascades. Fortunately, Douglas fir pollen grains are heavier than pine. It seems likely that artificial pollination may be practiced to some extent in Douglas fir seed orchards, as it has been for sometime in the apple orchards of eastern Washington.

In addition to these activities in applied tree improvement, there are basic and exploratory studies being conducted in the major forestry schools of our region and by several public and industrial organizations. Lines of work which have not yet reached the seed orchard stage include studies of blister rust resistance in white pines, of weevil resistance in Sitka spruce and other spruce species and hybrids. Individual variation in wood properties are being studied in a number of institutions.

In summary, I believe a conference such as yours, held in the Northwest, would cover much the same subjects, but, at present, would have fewer active workers to call on. We like to think that our tree improvement activities may be like our Douglas fir - slow to start compared to your southern pines, but with lots of staying power.

Publications and Reports Prepared in Cooperation With the Committee on Southern Forest Tree Improvement:

Report of the first southern conference on forest tree improvement. Atlanta, Georgia, January 9-10, 1951. U. S. Forest Serv., Atlanta, Ga. (Mimeo.) *

Proposal for a cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1951. (Mimeo.) *

Standardized working plan for local tests of seed source. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1951. (Mimeo.)

Hereditary variation as the basis for selecting superior forest trees. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Expt. Sta. Paper 15. 1952.

Directory of forest genetic activities in the South. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman. Southeastern Forest Expt. Sta. Paper 17, 1952.

Working plan for cooperative study of geographic sources of southern pine seed. Subcommittee on Geographic Sources of Seed, Philip C. Wakeley, Chairman. Southern Forest Expt. Sta. 1952.

Suggested projects in genetic improvement of southern forest trees. Committee on Southern Forest Tree Improvement. Southeastern Forest Expt. Sta. Paper 20, 1952.

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Progress in study of pine races. Philip C. Wakeley. Southern Lumberman 187 (2345): 137-140. December 15, 1953.

The role of genetics in southern forest management. Special subcommittee of the Committee on Southern Forest Tree Improvement, Bruce Zobel, Chairman. Pt. 1, Forest Farmer 14(1): 4-6, 14-15. Pt. 2, Forest Farmer 14 (2): 8, 14-19. Pt. 3, Forest Farmer 14(3): 8-9, 14-15. (Reprint, 11 pp. 1954.

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Better seed for better southern forests. Subcommittee on Genetic Control of Seed, T.E. Maki, Chairman. N.C. State College School of Forestry Tech. Rpt. 9. 1955.

Forest tree improvement for the South. Committee on Southern Forest Tree Improvement, T.E. Bercaw, Chairman. 1955.

Supplement No. 1 to the original working plan of September 12, 1952, for the southwide pine seed source study. Subcommittee on Geographic Source of Seed, Philip C. Wakeley, Chairman.

Time of flowering and seed ripening in southern pines. Subcommittee on Tree Selection and Breeding, Keith W. Dorman, Chairman, and John C. Barber, Southeastern Forest Expt. Sta. Paper 72. 1956.

Proceedings of the Fourth Southern Conference on Forest Tree Improvement, University of Georgia, 1957.

Pest occurances in 35 of the southwide pine seed source study plantations during the first three years. Southern Forest Expt. Sta. 1957.

* These reports are out of print.