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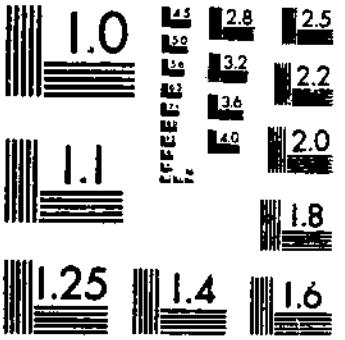

MICROCOPY RESOLUTION TEST CHART
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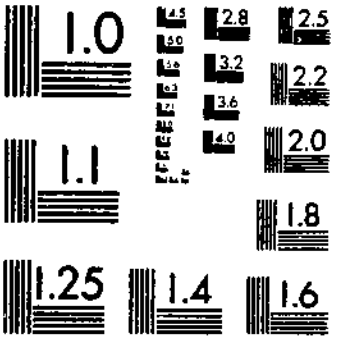

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ARTIFICIAL REFORESTATION IN THE SOUTHERN PINE REGION

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INTRODUCTION

Much land in the southern pine region that is better suited to forest production than to any other use has been rendered incapable of prompt natural restocking with timber species, principally through undesirable logging methods and through fire. If this land is to produce merchantable forest products within the next 40 to 100 years, it must be reforested artificially. Artificial reforestation involves collecting tree seed, growing tree seedlings in nurseries, and planting the seedlings. The purpose of this bulletin is to set forth principles governing this work and the technic involved, on the basis of 10 years' study and experimentation by the Southern Forest Experiment Station and of the station's acquaintance with State and private planting throughout the southern pine region.

The ranges of the principal southern pine species are shown in figure 1.

Accurate figures on the extent of nonrestocking land in the region are unavailable, pending completion of the forest survey now being conducted by the United States Forest Service. Even when completed, the survey will not have shown exactly what portions of the land now nonproductive are incapable of restocking or what portions can be planted with promise of good financial returns. (Much light will be thrown on the latter subject by the productivity attained under good forest management by the large areas on which natural reproduction is already in progress.) There is good reason for assuming, however, that the nonrestocking southern pine land on which

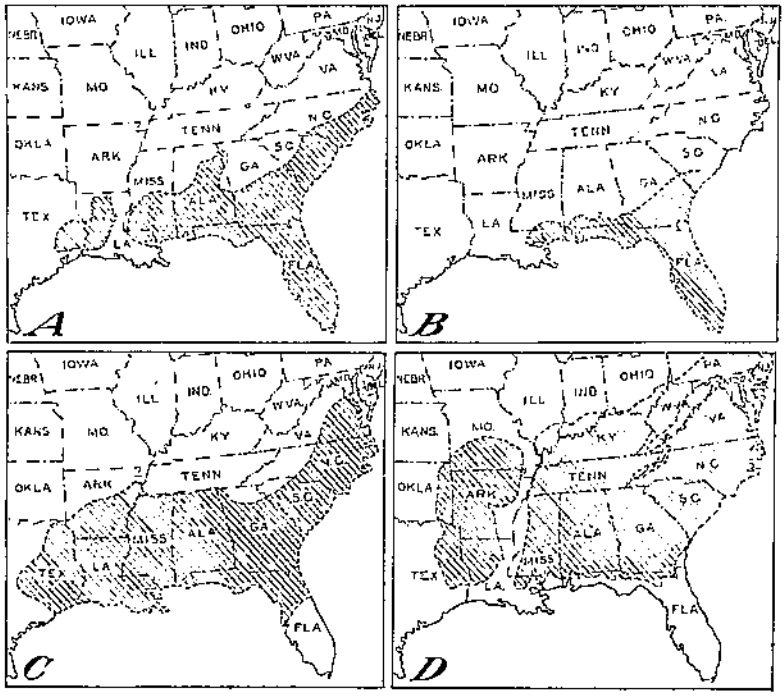

FIGURE 1.—Natural ranges of longleaf (*A*), slash (*B*), loblolly (*C*), and shortleaf (*D*) pines.

planting would be desirable within the next 20 years exceeds 5,000,000 acres. On a large additional area it would seem justifiable to augment and improve the natural stands by planting.

The feasibility of planting for timber production depends on the ease and certainty with which trees can be established in the field, the cheapness with which they can be produced and planted, and, in most cases, the financial returns that can be obained. Climate, topography, characteristics of the principal species, and geographic location combine to make artificial reforestation at least as easy and certain, and economically as promising, in the southern pine region as in any other region of the United States.

Mean annual temperature, a rough index of growing conditions, ranges from 55° F. in Delaware and Maryland to 75° in Florida.

Mean annual rainfall ranges from 40 inches in Maryland and in the extreme western portion of the shortleaf pine type in Texas, to more than 60 inches in the extreme western portion of Florida and in the extreme southern portions of Alabama and Mississippi (*34*).[1] Through most of the region, the topography is flat or only moderately rolling. A large part of the land in need of planting is wholly free from surface stones.

The region is readily accessible to markets for forest products.

Four principal species make up practically the entire cut of southern pine: Longleaf pine (*Pinus palustris* Mill.), slash pine (*P. caribaea* Morel.), loblolly pine (*P. taeda* L.), and shortleaf pine (*P. echinata* Mill.). One or more of these species compose an important part of the commercial forests of each of the following 13 States: Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Texas, Arkansas, and Oklahoma.

All four of the principal southern pine species produce wood of high technical quality and utility. Within the sizes ordinarily attained by the trees they are unexcelled for structural timbers. They yield poles, piling, railroad ties, and other products of great value and are being used increasingly for kraft paper. Longleaf and slash pine yield the entire national output of naval stores (turpentine and rosin).

These four species are among the most rapidly growing and most highly productive timber trees in the United States. The extreme openness of the existing old-growth stands, only a small percentage of which contain so much as 12,000 board feet per acre, is due to lack of management, and particularly to indiscriminate burning. Likewise the yields of the existing second-growth stands of merchantable size, ordinarily from 1,000 to 10,000 board feet per acre, are much below their potential yields, owing to present utilization practices. Yields of fully stocked second-growth stands subjected only occasionally to fire and cut under extremely close utilization practices are given in table 1. On the better sites, plantations may exceed the yields given in the table. Yields of turpentine under up-to-date practices are given in table 2.

TABLE 1.—*Normal yields per acre of unmanaged natural stands of southern pines on approximately average sites*[1]

Age	Longleaf pine			Slash pine			Loblolly pine			Shortleaf pine		
	Cords	*Board feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*	*Cords*	*Board feet*	*Cubic feet*
15 years	7	200	825	27	1,500	2,150	18	850	1,600			1,010
20 years	14	1,000	1,325	35	4,000	2,700	27	5,000	2,300	18	250	1,670
25 years	21	3,000	1,800	42	8,000	3,250	37	11,000	3,100	31	2,800	2,400
30 years	28	5,000	2,200	48	13,000	3,750	46	17,000	3,850	41	6,000	3,120
35 years	33	8,000	2,700	54	17,500	4,250	54	23,000	4,600	49	12,000	3,750
40 years	39	11,000	3,100	58	22,000	4,600	61	28,500	5,200	56	17,500	4,380
45 years	43	14,000	3,550	62	25,500	4,950	67	33,500	5,700	61	23,000	4,880
50 years	48	17,500	3,950	65	28,000	5,300	71	37,500	6,150	66	27,200	5,320
55 years	52	20,500	4,300	67	30,500	5,500	75	40,500	6,450	70	30,700	5,680
60 years	55	23,500	4,650	69	32,000	5,750	78	43,000	6,700	73	33,500	6,000

[1] Exclusive of naval stores yields, and of intermediate yields such as wood cut in thinnings. Table based on (*31, tables 30, 46, 63, 71, 78, 85, 103, 135, 142, 149.*) The following site indices (dominant heights at 50 years) are taken as average: Longleaf pine, 70 feet; slash pine, 80 feet; loblolly pine, 90 feet; shortleaf pine, 70 feet. Yields are figured as follows: In cords, from rough wood, all trees 4 inches d. b. h. or more; in board feet, by International (¼-inch) rule, from 1-foot stump height to a top diameter inside bark of 5 inches; in cubic feet, from total peeled volume of all trees 2 inches d. b. h. or more.

[1] Italic numbers in parentheses to Literature Cited, p. 108.

TABLE 2.—*Average annual yields*[1] *of turpentine per crop of 10,000 second-growth trees, by diameter, species, and stand density*

Diameter breast high	Slash pine		Longleaf pine, open stand
	Open stand	Dense stand	
	Barrels	*Barrels*	*Barrels*
5 inches	12		
6 inches	19		20
7 inches	26	13	26
8 inches	34	22	32
9 inches	41	32	38
10 inches	48	40	44
11 inches	56	49	50
12 inches	63	59	56

[1] Table based on (*39, figs. 20, 22*). Production of 1 barrel of turpentine (50 gallons) is accompanied by production of approximately 2½ barrels of rosin.

The high productivity and early merchantability indicated in the tables result from the combination of long growing season and adequate rainfall with species characteristics.

The cost of establishing forest plantations is potentially lower in the South than in any other forest region of the United States, because of the favorable climate and topography and because the southern pines can almost invariably be planted as 1-year-old seedlings instead of as the older seedlings or transplants commonly used in other regions.

If planting is done judiciously and skillfully, there is every reason to believe that the financial returns from the planted stands will be almost as good as those from stands produced naturally. In some instances they will probably be better. This probability is particularly high for longleaf pine, which is relatively difficult to reproduce by natural means but which can be planted at about the same expense as the other species.

Aside from direct financial returns to an individual landowner through sale or use of forest products such as saw timber, piling, poles, and pulpwood, several kinds of benefits from plantations call for consideration. A moderate planting program undertaken at the right time may make possible perpetual operation of a sawmill or pulp mill. Federal agencies, by establishing extensive plantations, may create a source of future public income from districts the tax revenues from which have practically disappeared because of exhaustion of forest resources. In certain localities, particularly in the silt loam uplands of northern Mississippi and the piedmont section of central Georgia, forest planting appears to offer the best means of controlling erosion, simultaneously defraying part of the cost of control by providing salable products. Plantations have value also for game management.

Forest planting in the southern pine region is of very recent development. A few existing plantations are known to have been established in the region by farm owners as far back as 1907, 1896, and 1892, usually with wild stock. These early plantations, however, make a pitifully meager showing in comparison with those established during the same period in New England and New York. In 1911 the Forest Service attempted to reforest artificially approxi-

mately 900 acres on what are now the Choctawhatchee and Ocala National Forests, in Florida, partly by planting and partly by direct seeding. This venture, undertaken on what are perhaps the poorest sites in the South, failed almost entirely. During the decade 1911–20 sporadic private experiments with wild stock increased slightly, and several planters in the Atlantic Coast States established southern pine plantations that have developed satisfactorily. For all these early plantations, establishment costs were so high as to indicate that the methods used were unsuited for any extensive reforestation program. Up to and including 1919, the area successfully planted with southern pines by all agencies combined totaled probably less than 500 acres.

In the winter of 1919–20 the Great Southern Lumber Co., in southern Louisiana, began artificial planting on a large scale, at a moderate cost per acre. By the spring of 1926 it had established plantations totaling 12,700 acres. In 1933 the area planted by this company reached a total of 28,500 acres.

Since 1926, planting has become rather general throughout the southern pine region. Information concerning seed and improved nursery practice and planting methods has been made available, together with much other information relative to the southern pines, in a series of Forest Service and other bulletins. Rapid progress has been made both by lumber and paper companies and by farmers and other owners of small tracts. Part of this progress is traceable to the activities of State forestry departments and to Federal aid extended under provisions of the Clarke-McNary Act of 1924. The approximate extent of planting by all agencies combined is shown in table 3.

TABLE 3.—*Extent of forest planting*[1] *in the 13 States lying wholly or partly within the southern pine region, by all agencies*

State	Before 1928	1928	1929	1930	1931	Total	Total for States planting southern pines almost exclusively
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Delaware	70	60	25	122	99	376	
Maryland	1,381	133	220	336	521	2,591	
Virginia	337	47	349	316	401	1,450	
North Carolina	1,525	306	544	270	468	3,113	
South Carolina			112	481	745	1,338	1,338
Georgia	1,500	6	800	2,542	154	5,002	5,002
Florida	966	0	34	1,468	1,867	4,335	4,335
Alabama	89	50	328	266	34	767	767
Mississippi				535	594	1,129	1,129
Louisiana	19,540	9,273	10,583	6,556	2,474	48,426	48,426
Texas				260		260	260
Arkansas	772	0	0	73	9	854	854
Oklahoma	2,538	28	121	181	147	3,015	
Total	28,718	9,903	13,116	13,406	7,513	[2]72,656	[3]62,111
Cumulative total	28,718	38,621	51,737	65,143	72,656		

[1] Table based on reports submitted by State foresters under sec. 4 of the Clarke-McNary Act. Includes not only pine plantations but all forest plantations reported, and not only plantations that survived but those that failed or were destroyed. It is not believed that any considerable acreage of southern pine plantations was omitted from the State foresters' reports.

[2] Of this total 49,171 acres (67 percent) was planted by lumber and paper companies and 15,452 acres (21 percent) by farmers.

[3] Of this total 48,712 acres (78 percent) was planted by lumber companies and 8,738 acres (14 percent) by farmers.

Prior to the expansion of planting on national forests in 1933 as a phase of Emergency Conservation Work, lumber and paper companies dominated the field of forest planting in the southern pine region. At the end of the calendar year 1931, such companies had planted 67 percent of the total area artificially reforested in the 13 States lying wholly or partly within the southern pine region. More than 20 lumber and paper companies had planted 78 percent of the area reforested artificially in South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, and Texas, the States in which practically all forest planting has been done with southern pines. In these same States, some 787 farmers had planted a total of only 13.9 percent of the area reforested artificially.

Most of the early work was done with loblolly pine. In some instances this species was used on longleaf pine land, for which loblolly pine is usually unsuitable. About 1926, slash pine became the favored species for planting use. Slash does far better on cut-over longleaf land than loblolly, at least within or near its natural range. Meanwhile the mattock had been replaced in the South as the common planting tool by an iron planting bar that greatly expedited the work.

The first successful commercial plantation of longleaf pine was established in 1924. Previous to that time it had been considered difficult or impossible to establish this species artificially. By 1927–28 studies and large-scale tests by a number of agencies had demonstrated that longleaf pine, if skillfully handled, can be planted as cheaply and effectively as the other species. Since the species is preeminently suited to certain sites and conditions, this marked a great step forward.

Later noteworthy developments include reduction of cost by improvement of equipment and simplification of procedure; improvements in the quality of plantations through better choice of species, mixture of species, and the use of closer or wider spacing to meet certain exacting local conditions; and better organization of planting work through systematic planning and careful records.

Direct seeding, that is, scattering seed broadcast or sowing it in furrows, on prepared spots, or on areas prepared by harrowing, has been tried in some reforestation projects in the South, principally in order to avoid the expense of money and effort involved in growing seedlings in a nursery. Occasionally the theory is advanced that sowing the seed directly on the site where it is desired to grow the trees insures sounder and more normal development of the root system than is possible in the case of trees transplanted from a nursery.

Records are available of the results of efforts to establish southern pines by direct seeding on 34 tracts, plots, or groups of plots on 21 different areas in 18 localities in the southern pine region, from Maryland to Texas. These figures include no attempts in which there is reason to doubt the viability of the seed used. On only 6 of the tracts, plots, or groups of plots (17.6 percent) was direct seeding clearly and consistently successful. On only 10 others (29.4 percent) could the process be called even partly or possibly successful. Of the total 16 plantings that constitute clear or possible successes, 10 involved elaborate site preparation such as clearing, plowing, and

harrowing, or the use of prohibitively expensive quantities of seed, or both; success was attained in one instance by sowing 25 pounds of longleaf pine seed per acre, and in another by sowing 13.5 pounds of loblolly pine seed per acre.

A summary of these records indicates that in regard to successful establishment by direct seeding the principal southern pine species rank as follows, in order of increasing success: Longleaf, slash, loblolly, shortleaf. This is the same order in which they rank as to size of seed, longleaf pine having the largest seed and shortleaf the smallest. The coincidence is interesting in relation to the reasons given for failure of direct seeding on the 25 tracts, plots, or groups of plots for which such reasons were recorded. Failure was attributed, wholly or partly, to birds on 12 tracts, to rodents on 9, to insufficient seed-bed moisture on 7, and to one or more other causes on lesser numbers.

Planted stands usually make better initial growth than direct-seeded stands. The most obvious reason for this is the good start obtained by seedlings on the cultivated and artificially watered soil of the nursery. Generally, a 1-year-old seedling of slash pine grown in a nursery is as large as one 2 or 3 years old that has grown wild in the woods or on cut-over land, and a top-grade nursery-grown longleaf pine seedling 1 year old is as large as an ordinary 5-year-old or older longleaf pine seedling grown naturally.

It would seem inadvisable to attempt direct seeding on a commercial scale by any method yet demonstrated.

Another scheme that has been tried without much success as a method of establishing stands of southern pine is to plant wild seedlings dug up in the forest or in old fields. It is true that the earliest successful plantations in the South, and a few excellent later plantations, were established with wild stock, and that wild stock still occasionally fills a need in experimental work, in a small or moderate-sized private planting, or in a preliminary demonstration by a public agency. In general, however, wild stock is too hard to find when wanted, too expensive to lift, and too uncertain in survival and growth to justify the practice.

SEED

Characteristics of the seed used affect practically every step and process involved in artificial reforestation with the southern pines. Fluctuations in the quantity of seed produced cause great and costly fluctuations in planting schedules; the area planted by one lumber company dropped from 2,200 acres in 1926–27 to 300 acres in 1927–28, and increased again to 7,000 acres in 1928–29, solely because of variations in the seed crop. The behavior of cones during seed extraction, and differences in the yields from different lots of cones, affect the cost of the seed. Since seed of the southern pines especially in demand for reforestation run fewer to the pound than most conifer seeds, and since nursery and planting costs are low in the South, anything tending to increase the cost of seed has a relatively greater effect on the final cost of planting southern pines within their natural ranges than on the final cost of so planting most other species. All nursery technic hinges on the seed's germination requirements.

its germination percentage, the length of time it requires to germinate, its attractiveness to birds, the season of sowing that best suits its temperature requirements, and the problems of controlling weeds, insects, and damping-off (which, in their turn, are affected by season of sowing). Lastly, for successful planting the characteristics transmitted from the parent trees as to form, vigor, gum production, hardiness, and resistance to disease must be such as to fit the seedlings to the planting site and to the purposes of the plantation. Preferably, planting should not be undertaken without a thorough knowledge of the origin and quality of the seed.

Southern pine seeds, like those of most other pines, take two growing seasons to mature. Rain or frost during pollination in the spring may ruin the crop that would normally mature in the fall of the succeeding year, and adverse weather or insect attack at any time during either of the two summers or the winter intervening can destroy the cones or seed.

The male or pollen-bearing flowers of the southern pines grow in clusters between the preceding year's needles and the new bud; that is, at the base of the current year's growth. They may appear on practically all twigs throughout the crown of the flowering tree, except the most vigorous twigs at the top of the crown and on the stronger side branches. On these more vigorous twigs the female or cone flowers develop, not at the base of the new growth but at the tip of its first node.

Pine pollen is wind-blown. Pollination of slash pine takes place in late January and early February; in the Gulf States longleaf and loblolly pines are pollinated for the most part in March, and shortleaf pine about the middle of April. The time during which cone flowers are receptive to pollen is very short, and differs somewhat among individual trees of the same species. Moreover, the male and female flowers of an individual tree do not always mature simultaneously; in some instances at least, the male flowers mature first and shed most or all of their pollen before the scales of the cone flowers on the same tree open to receive it. This difference in date of maturity, together with the location of most of the female flowers in the crown, above most of the male flowers, may account for the failure of some trees to produce seed abundantly, and may also permit some cross-pollination that would not otherwise take place. Cross-pollination makes it difficult to obtain seed of known male parentage and even leads to hybridization, as of longleaf with loblolly.

During the summer, fall, and winter after pollination, the cones increase very little in size. They enlarge rapidly in their second spring, and early in the ensuing summer attain their full size. The usual dates of maturity are given in table 5, and are discussed more fully in the section on seed collection.

Estimates as to the frequency of cone crops of the southern pines cannot reliably be based on stem analyses of seedlings or saplings that appear to have come from the same seed crop; such evidence is inconclusive because of the likelihood that on any area from which stems are taken for analysis drought and fires will have wiped out practically entire crops of seedlings and, in the case of longleaf pine, because of an extended, nonuniform delay in beginning height growth and of a general failure to become dormant in winter and

thus form distinct growth rings. Systematic cone-crop reporting for the southern pine region as a whole was first undertaken in 1931. The records thus obtained cover too short an interval to permit drawing any detailed conclusions concerning seed production of the southern pines; but from earlier, though less comprehensive, records it appears that seed of each species is produced in some part of the region every year with but few exceptions, and that of the four principal species loblolly pine produces seed most frequently. Records for longleaf pine on specific areas show 2 and 3 good seed crops in consecutive years, and 5 fair to heavy crops within 10 years.

Seeds of longleaf pine are remarkable for their size, their comparatively soft and leathery seed coats, the firmness with which their wings are attached, the low temperature at which they germinate, and the quickness with which they lose their viability in warm weather. The seeds of the other southern pines have harder coats and less firmly attached wings, and in general are more like the seeds of pines native to the Northeastern or Western United States. They usually germinate less promptly than longleaf pine seeds, but keep better at natural air temperatures; they sometimes pass into a dormant state, which is, however, less marked than that characterizing the seeds of the five-needled pines of the North and West.

In size, form, and color the seeds of the southern pines are extremely variable, even within species. The seeds from any one tree, however, are similar to each other in form and color, because not only the cone but also the seed wing, the outer and inner seed coats, and even the endosperm or "meat" of the seed are invariably made up of tissue derived entirely from the female parent tree, only the embryo itself having possibly resulted from cross-pollination. The number of cotyledons or seed leaves of southern pines varies considerably even among seedlings from seeds of the same cone.

The technic of collecting, extracting, and marketing southern pine seed, and investigations dealing with treatment, storage, and source of the seed, have passed little if at all beyond the pioneer stage. There has been a gradual improvement in cone kilns, and several agencies and individuals have raised the standard of seed for their own use or for sale by cleaning it in agricultural seed mills capable of removing the empty seeds. Seed testing has been insufficiently developed and applied. Records of seed source and of the quality of the parent tree have been inadequate or wholly lacking for all but a few plantings.

COLLECTION

Because the trade in southern pine seed is comparatively undeveloped, private and State foresters concerned with forest planting in the southern pine region frequently find it necessary to collect and extract their own seed supplies.

An area's desirability for pine-seed collection depends on four things: (1) Abundance and quality of cones, (2) presence of a logging operation or of trees that can be climbed economically, (3) accessibility, and (4) hereditary qualities of the parent trees.

The first three of these considerations affect directly the cost of the seed, and hence the cost of nursery stock and of plantation

establishment. It is obviously less expensive to collect cones from well-loaded trees and from areas near a source of labor or readily accessible by truck. The nearer to the seed-extracting plant the cones are collected, the lower are the shipping charges.

Hereditary qualities of the parent trees affect vitally the success and ultimate value of the plantation. In general it has proved unwise to use seed from one region in another region markedly different as to temperature, especially if the differences are in average summer temperature, minimum winter temperature, or annual duration of temperatures high enough to permit rapid growth (*6*, *12*, *16*). Even if no marked regional differences as to temperatures are involved, it may be unsafe to introduce a forest-tree strain in a region where the rainfall differs greatly in quantity or distribution from that of the strain's natural range. If an area must be planted with seed originating at any considerable distance, therefore, care should be taken to choose seed from a locality for which weather records [2] indicate a climate similar to that of the planting site.

It should be a fixed policy to choose as a seed source the stands and individual trees that are the best available as to form, growth rate, quality of wood, and freedom from injurious insects and disease. Although precise information is lacking as to the extent to which any of these characteristics are hereditary in the southern pines, the probability that the use of choice seed will increase considerably the thrift and productiveness of the planted stands is too great to be disregarded—particularly in view of the fact that stands now being established by planting are expected to give rise, by natural reproduction, to successive generations of commercially valuable trees. If only a part of the quantity of seed needed can be obtained from parent trees of the best quality, this part should be planted separately from the other seed used and separate records should be kept of the results obtained with the different grades. Separate records should of course be kept, also, of results with seed from different geographic sources.

Success in collecting cones depends in part on systematic scouting, which usually should be done during August. Scouting trips should be supplemented by correspondence with landowners, contractors, and other local observers. Particular care must be taken to base the estimate of a crop's abundance on actual counts of cones borne by a considerable number of representative trees.

Counts of longleaf and slash pine cones are likely to be considerably more accurate than counts of loblolly and shortleaf pine cones, because cones of the latter species are smaller. A count of cones on standing trees is particularly difficult in the case of shortleaf pine, because cones of this species remain attached to the branches for several years and the count must be restricted to the current crop.

Figures are given in table 4 for converting numbers of cones to bushels. Figure 2 shows the relative size of representative unopened cones of the four principal species.

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[2] Weather records are obtainable from the Weather Bureau, U. S. Department of Agriculture, Washington, D. C.

TABLE 4.—*Usual sizes*[1] *of unopened cones and usual numbers of cones per bushel*[2]

Species	Length of cone		Diameter of thickest part of cone		Cones per bushel	
	Average	Range	Average	Range	Average	Range
	Inches	*Inches*	*Inches*	*Inches*	*Number*	*Number*
Longleaf	6	4–10	2.0	1.6–2.7	100	86–118
Slash	3–4	2.4–6.0	1.6	1.3–1.8	200	157–243
Loblolly	3	1.8–4.4	1.2	.7–1.7	500	393–1,080
Shortleaf	1.6–2.0	1.1–2.8	.8	.5–1.1	2,000	1,444–2,545

[1] Cones from vigorous young trees tend to be above average in size, and hence below average in number per bushel. The reverse is true of cones from old trees.

[2] Figures that indicate the approximate range are of averages for lots of cones. Individual cones outside the length and diameter ranges indicated are found not infrequently. Figures for length and diameter are based on measurements of samples from relatively few collections. Figures for numbers of cones per bushel are based on more ample data.

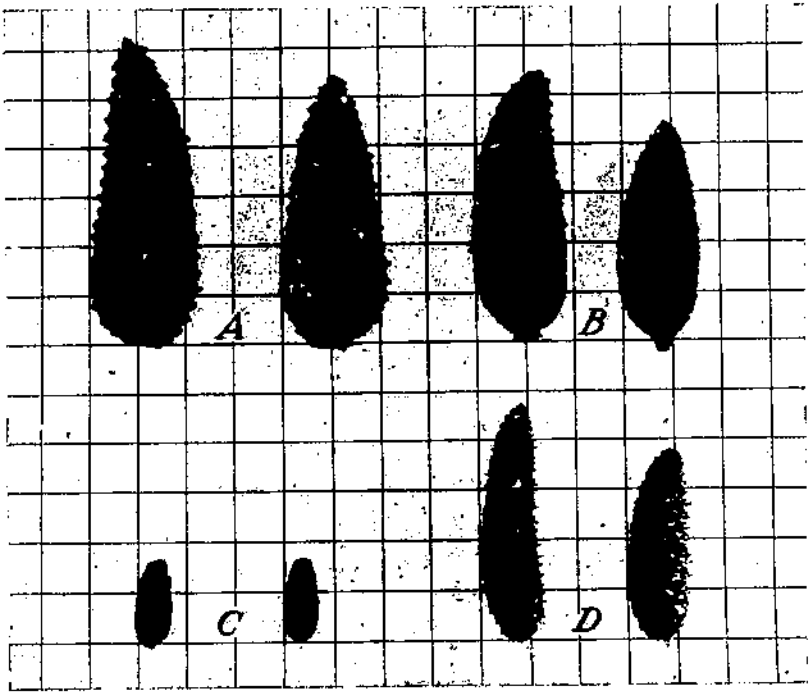

FIGURE 2.—Unopened cones: *A*, Longleaf; *B*, slash; *C*, shortleaf; *D*, loblolly pine. (Background ruled in inches.)

Table 5, based on data collected during the period 1923–30, gives for each of the four species the period within which the cones usually ripen and that within which they usually open on the trees and the period preferable for collection. Particularly notable is the early ripening and opening of the cones of slash pine.

TABLE 5.—*Usual dates of maturity and opening of cones of southern pines, and periods preferable for collecting them*

Species	Ripening	Collection	Opening on trees
Longleaf	Oct. 1–20	Oct. 1–20	Oct. 20–Nov. 10.
Slash	Sept. 1–10	Sept. 1–20	Sept. 20–30.
Loblolly	Sept. 20–Oct. 10	Oct. 1–20	Oct. 10–30.
Shortleaf	Oct. 1–20	Oct. 11–30	Nov. 1 on.

Seasonal weather variations during the period of ripening, and other weather influences, often cause considerable departures from the usual dates of maturity. In 1924, for example, unopened slash pine cones were collected near Slidell, St. Tammany Parish, La., as late as October 18, but in 1927 slash pine cones in the same locality had opened and shed all their seed by September 20. In 1927 longleaf pine cones in southern Jackson and Harrison Counties, Miss., near the Gulf coast, began to shed their seed by September 15 and had shed practically all of it early in October, whereas on a similar area in Pearl River County, 40 miles farther from the Gulf, the first longleaf pine seed was shed about October 10 and the last was not shed until November.

The figures in table 5 furnish a general guide for use in planning cone collection; the exact date on which to begin gathering the crop should be determined by observation in the field. As a rule, cones should not be collected until they have begun to turn brown. Cones of any species may ripen, open, or be collected 1 to 3 weeks before or after the periods shown in table 5. Slash pine is perhaps more likely than any of the three other species to ripen and shed its seed ahead of the time indicated by the table.

The ideal time to collect is when the first few cones in an entire stand begin to open. Such late collection insures the greatest possible ease in extraction and, since by that time the cones have lost much of their weight through drying on the trees, reduces transportation costs. It involves some risk of missing part or all of the crop. The risk is greatest in the case of slash pine, the cones of which open particularly easily and quickly and, over most of the range of the species, mature early in the season, when spells of hot, dry weather are still frequent. Collection should begin fairly early in the season if large quantities of seed are needed. Very early collection, on the other hand, adds to transportation costs and to extraction costs, because of the excessive quantity of moisture in the cones, and involves danger of difficulty or failure in extraction.[3]

In the South, no species of squirrels are known to hoard cones. Even after the heaviest seed fall, seed cannot be collected in satisfactory quantities from the ground or other flat surfaces. Collection from ponds or streams is hardly possible, unless in the case of longleaf pine; wetting combined with any rubbing or tumbling removes the wings from seeds of the other southern pines, and sound seeds without wings usually sink in water.

[3] Southern pine seed mature earlier than the cones containing them; but extraction of the seed from immature cones, that is, cones not in condition to open readily when subjected to drying, is too difficult to be practical.

Collection from felled trees is easier and cheaper than collection from standing trees. Cones of longleaf and slash pine are so heavy and so easily detached that most of them fall off when the tree top hits the ground, and need only be picked up. Collection from felled trees has the disadvantage that, even though the seed of certain individual trees proves especially adapted to a given planting site, later crops cannot be obtained from them. Felling trees for their seed alone usually does not pay, because of the stumpage value and the labor cost involved.

The equipment needed for collecting from standing trees includes light ladders, climbing irons, and pruning hooks or poles. Some workmen prefer to use only ladders for climbing second-growth trees of moderate size. Ladders are easy to obtain locally; but when climbing irons and hooks or poles are to be used, collectors sometimes find it a good plan to supply this equipment to contractors as well as to day laborers, making them financially responsible for it.

Some use has been made of a pruning pole having at one end a movable blade worked by a wire running to a lever at the other end. Less expensive and cumbersome, and ordinarily much more efficient, is a light pole 8 or 10 feet long, having bolted to one end a Y-shaped blade of ¼-inch iron, the fork of which is 2 inches deep and 1¾ inches from point to point. With this, any cone within reach can be poked, knocked, or twisted off. A modification of this pole especially adapted to the collection of loblolly cones has a hook-shaped instead of a Y-shaped blade. A thong at the handle end to go around the wrist facilitates use of the pole, and an extension may be slipped onto the handle to permit reaching cones on particularly wide-crowned trees.

Most workmen can handle longleaf, slash, and shortleaf pine cones with their bare hands, but few care to handle loblolly pine cones without leather-palmed gloves.

Whether collection is from felled timber or from standing trees, it is quicker to gather the cones in bushel or half-bushel baskets and pour them from the baskets into sacks than to gather them directly into the sacks. Cones should be sacked in either 1-bushel or 2-bushel lots, to simplify tallying the quantity obtained. Bushel sacks are easier to handle. Payment for piecework on unopened cones, and purchase of such cones, should be based on volume, not weight, because weight changes rapidly and irregularly as the cones dry. The accuracy of the measure of sacked cones can be checked at delivery by measuring the contents of a few sacks chosen at random, and checking the remaining sacks by eye as they are tallied.

All pine needles and other trash should be separated from the cones before they are sacked, preferably before they are placed in the baskets. This cleaning saves the cost of transporting waste material, makes it possible to empty cones from sacks into drying racks without further cleaning, and simplifies cleaning of the seed. Even with the best seed-cleaning equipment, bits of dried, broken needles are hard to remove.

Except when seed is very scarce, all wormy cones should be culled at the time of collection. They yield only one-third or one-half

as much seed as sound cones; in addition, they break badly during tumbling, with the result that bits of cone scale, almost impossible to remove, become mixed with the seed.

Any company or individual collecting more than one lot of cones, even of a single species, should place on every sack before it is moved from the collecting ground a label showing unmistakably the species, place of collection, and quantity. A tag that can be removed from the outside of the sack and put in the drying rack with the cones is perhaps the most satisfactory. Labels inside the sack are useless both because they cannot be read without opening the sack and because the cones are likely to grind them to pieces.

Necessary notes on character and location of seed trees should be taken in the woods when the cones are collected, not left to memory until some more convenient time.

EXTRACTION

A bushel of unopened cones of any southern pine species weighs from 28 to 45 pounds. Of this weight 35 to 65 percent or more represents water, nearly all of which must be removed before the cones will open and free the seed. When opened, the cones occupy from two to three and one-half times the space they occupied before. Any equipment used in extracting the seed must be strong enough for the maximum weight of the cones before opening and roomy enough for their maximum volume after opening.

PRECURING

The term "precuring" covers both the storage of cones waiting their turn in drying racks or kiln and the preliminary air-drying of cones that, because of excessive moisture content or other adverse conditions, would fail to open normally if subjected at once to artificial heat. In the former, the chief purpose is to keep the cones from molding or fermenting. Precuring as a preliminary to final drying by artificial heat is needed rather frequently by longleaf cones, and somewhat less frequently by shortleaf cones. It may be needed occasionally by slash and loblolly cones. Without preliminary drying the cones may caseharden; that is, the outer surfaces may dry almost completely before the inner portions lose much moisture, with the result that the cones remain permanently closed.

FINAL DRYING

Drying at (natural) air temperature requires only relatively simple and inexpensive equipment, and involves no danger of injuring the seed by overheating. On the other hand it is slow; tends to leave many sound cones unopened; fails entirely to open the cones of such species as sand pine (*Pinus clausa* [Engelm.] Sarg.) and pond pine (*P. rigida serotina* [Mich.] Loud.); exposes the seed to birds, mice, and rats; and, for large-scale operation, requires very bulky equipment. It is often the preferable method of handling small lots of cones, is especially adapted to certain types of research, and is sometimes useful for supplementing large kiln operations.

Final drying at air temperature takes from 3 days to 3 or more months; usually, it takes at least 3 to 6 weeks. Except from well-

matured cones of very high quality, the yield obtained by such drying is usually lower than that obtained by using artificial heat. Representative yields for various species are shown on page 23.

Drying at air temperature is carried out most effectively and efficiently indoors, with the use of movable racks or trays arranged in tiers. Drying in bins or on tight floors makes less efficient use of room space, and yields less seed per bushel of cones unless great care is exercised to keep the layers shallow and to stir the cones often.

In the South heavy dews and frequent rains make it impracticable to dry cones by spreading them outdoors in the sun on tarpaulins and covering them with other tarpaulins at night as is done in other regions. Tiers of cone trays mounted on light trucks, which could be run out when the sun shone and pushed back into a shed at night or during rains, have been used with success on one small operation in the South; but this method requires too much equipment for large operations. Extraction in well-ventilated bins under glass has been suggested, but would require expensive equipment.

Extraction by artificial heat requires more elaborate equipment and demands more skill on the part of the operator. Having the advantage of speed, in large operations it requires less outlay for building space and for racks and other bulky equipment than would be required by air drying. It usually results in more complete extraction; in the majority of cases, probably, it is essential to obtaining full yields. It involves much less danger of destruction of seed by insects, mice, and birds, because the period of exposure is shorter, the temperatures are higher, and workmen are present much of the time.

Final drying by artificial heat ordinarily takes from 12 to 72 hours. A plant requiring the latter period is inefficient. Representative yields of seed of various species are shown on page 24.

If cones are to be dried entirely at air temperature, provision should be made for abundant openings in the side walls of the drying room, free movement of air across the racks, and the admission of as much sunlight as possible. Fans can sometimes be used to good effect to force the circulation of air. In a kiln, on the other hand, if the convection type is used, there should be the fewest possible openings in side walls, but abundant provision for the escape of moisture-laden warm air at the top; if a forced-draft kiln is used, the openings must be an integral part of the particular system installed. Information concerning the most recent developments in kiln design is obtainable from the Forest Products Laboratory, United States Forest Service, Madison, Wis.

A cone-drying device that is suggested for use with southern pine species is a large horizontal drum rotated in a column of hot air. Seeds loosened from cones contained in this drum are shaken out onto an inclined screen leading to temporary storage boxes. Other devices consist in hand-moved trays or power-driven endless belts (*4*) or metal spirals (*2*), by the use of which cones are introduced into the top of a column of warm air and, as they dry, are moved downward into hotter, drier air. In Europe, a truck has been devised in which cones are partially dried on the way to the seed house by means of heat from the engine.

TUMBLING

With most types of drying equipment, when drying has been completed it is necessary to tumble the cones vigorously to shake out the seed. This tumbling is best done in a container made of wire the mesh of which is small enough to stop unopened cones and the larger fragments of broken cones but large enough to permit the passage of seeds with wings attached. Hardware cloth of ½-inch-square mesh is good for this purpose. A tumbler of this material separates the seed from the cones in one operation.

Revolving tumblers have generally proved satisfactory. They may be round, square, or hexagonal in cross section, and either intermittent or continuous in action. An intermittent tumbler is uniform in cross section, has closed ends, and is loaded and emptied by means of a door running the full length of one side. A progressive tumbler usually tapers slightly, has no side door, and is open at both ends; the cones are fed in at the smaller end and, as the tumbler revolves, work down to the larger end and drop out. In either type, the seeds fall through the wire sides of the tumbler into a receptacle below.

DETAILS OF EXTRACTION

Throughout the three stages of extraction just described the man in charge must constantly guard against injury to the seed, loss of seed, mixture of seed of different lots, and excessive cost of the operation as a whole.

The chief sources of danger to the seed are excessive temperature and overlong exposure during final drying by artificial heat. No harmful effects from the use of artificial heat need be feared if the temperature in the extracting plant never exceeds 120° F., if good ventilation is provided, and if the seed is removed shortly after all the cones have opened. Preliminary tests indicate that seed of species having cones difficult to open, such as sand pine, pond pine, and, under certain conditions, shortleaf pine, may safely be extracted at kiln temperatures of 140° or more.

In general, a maximum temperature of 120° F. and a relative humidity of 20 to 30 percent, with free circulation of air, are recommended for final drying by artificial heat.

The results of germination tests with several lots of southern pine seed, of which some were extracted at air temperature and others under controlled conditions in a lumber kiln, are summarized in table 6. With one important exception, the differences in germination of these lots of seed were explainable by errors of sampling or variations in the completeness with which defective and empty seed were extracted from the cones. The exception is the low germination of longleaf pine seed extracted at 140° F.; seed of this species, according to the results of this and other tests, is injured by temperatures higher than 130°.

TABLE 6.—*Average germination, in standard sand flats, of seed extracted from comparable lots of cones under different conditions of temperature and relative humidity*[1]

Species, time of collection, and State	Average germination,[1] in standard sand flat, of seed—			
	Extracted in outdoor racks at air temperature	Extracted in lumber kiln at—		
		120° F.,[2] 20% rel. hum.	120° F.,[2] 30% rel. hum.	110° F.,[2] 10% rel. hum.
	Percent	*Percent*	*Percent*	*Percent*
Longleaf pine, October 1925, Texas	83.5	74.7	.....	12.4
Loblolly pine, Oct. 6–11, 1925, Louisiana	53.5	.....	53.4	45.7
Loblolly pine, Oct. 19, 1925, Arkansas	59.5	.....	53.8	65.4
Shortleaf pine, Oct. 19, 1925, Arkansas	64.5	.....	65.3	67.6

[1] Table based on studies made by E. W. Hadley when assistant silviculturist, Southern Forest Experiment Station. Germination is in terms of all seeds sown.
[2] Temperatures practically constant.

Excessive molding or fermenting of cones not only makes them harder to open but also injures the seed and apparently decreases its ability to remain viable in storage. Cones are seldom seriously affected by mold unless they have been rained on during shipment or have been stored for a week or more in the sacks, in poorly ventilated bins, or in deep layers on the floor. If cones must be stored in sacks, the sacks should be set on end far enough apart so that the air can circulate freely about each.

The first step in avoiding loss of seed is careful selection of cones, specifically avoidance of immature or wormy cones. As a second step proper precuring to prevent casehardening is important particularly in the case of longleaf and shortleaf pine cones, and of cones of any species that are collected before turning brown. To prevent heavy losses of seed through action of birds and animals, in operations carried on at air temperature, it is recommended that all openings be carefully screened and that pests be systematically trapped and poisoned. Tumbling should be done in moderately dry weather, particularly if the cones have been dried without artificial heat; otherwise, there is danger that the cones will absorb moisture from the air and their scales close sufficiently to retain some seeds even if tumbled vigorously.

Danger of fire in cone kilns arises from the fact that the floor, cone trays, and other woodwork become extremely dry and that the hot, dry, resinous cones are highly inflammable. It is increased if poor ventilation results in accumulation of turpentine-laden vapor from trays of unopened cones recently placed in the kiln, or of dust from the tumbler or seed mill. The worst of the fire danger is avoided if heat is supplied to the kiln not from a furnace in the same building but by means of steam from a source outside the building. Prohibition of smoking, and scrupulous care with fire in general, should be sufficient additional safeguards.

Loss of seed by spilling is lessened by proper design and handling of equipment. In some extracting plants the men work in stocking feet to avoid crushing spilled seed.

Accidental mixing of trays or lots of seed can be avoided by using good labels on all trays. Use of a distinctively colored tag or card for each species is suggested, with appropriate numbers or letters for the separate lots. All cone trays should be made of wire fine enough to hold the smallest seeds extracted; screen wire having 16 meshes to the inch is satisfactory. If coarse wire is used, seeds drop through the bottom of the tray when it is moved, or sift down into other trays in the tier, perhaps to become mixed with seed of other lots. To keep seeds from catching in cracks of the cone tray and later mixing with seed of other species it is well to bring the edges of the wire bottom of the tray up inside the tray frame and tack them at the top, instead of tacking them flat on the bottom of the frame. The cone tumbler, also, should be constructed with the fewest possible cracks or edges capable of catching seeds. In an extraction operation involving more than one lot of seed, any cones or any seeds falling out of the proper container should be discarded. These precautions against mixing seed are particularly necessary if the seed is to be certified to a purchaser as to origin or is to be used in research.

To avoid excessive cost in extracting seed, the operator must locate his extracting plant advantageously, keep his investment in equipment within reasonable limits, prevent waste of heat and power, and make efficient use of labor.

For an agency extracting seed and also maintaining a nursery it may be most advantageous to locate the extracting plant at the nursery, especially if the nursery is centrally situated in the district from which cones are to be obtained. On the other hand it may be preferable to establish the extracting plant in connection with a sawmill or pulp mill, so as to take advantage of the supply of steam. The choice of a location may be influenced also by availability of suitable buildings; the space requirement argues against using property of high rental value, or constructing new buildings when old ones will do.

If large quantities of cones are to be collected at a point far distant from the main extracting plant or nursery, the cost of setting up a temporary plant and extracting the seed at the place of collection, plus the cost of shipping the seed alone, should be weighed against the cost of shipping the cones and extracting the seed at the main plant.

Time and effort expended in handling cones give greater returns if the drying racks are above the level of the tumbler and the tumbler is well above the receptacle for empty cones, instead of all operations being carried out on the same level. If artificial heat is to be supplied by any means other than flat steam coils, the deck supporting the cone racks must be high enough to make room for the furnace, stove, or vertical steam radiators. A plant having an elevated deck for the drying racks should preferably be located on a side hill, since in that case the cones can be transferred from trucks to the drying deck without waste of effort.

In constructing a building for an extraction plant it behooves the operator to make sure that his floors are strong enough to bear the weight of undried cones in the quantity for which he is providing space. Five hundred bushels of cones collected early in the season may weigh more than 11 tons.

If all final drying is to be done at air temperature, enough trays should be provided to hold the entire season's collection of cones at one time. Even at plants where half the seed extracted is slash pine, maturing in September, and half is longleaf, maturing in the middle or final third of October, it is unwise to count on getting the slash pine cones open by air-drying alone in time to free the trays for the longleaf cones. If artificial heat is used fewer trays are necessary, even though there must be several extra sets for precuring in addition to those used in the kiln. The more efficient the kiln, the fewer the trays required.

An operator should not construct or buy an extracting plant and its accessory equipment until he is reasonably sure what quantity of cones he will be obliged to handle in the near future. In laying out the plant provisions usually should be made for expansion, which may be occasioned by bumper crops, an increased planting program, or an improved market for seed.

Once cones have been freed of needles and other trash and have arrived at the extracting plant they should never again be handled singly, but always in baskets, bags, or trays or by means of scoops or chutes.

One handling of loose cones is saved by providing extra trays of standard size into which cones can be emptied from sacks for precuring, as these trays can be transferred directly to air-drying racks or to the kiln as soon as space is available. If standard trays are not available cones should be precured on tight floors from which they can be scooped up with shovels, or in shallow bins having removable sides to permit raking the cones out into the trays in which they are to be dried.

In small extracting plants, trays should be light enough to be handled by one man even when they are full of unopened cones; otherwise two men may often be required for filling, transferring, and emptying trays when the speed requirements and quantities involved justify the efforts of only one. The trays should be of the lightest construction consistent with good wearing qualities; if not designed to hold more than a bushel apiece of unopened cones, they may be made of 1- by 3-inch cypress reinforced at the corners with flat angle irons. Galvanized screen wire of $\frac{1}{4}$-inch mesh makes good bottoms. In the racks or kiln each tray should slide on separate rails or brackets, so that it can be removed independently of other trays whenever the cones open.

Trays 3 by 4 feet are about the largest a man can handle alone. Trays 3 by 3 feet or 2 by 4 feet are easier to handle and less likely to twist out of shape when heavily loaded.

The capacity in bushels of unopened cones one layer deep in 2- by 4-foot trays varies from 1 bushel for the large longleaf cones to 0.4 bushel for the small shortleaf cones. In the 3- by 4-foot trays the capacity is 1.5 and 0.6 bushels, respectively.

For extracting longleaf pine seed the trays should be placed 10 inches apart, bottom to bottom, to allow plenty of clearance for the opened cones. Other species require less space between the trays, with a minimum of 5 or 6 inches for shortleaf pine; details of spacing must be worked out to suit the special conditions and requirements of the extracting plant concerned.

For the most efficient extraction either at air temperature or by artificial heat, unopened cones should not lie more than one layer deep in the trays.

Any hopper or tumbler door for receiving cones should be considerably wider than the tray or other receptacle from which the cones are to be poured; if it is not, many cones will bounce out.

An intermittent tumbler of the type described on page 16 and shown in figure 3 (2½ by 2½ by 6 feet and mounted on a shaft of 2-inch iron pipe) will hold at one time the equivalent of 3 or 4 bushels of unopened cones. Considerably larger tumblers may be desirable in large extracting plants. A tumbler of the progressive type may well be 12 or 16 feet long, 3 feet square at one end and 4 feet square at the other. A progressive tumbler with this tapering form and a horizontal shaft is better than one of uniform cross section mounted on an inclined shaft, because it is free from the end-

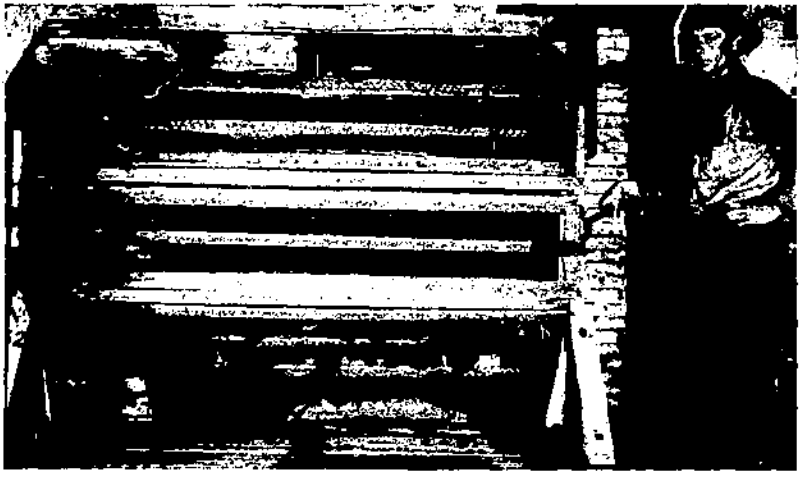

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FIGURE 3.—Intermittent tumbler for shaking seed out of opened cones. The seeds fall through grids underneath the tumbler and remain in a large, shallow box on the floor until the entire kilnful of cones has been run through the tumbler.

wise thrust of the inclined shaft. Cones are shoveled into the tumbler or run into it through a chute, at the small end. A 4-inch rim of wood keeps them from bouncing out. A few cleats across the sides may be used if needed to keep the cones from moving too rapidly to the large end, where they emerge.

Tumblers are usually turned by hand, but can be run by motor if geared down sufficiently to keep the cones from clinging to the wire because of centrifugal force.

A tray large enough to catch all the seeds dropping from the tumbler adds to convenience of operation. Where large quantities of cones are handled a better device is a wide, shallow bin built on a smooth floor under the tumbler and covered with a removable grid of narrow boards set on edge. The upper edges of these boards should be beveled to keep seeds from being lodged on them and crushed by the feet of the men operating the tumbler. Such a seed catcher is shown in figure 3; in this instance the catcher was de-

signed to hold 350 pounds of seed, all of which was shoveled out at one time.

If any considerable number of cones fails to open, these should be removed before the remainder are tumbled and should be given further treatment or discarded. A good method of sorting out unopened cones would be to slide the cones into the tumbler through a steep chute having in its floor longitudinal grids spaced widely enough to let unopened cones drop through but closely enough to stop cones that have opened half way or further. A coarse wire rack to catch the unopened cones would permit such seeds as passed between the grids to fall through into a seed tray. The grids would have to be removable and should be available in varying spacings from 0.8 or 1.0 inch for shortleaf to 2.0, 2.5, or 3.0 inches for longleaf.

CLEANING

The more fully the seed is freed of wings, empty seed, needles, and other trash the more accurate is the determination of cost, the cheaper the shipping, and the easier the sampling, testing, and sowing. As has previously been noted, seed cleaning is greatly simplified by sending to the extracting plant none but clean, sound cones.

Since the seed wing of longleaf pine is attached with remarkable firmness, seed of this species is ordinarily sold and sown without removing the wings. The greater part of the wing may be broken off, however, by running the seed through a winging machine consisting of stiff wire brushes bearing against the inside of a wire-lined cylinder, or by putting a bushel of seed at a time into a large sack and beating it sharply against a post. Care must be taken not to crack the seeds by banging them too vigorously. Partial removal of the wing not only saves shipping weight but makes possible the use of a number of mechanical devices for sowing in drills, and also reduces the probability that seed sown broadcast will be blown about by the wind.

The seed wings of all the southern pines other than longleaf are more or less easily removed either by hand rubbing or by means of a winging machine. A more efficient method is to wet the seed quickly but thoroughly, preferably with a strong jet of water, and then spread it in a wire-bottomed tray and dry rapidly, with frequent vigorous stirrings, either in the sun or under an electric fan. Wetting of seeds of these species loosens the two curved prongs with which the wing grips the seed. This treatment removes practically all the wings, and if properly carried out has no unfavorable effect on the seed.

Most of the wings and some of the other light trash can be removed by spreading the seed in a thin layer in a small cone tray or other wire-bottomed tray, holding the tray at the level of the shoulders, and then lowering it quickly about 2 feet, swinging it out of the path of the descending wings, which remain in mid-air for an instant before they begin to flutter down.

During the first 10 years of large-scale commercial collection, 1920–29, practically all southern pine seed was hand-rubbed and was either winnowed in the wind or cleaned over a fan. That these methods are far from satisfactory is shown by the high percentages of empty seeds given in table 7.

TABLE 7.—*Average percentages of empty seed in lots cleaned commercially by means other than agricultural seed-cleaning mills*

Species	Empty seed	Basis[1]	
		Cone lots	Cutting tests
	Percent	*Number*	*Number*
Longleaf	19	15	141
Slash	24	7	35
Loblolly	30	21	103
Shortleaf	43	14	82

[1] Includes all lots of unmilled commercially cleaned seed for which records of cutting tests in the 10 years 1920–29 are on file at the Southern Forest Experiment Station.

The use of good agricultural seed mills, operated either by hand or by motor, is replacing cruder methods of cleaning southern pine seed, to the great improvement of the seed. These mills remove impurities, if need be sort or grade the seed by means of oscillating screens of various degrees of coarseness, and winnow by means of an air blast, usually vertical, from a fan built into the mill. They dispose of practically all empty seed with a negligible loss of sound seed. One type at least is capable of cleaning longleaf seed with wings attached. Such mills are essential to efficiency in both commercial and investigative work involving any considerable quantities of seed. They are available in various sizes at low cost.

Where such mills are not available, seed can be given its final cleaning by pouring it from box to box in a strong wind, or by pouring it down a steeply sloping wire screen placed over an upward-tilted electric fan. When the fan is used, proper adjustment of its speed and of its distance from the screen makes possible the removal of some of the empty seed. Seed of southern pines other than longleaf can be freed of empties by immersion in water. Once they are thoroughly wet, most of the sound seed will sink and most of the empty ones will float. In a sample of loblolly pine seed studied, a cutting test made before immersion showed 33.4 percent of empty seed. After immersion, cutting tests showed 87.8 percent of empty seed in the portion that floated, and only 3.2 percent in the portion that sank.[4]

In buying seed, inquiry should always be made as to the method of cleaning, and assurance obtained that the process has not damaged the seed.

The price per pound of southern pine seed is likely to be higher the better the cleaning, both because of extra labor involved and because each bushel of cones yields a smaller weight of well cleaned than of poorly cleaned seed. The number of seeds per pound is smaller the better the cleaning, because it takes fewer full seeds than empty ones to make a pound. Even so, well-cleaned seed is likely to cost less per 1,000 trees produced.

[4] Baldwin (*1*), working with red spruce (*Picea rubra* Link.), obtained separation better than this by using absolute ethyl alcohol, but at the cost of some decrease in the power of the seed to remain viable in storage.

YIELD PER BUSHEL OF CONES

The yield of clean seed per bushel of unopened cones varies according to species, cone quality, method of drying, quantity of seed lost during extraction, percentage of empty seed, and method of cleaning. With so many factors involved, average figures for yields provide no definite indication of cone requirements. Table 8 gives figures for representative yields of seed, under normal conditions, per bushel of unopened cones. These figures are for seed cleaned in the wind or with an electric fan, not in modern seed mills. Table 9 gives numbers of seed per pound for such unmilled seed, for which percentages of empty seed coats are shown in table 7. Milling, by eliminating the empty seed, reduces the yield of seed per bushel of unopened cones, as given in table 8, by approximately 10 to 30 percent.[5] Even for cones of good quality, this reduction frequently brings the yield somewhat below the empirical figure commonly quoted, 1 pound per bushel. With cones of inferior quality the yield is often much below that figure.

A comparison between rates of drying at air temperature and by artificial heat, and between quantities of seed yielded, is given in table 10.

TABLE 8.—*Representative yields of clean seed per bushel of unopened cones dried at air temperature and by artificial heat*[1]

Species	Dried at air temperature	Dried by artificial heat	Species	Dried at air temperature	Dried by artificial heat
	Pounds	*Pounds*		*Pounds*	*Pounds*
Longleaf	1.08	1.45	Loblolly	0.76	----
	1.00	1.65		.81	1.16
	1.14	----		.97	1.58
	.87	----		1.00	1.62
Slash	1.00	----		1.15	----
	1.16	----		1.61	----
	1.43	----	Shortleaf	.83	----
				1.65	1.85

[1] Table based on all records available to the Southern Forest Experiment Station except those of yields rendered abnormal by adverse weather, premature collection, improper extraction, or abnormal insect damage. Seed was winnowed in wind or over electric fan, not in agricultural seed mill with oscillating screens and vertical air blast.

TABLE 9.—*Usual average numbers and extreme observed numbers of seeds of Southern pine per pound in samples of seed commercially cleaned*[1]

Species[2]	Usual average	Minimum	Maximum
	Number	*Number*	*Number*
Longleaf[3]	5,200	4,010	8,000
Slash	15,500	13,470	19,660
Loblolly	21,300	17,241	20,264
Shortleaf	[4] 69,200	41,614	84,985

[1] Table based on all records available to the Southern Forest Experiment Station of seed cleaned otherwise than with an agricultural seed mill with oscillating screens and vertical air blast. Samples measured were 100 percent pure but containing varying percentages of empty seed; see table 7. "Usual average" is based on inspection of an array, and checked against an arithmetic mean of the same data. "Minimum" and "maximum" are drawn from all samples observed by the station, exclusive of samples from strikingly abnormal lots of cones.

[2] For less important species, records for single samples, or for 3 or 4 samples at most, indicate the following numbers of seeds per pound: Sonderegger pine (longleaf-loblolly hybrid), 13,400; pond pine, 50,000; sand pine, 74,400; and spruce pine (*Pinus glabra* Walter), 77,500.

[3] Seed with wings attached.

[4] This figure may be unreasonably high, because of high percentage of empty seed in some samples (table 7).

[5] On the basis of 5 years' commercial collection, A. D. Read gives the following figures for average yields of kiln-extracted milled seed per bushel of unopened cones: Longleaf, 0.75 pound; slash, loblolly, and shortleaf, 0.90 pound.

TABLE 10.—*Rates of drying and seed yields, for cones of 1925 crop, at air temperature and by artificial heat* [1]

Species, time and place of collection, and method of drying	Period required for extraction [2]		Yield of seed per bushel of cones	
			Uncleaned	Commercially cleaned [3]
	Days	*Hours*	*Pounds*	*Pounds*
Longleaf pine, October, Texas, kiln-dried [4]		22	1.45	1.45
Loblolly pine, Oct. 6–11, Louisiana:				
Air-dried	15		1.25	.97
Kiln-dried		22	1.51	1.16
Loblolly pine, Oct. 19, Arkansas:				
Air-dried	7		1.90	1.62
Kiln-dried		22	1.96	1.58
Shortleaf pine, Oct. 19, Arkansas:				
Air-dried	7		2.00	1.65
Kiln-dried		22	1.82	1.65

[1] Table based on studies made by E. W. Hudley when assistant silviculturist, Southern Forest Experiment Station.
[2] Kiln-dried cones were kept at 120° F., with constant relative humidity of 30 percent, except the longleaf lot, which had 20 percent relative humidity.
[3] Over electric fan, not in seed mill.
[4] Records of seed of this lot extracted at air temperature are unavailable because part of the seed so treated was destroyed by birds.

There is some evidence (*35*) that the yield of sound seed per bushel of cones is less when the cone crop is light than when it is heavy. Experience and general observation suggest, also, that the yield per bushel of cones gathered from isolated trees or in very open stands is below average, owing to relative incompleteness of pollination.

STORAGE

An effective method of storing seed for at least 1 or 2 years is of the utmost importance as insurance against failure of seed crops. It also facilitates obtaining seed of suitable heredity for planting on given areas; may reduce the cost of artificial reforestation during periods when crops are light and collection expensive; and may prevent total loss of seed not used in the first season following collection.

Seed of southern pines, particularly longleaf pine, has been noted to deteriorate rapidly in storage. This rapid spoiling may have resulted partly from inherent characteristics of the seed, partly from climatic conditions, and partly from unsuitability of the storage methods used. Cold storage, according to the results of recent tests, keeps all species of southern pine seed in good condition for at least 1 or 2 years.

A further important consideration in seed storage is its effect upon promptness and completeness of germination. It has, however, been very difficult to obtain conclusive data on this point because of the wide variation that often occurs in tests of comparable seed samples. Figure 4 shows differences in promptness of germination between fresh seed and seed in cold storage for 1 and 2 years. The significant fact is that the differences here shown are less than differences that often occur between comparable samples of fresh seed.

The most convincing data obtained in this study indicate that the temperature at which seed is stored has a considerable influence on

subsequent germinability. In one instance two lots of longleaf pine seed that had been stored in paper sacks for 1 year yielded 60 percent germination for the one lot that had been stored at 32° F. and 26 percent for the second, stored at ordinary room temperature. Check tests of fresh seed from these two lots each yielded 55.6 percent. In these tests the only important variable was temperature, and the very decided indication in favor of a freezing temperature for seed storage was supported by other tests of longleaf, slash, and shortleaf pine in which seed was stored in sealed or

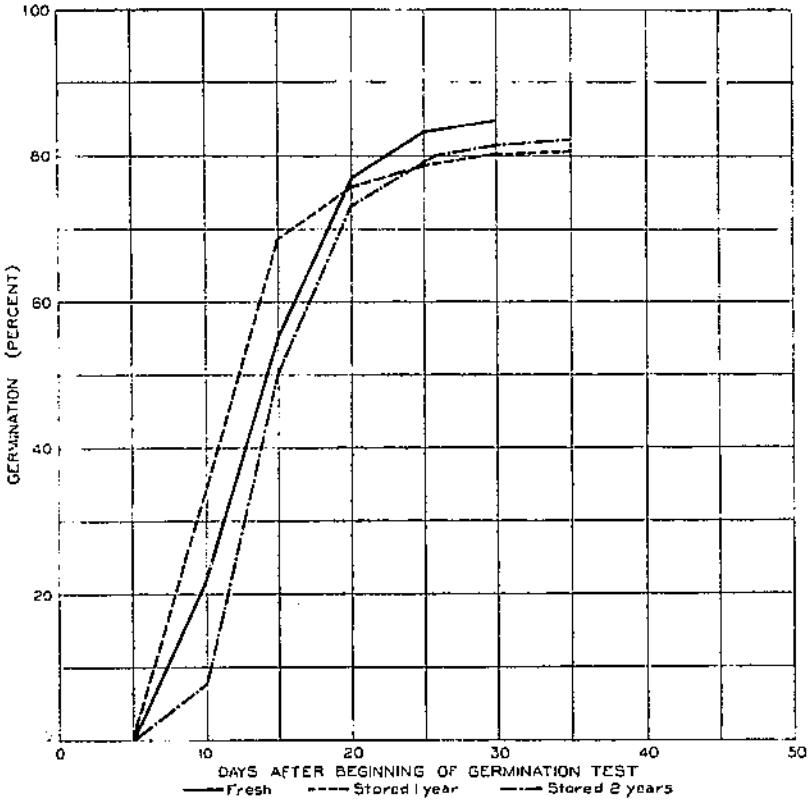

FIGURE 4.—Rates of germination of longleaf pine seed when fresh and after storage in sealed glass jars at 25° to 35° F. for 1 and 2 years, respectively. Percentages based on total numbers of seed with kernels.

closed containers. In every case seed stored for 1 year at room temperature had a notably lower germination than either the seed in cold storage or the check sample of fresh seed. In two 2-year tests of longleaf pine seed in sealed or covered containers, germination of seed in cold storage compared very satisfactorily with the check samples, whereas the two samples of the same seed stored at room temperature completely failed to germinate.

So far as these few tests can be relied upon, they indicate that slash pine seed fares as well at a temperature around 40° F. as longleaf and shortleaf seed do at freezing temperature.

In all of the tests made, the tendency of several methods of storage to give very different results with different groups of the same species indicates that some unknown factor—such, perhaps, as moisture content of the seed when it is placed in storage—has a marked effect on keeping quality. Coile (7) has shown that in sealed glass tubes at natural air temperatures slash pine seed keeps better if its moisture content is low. For the present, cold storage is the only method recommended.

Every container of seed placed in storage should be labeled with particular care, one tag being placed on the outside of the receptacle and a duplicate inside.

TESTING

Intelligent use of seed depends upon knowledge of its identity, purity (i. e., freedom from foreign matter and dwarfed, malformed, broken, or weeviled seed), and germinative ability, and of the number of seeds per unit of weight.

The species of a sample of southern pine seed can usually, but not always, be determined by comparing the sample with others the species of which is known. To be certain as to place and date of collection, and to be certain in all instances as to species, the nurseryman must supervise the collection of his seed supplies or buy from reliable dealers only, and must exercise care in regard to all seed records and labels. To determine purity requires only simple analysis and weighing, and to determine number of seeds per unit of weight requires only simple weighing and counting. Determining germinative power is a more complicated process.

PURITY

To determine the purity of a lot of seed, a representative sample is weighed and the apparently sound seeds in it are separated out and weighed. The weight of the apparently sound seeds as a percentage of the gross weight of the sample is used as the purity percentage of the lot. This percentage times the weight of the lot, times the number of seeds per unit of weight, gives the number of seeds available for sowing.

The separation of apparently sound seeds from other seeds and trash for this purpose does not involve removing wings that have remained attached to seed.

For determining purity percentage it is best to take 5 or 10 random samples. Suitable weights for individual samples are: Longleaf pine, 4 ounces; slash pine, 2 ounces; and loblolly and shortleaf pine, 1 ounce. The separation can be made most easily by spreading the seed in a thin layer on a sheet of white paper and pulling away individual seeds with one finger. The balances used to weigh the seed must be sufficiently sensitive and accurate so that instrumental errors will not obscure differences in purity between samples.

NUMBER OF SEEDS PER UNIT OF WEIGHT

The simplest way to determine number of seeds per pound is to count out a few 1,000-seed lots from the clean seed. A quick way to do this without sacrificing accuracy is to spread the seeds in a single layer on one-half of a sheet of white paper, and then, with

one finger, pull them onto the other half in groups of 10. The accuracy of the count of each group can be checked at a glance. Ten groups of 10 seeds each can then be swept aside onto another sheet in a compact pile, until there are 10 piles of 100 seeds each.

One thousand seeds from each sample of the sizes specified in the foregoing should form a sufficient basis for determining the number of seeds per pound. Weight per 1,000 seeds in grams can readily be converted into number of seeds per pound by dividing, by it, the number 453,592, since 1 pound equals 0.453592+ kg.

CUTTING AND HAMMER TESTS

The potential germination of fresh seed can be roughly determined through either a cutting test or a hammer test.

In the cutting test seeds are cut open with a sharp knife and the kernels examined. The kernel of a sound seed is firm and whitish. For a simple cutting test intended only to afford a rough guide to density of sowing, 5 samples of 100 seeds each from each homogeneous lot or shipment may be adequate. In more elaborate cutting tests, particularly in connection with studies of germination, it is suggested that use be made of a 250-seed sample divided into 10 equal parts. (The reasons for using this form of sample are discussed in connection with the standard sand-flat germination test.)

In the hammer test, seeds are laid one by one on an anvil and hit with a hammer. The hammer smashes empty seeds, but crushes sound ones into oily white spots studded with bits of brown seed coat. The hammer test consumes much less time than the cutting test.

It is practically useless to apply either cutting tests or hammer tests to stored seed. Even when applied to fresh seed, these tests fail to show in full the percentage of seeds that will not germinate. If estimates of quantity of seed needed for sowing are based on cutting tests only, a moderate to heavy reduction must be made in the expected germination percentage as indicated by the test. This reduction must be based on experience with the species and in the nursery in which the seed is to be sown.

GERMINATION TESTS

Actual germination tests of representative samples are a better basis than cutting or hammer tests for judging the quality of fresh seed, and furnish the only acceptable basis for judging the quality of stored seed of the southern pines. They are essential to investigations of many different kinds, for example, studies of the effectiveness of very young or very old trees as seed producers and studies to determine what temperatures and humidities should be used in extracting seed by artificial heat.

STANDARD SAND-FLAT TEST

A standard sand-flat germination test particularly adapted to southern pines, although not ideal, gives comparatively consistent results and is relatively simple and inexpensive. When conducted strictly according to directions, and with seed pretreated as described on page 33, it should be of practical value to seed dealers and nursery operators alike.

In this test 25 seeds are sown in each of 10 drills. Records are kept separately for each drill. The flats are examined daily, and germinating seeds are pulled as soon as they break through the sand or make conspicuous humps in it.

The flats containing the sand are 10½ by 10½ by 3½ inches inside. The sides are made of 1-inch pine strips. The bottoms are either of tongue-and-groove ½-inch pine flooring or of 1- by 12-inch pine.

Before being put into the flat, the sand is uniformly moistened by the addition of water equivalent to 15 percent of its dry weight. The sand is packed in the corners, to avoid later settling, but is not settled or packed elsewhere except so far as this is unavoidable.

The seeds to be sown are drawn from the entire sample by mixing the sample thoroughly, heaping it in a broad cone-shaped pile, flattening the pile, halving or quartering it, remixing a half or a quarter, and repeating until the final sample contains slightly more than 250 seeds. From this sample 250 unbroken, apparently normal seeds are taken at random for sowing. The wings of longleaf pine seeds must be removed, to conserve space in the flats.

The drills are slightly more than one-eighth inch deep. They are made with a scraper of which the ends rest on the edges of the flat and the edge projects down into the moist sand.

A device used in preparing the flat is a trough or tray, three-fourths by 10¼ inches and three-fourths inch deep, of galvanized wire having 16 meshes to the inch. The flat is set up with 10 such trays just under the surface of the sand. The drills in which the seed is to be sown are made directly over the centers of the trays. When germination is complete and it is desired to make a cutting test of the ungerminated seeds, the seeds remaining in each drill are lifted simultaneously simply by lifting the tray, and freed of sand by dipping the lower portion of the tray into a pail of water and gently shaking the tray. Trays can be cut and folded at the rate of 50 to 80 an hour. They ordinarily last for 2 or 3 tests of 2 months each. Their use reduces by about three-quarters the time required to lift the seed.

In sowing the seed, use is made of a drill seeder (fig. 5) of galvanized iron, fitted to the top of the flat. A slit 10¼ inches long, near one edge, opens downward into one drill. Other parts of the seeder cover adjacent drills, and the upturned section at the opposite edge prevents loss of seeds. Successive samples of 25 seeds each can be counted out on the seeder, spaced evenly, and, by means of a straightedge, pushed through the slit into the drills far more rapidly and accurately than would be possible by hand alone.

The seeds are covered with dry sand to a depth of one-eighth inch from their centers; greater depth has been found to reduce germination.

After the sowing, the flats are watered with a small fine-spray watering can, and set in rows on laboratory tables in a room the temperature of which ranges between about 70° and 90° F. The watering is repeated as often as necessary, usually daily or every other day, and the flats are rearranged systematically each day to equalize their exposure to light and heat.

Daily individual and cumulative records of germination for each sand flat are made on a suitable form. If there are 25 seeds per

drill, each germinated seed counts 4 percent. Time is recorded from date of start, instead of by day of month. The sum of 10 drills divided by 10 gives the average germination percentage for the entire flat. The test is usually continued until new seedlings have ceased to appear at the surface.

TESTS IN MEDIA OTHER THAN SAND

Several germinating media other than sand have been tried by the Southern Forest Experiment Station and its cooperators. One of these is acid peat moss, known also as "florists' peat." This is used in the form of a mat, made by compressing moist moss upon a mold. The mold is made by tacking several triangular strips of wood to a smooth board and arranging around the series of strips a border of wire three-fourths inch high to hold the peat in place. To keep the wire from bulging, while the peat is being packed in place the

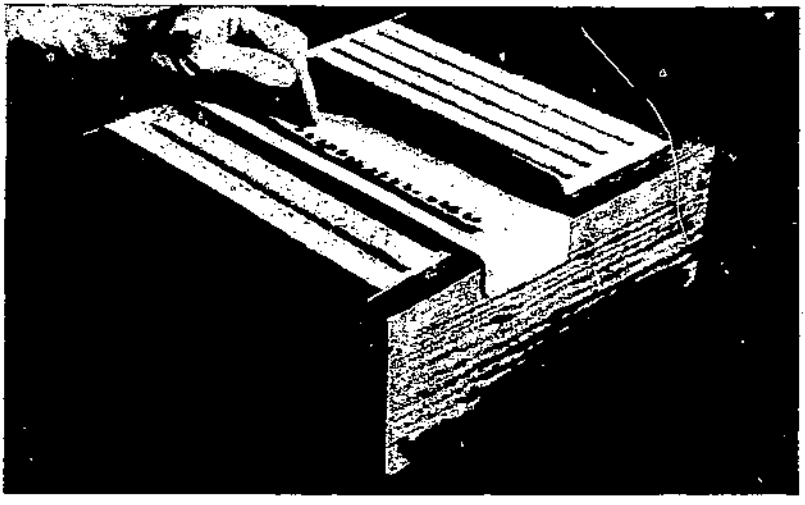

FIGURE 5.—Sowing seed in sand flat by means of the drill seeder.

wire is surrounded with a wooden frame. When the mat has been compressed as tightly as possible with the hands, mat, mold, and frame are inverted as a unit. First the mold is gently lifted off, and then the frame is removed from the mat, which remains supported by the wire border and bears on its upper surface a series of grooves impressed by the mold (fig. 6). The seeds are set up usually at the rate of 25 to each of 10 grooves. The mat is placed in a square glass baking dish of suitable size and depth and covered with glass. Enough water is poured into the dish so that after the peat has absorbed all it will take up, a shallow layer will remain free in the bottom. This medium keeps the seed well supplied with water, and offers somewhat less encouragement to mold than do most media on which the seeds are exposed directly to the air. The peat appears to stimulate the germination of seed of certain species, particularly slash pine. Exposing the seed to low temperatures as a preliminary to testing is particularly easy in connection with the peat-mat test; all that is necessary is to place the mat, with the seed on it, in a suitable refrigerator. The peat mat has the further advantages that it

requires much less space than the standard sand flat, weighs less, and does not contain any grit. At the present stage of development of its use, it gives less uniform results with some classes of seed than does the sand flat.

Germinating media that have been tried with less success are blotters or other absorbent papers used in various germinating chambers, including adaptations of the Jacobsen apparatus. These media are less easy to maintain at the proper moisture content than either sand or peat, and are more likely to become covered with mold. Several

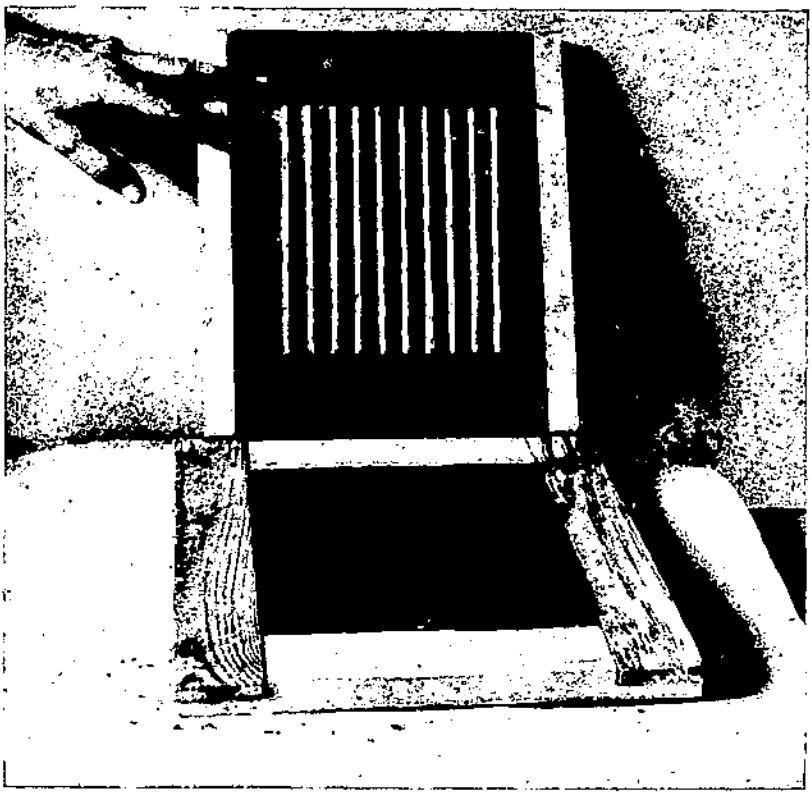

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FIGURE 6.—Removing the mold from the peat mat, which is still enclosed in the wooden frame.

of the species of mold particularly annoying in germination tests thrive upon paper itself.

A few tests of southern pine seed have been made in sand mixed with garden soil or other loam and in loam alone. Samples tested in this manner have shown germination percentages strikingly lower than those of samples from the same original lots tested in pure quartz sand. It is thought that damping-off fungi in the loam may have killed many of the seeds.

The most exacting standards of technic are necessary to obtain reliable results in seed testing. Unless germinated seeds are pulled and discarded when their germination is recorded, errors result

from their death and decay, or they become confused with more recently germinated seeds. The use of odd or irregular numbers of seeds in testing increases the likelihood of error, because such numbers are confusing and because they increase greatly the difficulty of computations and decrease the applicability of some desirable statistical methods.

At the end of a test all ungerminated seeds should be removed from the testing medium, cut with a sharp knife, and tallied as sound, spoiled, or empty. The total of the seeds tallied from day to day as germinated should be checked against the total number of seeds planted less the total number of ungerminated seeds lifted at the end of the test. Recording the number of empty seeds makes it possible to compute average germination, at any stage of the test, on the basis of all seeds with kernels (see next paragraph). The presence of a great number of ungerminated sound seeds at the end of the test indicates either that the test has not been run long enough or that the proper germination or pretreatment technic has not been used.

METHODS OF EXPRESSING AND ANALYZING RESULTS

The final germination percentage and the period required to attain it, or a curve showing the course of germination by 5- or 10-day intervals, is usually adequate as a statement of the results of a routine germination test. In tests to determine the quantity of seed to purchase or sow, final and intermediate percentages should be based on the total number of seeds tested. In tests to determine the effect of extraction or storage methods or special treatments to hasten germination, percentages based on total numbers of seeds with kernels are preferable.

The reliability of purity percentages, germination percentages, and seed weights may be estimated and expressed by computing the standard deviation of subdivisions of a single test, such as the 5 or 10 random samples suggested under Purity or the 10 drills of 25 seeds each used in the standard sand-flat test. Purity percentage, germination percentage, or weight as indicated by a series of tests may be expected not to differ (by chance) from the corresponding actual mean of the entire lot of seed by more than three times the standard deviation of the mean. The difference between the means of tests of two different lots of seed is ordinarily considered significant if it is three or more times the standard deviation of the difference.[6]

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[6] The formulae for the standard deviation of the individuals and the standard deviation of the mean, respectively, are

$$\sigma = \sqrt{\frac{\Sigma d^2}{N-1}}$$

$$\sigma \text{ mean} = \frac{\sigma}{\sqrt{N}}$$

The formula for the standard deviation of the difference between two means, M_1 and M_2, is

$$\sigma \text{ difference} = \sqrt{\frac{\sigma_1^2}{N_1} + \frac{\sigma_2^2}{N_1}}$$

In these formulae,
N = number of observations, e. g., the number of drills for which germination percentages are recorded separately or of random samples for which purity percentages or weights are recorded separately.
d = difference between the value of any one observation and the value of the arithmetic mean of all observations.
Σ = summation.
σ = standard deviation of the individual observations.
σ mean = standard deviation of the mean.
σ difference = standard deviation of the difference between two means.

Details of methods of testing the reliability of results of tests such as those here referred to are given by Collins (*8*), Gevorkiantz (*14*), and Youden (*40*), and in standard works on statistical methods.

Statistical analysis is a useful tool in research on forest-tree seed, but should not be attempted without an understanding of its limitations.

TENDENCIES INDICATED BY RESULTS

Among the tendencies noted as an outcome of the germination tests perhaps the most distinct is a tendency for both rapidity and completeness of germination to vary directly with size of seed. Seeds of longleaf, which are larger than those of any other of the four principal species, usually show the most rapid and complete germination, when fresh. They deteriorate more rapidly in storage than seeds of the other species, however, unless held at temperatures only slightly above freezing. Slash pine seeds come next to longleaf in rapidity and completeness of germination under the best conditions, but tend to become dormant when stored in the South at room temperature either for a full year or over a winter only. In many instances slash pine seed held over winter in unheated nursery seedhouses has germinated more promptly and completely than samples drawn from the same lots and held for a while in a heated office prior to testing for germination, and it has been demonstrated that slash pine germinates promptly and well after cold, moist stratification. Slash pine seed sometimes retains its viability for 2 or 3 years even without cold storage. Occasional samples of shortleaf pine seed approach the record for rapidity and completeness of germination set by longleaf seed of good quality.

In germination tests of southern pine seed it is unnecessary and possibly undesirable to maintain uniform temperatures. Longleaf pine seed germinates at temperatures very little above freezing (*3*, *15*, *35*). Germination of seed of the other species has apparently been delayed by temperatures below 55° and prevented by temperatures a little below 50°. Seed of all four species has been killed in the middle of the test by temperatures in excess of 120°. In germination tests started at intervals of 1 month throughout the year, longleaf pine seed from the same lot showed a sudden falling off of germination in June, minimum germination in July or August, and a gradual recovery in power to germinate during the fall, apparently in part because of changes in average temperature from season to season.

The relation of moisture content of the medium to the rapidity and completeness of germination has not been clearly shown. It has been noted, however, that permitting the moisture content to decrease for 2 or 3 days toward the end of a sand-flat test, and then bringing it approximately to the 15 percent at which the sand flats were originally set up, sometimes increases total germination by stimulating germination in a few seeds that would otherwise have remained dormant at the end of the test. Results of experiments in which seed was soaked with various disinfectants (and check lots were soaked with water) as a preliminary to germination tests

indicate that soaking hastens germination, although it does not necessarily increase germination percentage.

Mold causes relatively little trouble in germination tests run in sand, but on most other media it is always at least an annoyance. Heavy mold growth is sometimes associated with complete failure to germinate, particularly in the case of seed the germinative energy of which has been reduced by storage, especially longleaf pine seed. Usually the conspicuous mold development is on seeds that are already dead or nearly so; but some fungi, mainly those which do not make a very conspicuous external growth, are able to kill seed before it starts to sprout and may interfere to a considerable extent in tests on media containing organic matter (*23a*). Efforts to control mold by rinsing southern pine seeds in formalin solution or by coating them with bordeaux mixture or colloidal sulphur have not fully succeeded and in many instances have given no control whatever. The organic mercury compounds have not been tested so thoroughly as the compounds just referred to, because they appeared to reduce germination and to cause development of stubby radicles incapable of elongation after the first day or two.

TREATMENT BEFORE TESTING OR SOWING

Fresh seed of loblolly and shortleaf pine, or seed of these two species and slash pine kept for a year or more by means other than cold storage, often fails to germinate quickly and completely. Even fresh seed of slash pine sometimes germinates tardily and in unsatisfactory percentage. If this occurs in the laboratory, it decreases the value and increases the expense of germination tests. If it occurs in the nursery, it increases the cost of seed and labor per 1,000 trees and lowers the quality and uniformity of the planting stock. Obviously, therefore, it is desirable that such seed be subjected to some treatment conducive to prompt and complete germination.

Such a treatment, developed at the Boyce Thompson Institute for Plant Research (*3*), consists in mixing the seed with moist acid peat, or arranging thin layers of seed in alternation with layers of moist peat, and keeping seed and peat at temperatures of from 32° to 40° F. for a month or 6 weeks. Actual mixing of the seeds with the peat can be prevented by placing them between folds of cheesecloth. It is well to place in each tray or in each cheesecloth layer just enough seed for a definite area of seed bed. The seed and peat can be put up in shallow wire trays, and stored for refrigeration either in a commercial cold-storage plant or elsewhere. The seed should be inspected at intervals to make sure of its remaining moist, and should be stirred, if the trays are more than 3 inches deep, to insure proper aeration.

Table 11 gives the results of tests made by this method with seed of southern pine species at the Boyce Thompson Institute and the Southern Forest Experiment Station, and by the Brown Co., Berlin, N. H., and brings out the great increase in rapidity and completeness of germination that ordinarily results from the treatment. Figure

7 shows the course of germination of samples of southern pine seed tested with and without pretreatment in acid peat.

TABLE 11.—*Germination rat[illegible]d percentages of southern pine seed pretreated by stratification in moist acid peat at low temperatures, and those of comparable seed not so treated*

History of pretreated seed		Final germination		Total germination period		Agency[1]
Stratification period	Temperature	Pretreated	Untreated	Pretreated	Untreated	
	°C	*Percent*	*Percent*	*Number*	*Number*	
FRESH LONGLEAF SEED						
30 days	5	77.0	75.0	26	40	B. T. I.
36 days	3	72.0	55.6	40	40	S. S.
30 days	3	72.0	65.6	35	40	Do.
30 days	5–7	70.0	51.0	29	45	B. Co.
FRESH SLASH SEED						
60 days	8	95.0	79.0	15	60	B. Co.
36 days	3	93.2	58.8	25	50	S. S.
60 days	5	82.0	3.0	20	45	B. T. I.
60 days	5	78.0	37.0	29	100	Do.
FRESH LOBLOLLY SEED						
60 days	5	84.0	41.0	24	100	B. T. I.
36 days	3	68.0	12.4	40	50	S. S.
71 days	8	80.8	50.0	15	60	B. Co.
60 days	5	56.0	2.0	29	45	B. T. I.
YEAR-OLD LOBLOLLY SEED						
60 days	5	70.0	2.5	20	42	B. T. I.
71 days	8	68.0	64.2	15	60	B. Co.
35 days	0–5	60.4	58.4	50	98	S. S.
FRESH SHORTLEAF SEED						
36 days	3	98.0	74.0	20	50	S. S.
36 days	3	94.0	76.4	25	50	Do.
60 days	5	84.0	57.0	18	90	B. T. I.
YEAR-OLD SHORTLEAF SEED						
30 days	5	82.0	39.5	28	45	B. T. I.
58 days	8	81.2	88.8	30	60	B. Co.

[1] B. T. I.=Boyce Thompson Institute, data taken from (9); S. S.=Southern Forest Experiment Station; B. Co.=Brown Co.

COSTS AND MARKETS

The labor required to collect cones of the southern pines varies from about one-fifth man-hour per bushel of longleaf pine cones collected from felled trees in a good seed year to about 6 to 10 man-hours per bushel of shortleaf pine cones gathered by climbing in a year of poor seed production. An extracting plant with a capacity of 300 bushels of cones every 24 hours can be operated by 2 to 4 men; a less efficient plant with a capacity of less than 100 bushels every 3

days may require the same number. As a result of such variations, the cost per pound of cleaned seed ranges from $1 to $6 or more. Organizations collecting their own seed can sometimes get it for less: longleaf pine seed delivered at the nursery of the company collecting and extracting it has cost as little as 26 cents per pound.

Because of greater difficulty of collection or extraction, or greater uncertainty of demand, seed of pond, sand, or spruce pine usually costs more than that of any of the four principal species.

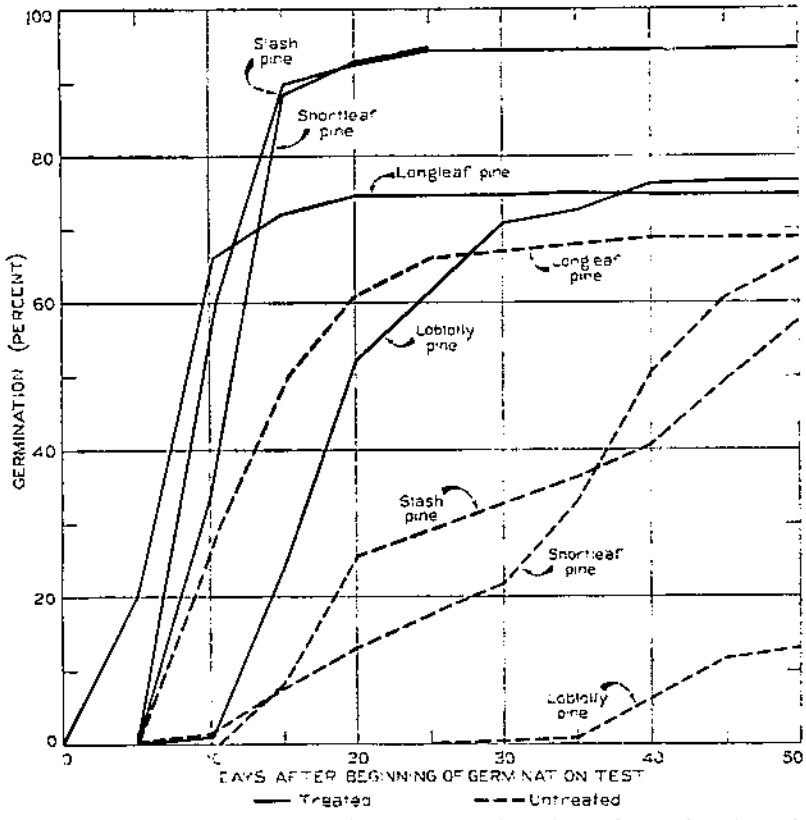

FIGURE 7.—Rates and completeness of germination of southern pine seed pretreated by stratifying for 1 month in moist acid peat at approximately 38° F., and of comparable seed not so pretreated.

On the basis of acreage planted and of average germination percentages it is estimated that the domestic consumption of southern pine seed in the decade 1923–32 may have totaled 34,000 pounds. Exports amount to several tons each year.

RECORDS

Tree seeds are not worth much unless accompanied by a record showing when and where they were collected and to what treatment they have been subjected, especially during extraction and storage. For seed to be used in research a much more complete record is often

needed, indicating the character of the parent tree and of the soil on which it grew.

An administrative organization using from 1 to 20 or 30 large lots of seed each year can keep its seed records most simply and easily by numbering each lot serially as received, noting species, source, date of collection, method of extraction, method of storage, total quantity, and use and final destination of each of the various portions into which the lot is divided. Purity percentage, germination percentage, and price per pound should be included in the record. The record should be kept systematically in a substantial bound book of ledger form. The number given to each seed lot will become a part of the nursery record and the plantation record.

THE NURSERY

General principles and practices common to most southern pine nurseries are discussed in this bulletin on the basis of data from four nurseries maintained by the Southern Forest Experiment Station in Mississippi, Louisiana, and Florida between 1923 and 1933, from a number of minor tests carried out by the station in the nurseries of cooperating lumber companies, and from systematic surveys by the station of 19 different experimental and commercial nurseries in 10 States. The details of nursery practice must be worked out on the ground for each individual nursery.

LOCATION AND SITE

It is important that the location of a forest-tree nursery be such as to permit easy and inexpensive transportation of planting stock to the area or areas where it is to be used. It is important also that a reasonably abundant supply of labor be available near the nursery. In the South it is usually possible by locating the nursery in or near a small town to obtain satisfactory labor without the necessity of providing living quarters or transportation for workmen and without incurring unduly high taxes or rents.

The importance of an adequate supply of water cannot be too strongly emphasized. Tree seedlings growing in dense stands require very large quantities of water in the top 6 or 8 inches of soil. If rainfall is poorly distributed, or if it totals much less than 5 inches during any month between April and September, it must be supplemented by artificial watering. To apply the equivalent of 1 inch of rain to an area of 1 acre requires 27,154 gallons of water. The commonest source of supply in the South is a deep well. A few nurseries use city water. An adequate supply can sometimes be assured by damming a small creek, if the flow is fairly constant throughout the year. Prospective water costs, including costs of pumps and of labor, must be estimated carefully before decision is made as to a nursery site.

A loam or sandy loam soil is the most satisfactory. Unless the land is very low and flat it is preferable that the loam be underlain by some slightly less permeable soil, since this decreases both moisture loss in dry weather and leaching of plant nutrients throughout the year. The surface soil should preferably be not less than 12 or

14 inches deep, so that plowing and, especially, any leveling that may be done will not expose the heavier subsoil.

Fairly sandy soils frequently meet all forest-nursery requirements if they are underlain by less pervious soils. The cost of enriching such soils with various fertilizers is offset by greater ease of working, and most species of pine develop better root systems in light than in heavy soils. Every effort should be made to avoid stiff soils, and to choose soil that will neither wash badly in rainy weather nor puddle during rain and cake and crack thereafter.

Southern pines thrive on slightly to moderately acid soils (pH 6.5 to 4.5).

The small number of species ordinarily grown in a southern pine nursery, and the lack of need of transplanting, make it unnecessary that the nursery contain a variety of soils. In fact, the more uniform the soil the better, as soil uniformity simplifies nursery practice and results in greater uniformity of product.

It is important that drainage be at least moderately good. "Crawfish land"[7] is undesirable, and a nursery should never be established on land at all likely to be flooded by stream overflow or by backwater.

A relatively level site is preferable. On slopes exceeding 3 percent most of the soil types adapted to the production of southern pine planting stock wash too easily to be desirable.

North and east exposures are preferable to west and, especially, to south exposures, because they have less tendency to dry out seriously and also because they involve less heat injury.

Planting stock of southern pines can be grown with fairly regular success by a competent nurseryman even on an adverse site, if the water supply is adequate. Stock of the best grade, however, can be produced only on soil naturally fertile or easy to fertilize, well drained, of good moisture-holding capacity, and easy to cultivate; and the better the site the more cheaply a given quality of stock can be produced.

Among several otherwise equally desirable nursery sites, choice should rest on the one where there seems to be least danger of infection with disease, infestation by insect pests, or attack by injurious animals or birds. In particular, a nursery in which longleaf pine is to be grown should be placed as far as possible from young stands of longleaf pine seriously infected with brown-spot needle blight. It is undesirable that a nursery be located near pecan groves or stands of other hardwood species the leaves of which furnish food for adult May beetles, since larvae of this insect are a nursery pest. Grasslands in particular are apt to harbor large grub populations.

It is well that the location of a nursery allow plenty of room for expansion.

LAY-OUT

The area desirable for a nursery varies not only with the quantity of stock to be produced but also with the species of the stock, the method of sowing to be used, optimum stand density as determined

[7] This term is applied to soil so poorly drained that it remains moist enough to furnish a home for semiterrestrial crawfish (*Cambarus* spp.). Such soil is difficult to work and unfavorable to the growth of pines, and the crawfish destroy much nursery stock by covering it with mounds of mud thrown out of the mouths of their burrows.

by character of soil, and the schedule of soil-improvement crops found necessary to keep the nursery soil in good condition. Drill sowing calls for somewhat more space than broadcast sowing. The lowest desirable density is usually about 20 seedlings per square foot, and the highest not more than 60. (Desirable densities for individual species are discussed on p. 46.) Table 12 shows the approximate areas, in square feet and in numbers of 4- by 50-foot beds, required to produce 100,000 seedlings at each of several densities.

TABLE 12.—*Net and gross areas and numbers of beds required to produce 100,000 seedlings at different densities when drill sown or broadcast sown*

Drill sown				Broadcast sown			
Seedling density (number)	Beds	Net bed area	Gross bed and path area	Seedling density (number)	Beds	Net bed area	Gross bed and path area
Per running foot:	*Number*	*Sq. ft.*	*Sq. ft.*	*Per square foot:*	*Number*	*Sq. ft.*	*Sq. ft.*
10	25.0	5,000	7,500	20	25.0	5,000	7,500
12	23.8	4,170	6,250	25	20.0	4,000	6,000
15	16.7	3,330	5,000	30	16.7	3,330	5,000
18	13.9	2,780	4,170	40	12.5	2,500	3,750
				50	10.0	2,000	3,000
				60	8.4	1,670	2,500
				75	6.7	1,330	2,000

[1] *Beds are 50 feet long and 4 feet wide; paths 2 feet wide. Drills 6 inches apart.*

Hand weeding is difficult in beds more than 4 feet wide and practically impossible in beds more than 5 feet wide. The standard width in the southern pine region is 4 feet. Beds may be of any desired length, but usually are much longer than the 12 feet common for many years in other regions. Beds 25 feet long are sometimes used if frames or covers of any sort are required, but still greater length is usually preferable because it reduces charges for both labor and materials. One State nursery uses beds 500 feet long. A bed 50 feet long and 4 feet wide is a convenient areal unit on which to base estimates as to quantities of seed or fertilizer to be used or of stock to be grown and shipped.

In a nursery having an overhead sprinkling system, it is preferable that the length of the beds parallel the sprinkler lines. This permits grouping beds in blocks according to the sprinklers by which they are watered. All the beds of a block supplied by a given line can be made up and sown at one time and be wet without wasting water or disturbing unsown beds. If arrangement with regard to sprinkling lines does not conflict, it is best to run the beds up and down the slope in nurseries that are nearly level or are poorly drained, and across the slope where slope is steeper, to retard run-off and reduce soil wash.

The size and arrangement of paths and roads depend so largely on conditions and management details of the individual nursery that no general rule can be laid down. Paths 2 feet wide, besides being more comfortable for workmen than narrower paths, allow room for wheelbarrows. Narrower paths are preferable where limitation of space makes it necessary to devote more than two-thirds of the nursery area to the beds themselves, or where the water supply is so

limited that it is particularly desirable to avoid wasting water on paths.

Nurseries less than an acre in area seldom need interior roads. The larger the nursery, the greater the need of permanent roads. Nursery roads should always be so laid out that passing and turning will require minimum space and time.

Tanks, pumps, and main pipe lines, for greatest efficiency, must usually be located at the upper side of the nursery. The location of the main feed line must be selected very carefully if water is to be supplied by gravity or applied to the beds by irrigation. A little sketching and measuring on a map of the nursery before the watering system is installed may result in substantial saving through more efficient arrangement of pipe lines.

It is always wise to construct a good fence around the nursery, to protect it from livestock or vandals. The fence should have two gates, so that trucks can pass through the nursery without turning. The gates should be well enough designed and constructed to stay closed when shut, to swing open at a touch, and not to swing back against an entering car or truck.

The nurseryman's living quarters should be at the nursery or close enough to enable him to watch developments daily throughout the year.

PREPARATION

Nurseries are plowed and harrowed according to the agricultural practice suited to the locality, except that the soil is not thrown up into rows or hills as it would be for cotton or certain other crops. Plowing should be deep enough to provide good growing conditions for roots to a depth of 8 inches, but not deep enough to expose any subsoil unfavorable to the seedlings.

The choice of harrow depends not only on the character of the soil but also on the character of the weeds most likely to cause trouble in the nursery. The presence of coco grass (*Cyperus rotundus* L.) makes it undesirable to use harrows other than the disk harrow, because they spread its bulbs. If coco grass is absent, certain forms of toothed harrows can sometimes be used to work roots of Bermuda grass (*Capriola dactylon* (L.) Kuntze) to the surface. A device known as a whirling harrow has been used very effectively for this purpose.

Seed beds should be laid out accurately as to size and perfectly as to alinement, unless some peculiarity of the nursery soil makes it necessary to fit the system of beds very closely to the contours of the land. A slipshod lay-out spoils the nursery's appearance and has an unwholesome effect on the attitude of nursery foremen and crews, making for slackness and carelessness in all operations.

Methods in common use for laying out beds vary all the way from regular engineering use of transit and steel tape to various simple applications of measuring stick and cord. One nurseryman working with small but experienced crews lines out his larger blocks of beds, his roads, and other main features with a steel tape, stretches cord along the boundaries of the blocks, and marks these boundaries by rolling a wheelbarrow wheel over the freshly prepared earth. Next, with the help of one man, he stretches cord across the block at

alternate intervals of 4 and 2 feet and again uses the wheelbarrow wheel to mark out beds and paths. He then plows along the marks with a light turning plow and sets his bed curbs in the shallow furrows, checking the distance from curb to curb with a 2- or 4-foot stick.

On level land, particularly if the nature of the soil prevents good drainage, the beds must be built up above the level of the paths. If the soil washes seriously, curbs are necessary to keep the beds in shape. These are made of low-grade lumber, usually 1 by 4's or 1 by 6's, nailed to pegs or stakes. To leave such curbs around the beds throughout the growing season is a mistake, except on soils that wash very badly; ordinarily they should be removed in June or July, as soon as the seedlings are large enough to protect the soil. The latter practice, making use of available labor at a slack season, adds a year or two to the life of the curbs by getting them out of contact with the ground, and saves time during lifting, when time is particularly precious. The curbs must of course be stacked properly after removal, or removal from contact with the soil will fail to save them from rotting.

In nurseries where soil washing is not severe, particularly where the beds need not be built up very high, the wooden curb has given way to the unsowed shoulder, that is, a strip at the edge of the path built up to the level of the bed. Such a shoulder is usually 6 inches wide; on soils only slightly subject to washing, it need not be more than 3 inches wide. During the spring and early summer months the shoulder is worked down into the path by washing and trampling, so that by the time the seedlings are large enough to protect the soil it has been eliminated. The use of the shoulder saves not only the cost of curbs but also a considerable labor cost.

On poorly drained soil, or in localities having heavy rainfall, the surfaces of beds should be rounded slightly to keep water from standing on them after rain. On very light sandy soils where a water-retentive subsoil is very far down or is altogether lacking, or in the localities of scanty rainfall near the western edge of the southern pine region, beds should be practically level, for maximum utilization of available moisture.

Southern pine seed germinates less quickly and readily than agricultural seed, and the seedlings themselves are slower to develop and more subject to injury than the young plants of most agricultural crops sown direct in the field. The seed bed must therefore be finished more carefully, and the soil pulverized more finely, than is necessary with many agricultural crops. Hand spading, or a thorough working of the soil with potato hooks, is not uncommon practice in the finishing of seed beds, even after careful plowing and harrowing. Raking is universally practiced, and skillful rakers are a great asset to a nursery crew. In some nurseries, the beds are given a final smoothing and rounding or leveling with a hand drag which leaves the surface finely pulverized.

Soils differ remarkably in their requirements as to final treatment before sowing. In some nurseries, it is a regular practice to make up the beds several weeks in advance of sowing so that the soil will settle to its final position under the impact of late winter or early spring rains. Raking to a depth of 1 or 2 inches then

puts the surface of the bed into best condition for sowing. In other nurseries, even a single soaking rain after the beds are made up necessitates respading the beds before sowing them, and any settling must therefore be done by means of rollers. On a few soils, even rolling before sowing is injurious and when raking is completed the beds must not be left unsown overnight because of the risk of damage by rain.

FERTILIZING AND OTHER SOIL AMENDMENTS

In southern forest-tree nurseries, largely because most of them have been laid out on fairly good soil and have not been in existence long, the use of either soil crops or fertilizer on a commercial scale has barely begun, and practically no systematic experiments with nursery fertilizers have been undertaken.

The object of fertilizing forest-tree nursery soils is to obtain larger seedlings in less time and at a lower final cost.

Southern nursery soils are typically somewhat acid. They are likely to be deficient or almost totally lacking in organic matter; and such a lack not only limits a soil's fertility and water-holding capacity but also makes its physical condition less favorable to proper development of seedling roots. Some soils are too heavy and stiff, others too light and hence sterile and dry, according to origin and topographic situation.

The fertilizers usually applied to pine seed beds are nitrogen, phosphorus, and potassium in the form of compounds that are immediately available to the plants as nutrients or that break down more or less rapidly, under the influence of weathering, into available nutrients. These elements can be added as concentrated commercial fertilizers, either nonorganic (such as sodium nitrate) or organic (such as tankage or bone meal). Nitrogen can be added in the form of barnyard manure or hen manure. Most fertilizers are added to the soil and worked into it at the time when the beds are prepared. The chief exceptions are sodium nitrate and ammonium sulphate, which are applied at intervals during the growing season, usually in solution, when it appears that the seedlings are not increasing normally in size. Nitrogenous matter, and much other organic matter tending to improve the physical character of the soil, can be added by growing various leguminous soil crops and plowing them under. Cowpeas and soybeans are among the soil crops most generally satisfactory in the southern pine region. *Crotalaria spectabilis* appears to be almost equally valuable. Nitrates tend to make soil alkaline; where species to be grown are susceptible to damping-off, ammonium sulphate is preferable unless the soil is strongly acid.

Very heavy applications of almost any fertilizer may cause injury or high mortality among young southern pine seedlings, particularly of the smaller-seeded species. It is possible that organic matter decreases germination; and it has been suggested (*22*) that abundant organic matter in the soil, by increasing damping-off, inhibits the early development of longleaf-pine seedlings to the point of determining the range of this species. A disproportionately high quantity of nitrogen is likely to cause vigorous top growth without corresponding root development, and may lead to heavy mortality of seed-

lings planted on a dry site or subjected to drought during their first season in the field. Better root development may be brought about by increasing the quantity of available phosphorus. Application of any highly soluble fertilizer late in the growing season may prevent proper hardening of the stock at the approach of cold weather; but a light application even as late as September sometimes enables poorly developed stock to make a final spurt of growth and thus reach a size suitable for planting. Fresh stable manure sometimes has an unfavorable effect on seedlings, particularly if it is not well broken up and worked into the soil, but well-rotted manure in quantities up to 1 ton per acre is usually an excellent addition to any soil.

Sand, charcoal, rotted hardwood sawdust, and commercial or florists' peat sometimes make valuable additions to heavy or poorly drained soil, though charcoal may possibly increase liability to heat injury. Rotted sawdust and commercial peat may improve the quality of very light sandy soil also. These two materials combine well with fresh manure or fresh weeds to form a compost that, after a year or two in the heap, adds to the soil readily available nitrogen and desirable organic matter. It is not good practice to compost weeds unless they are pulled before coming into bloom, or unless they are free from long-lived roots or bulbs.

SOWING

What season is best for sowing depends on what species of pine is to be grown; on the latitude, elevation, and local situation of the nursery; on soil conditions and the prevalence of various insect and fungous pests; and on the kind and abundance of weeds.

Loblolly and shortleaf pine seed should in general be sown early, in the Gulf States perhaps by March 1 at the latest. In the Forest Service nursery at Russellville, in north-central Arkansas, January seems to be the best time to sow shortleaf pine. In the northeastern part of the region, where freezing weather ordinarily makes nursery work impossible for a certain period each winter, it may prove desirable to sow seed of loblolly and shortleaf pine in November, practically as soon as it has been extracted. Seedlings of loblolly and particularly of shortleaf pine grow less rapidly than seedlings of longleaf and slash pine, and must have the longest possible growing season if they are to become large enough to plant in the winter following sowing. Moreover, loblolly pine seed, and sometimes shortleaf pine seed as well, germinates more promptly and completely if sown as soon as outdoor temperatures become high enough to permit prompt germination than if stored at room temperature until late in the spring. Seed of these species may germinate still better if it lies in contact with moist soil during a period of cold weather before being subjected to temperatures favorable to germination. Promptness in germination is desirable both because it simplifies the treatment of seed beds, especially watering and the removal of mulch, and because it results in greater uniformity of stock at the end of the season.

Slash pine seed is adapted to fairly late sowing. The seed ordinarily germinates promptly and completely, and the seedlings de-

velop so rapidly under favorable conditions of soil and climate that if started early they may be too large for planting by the end of their first growing season. Slash pine can ordinarily be sown to best advantage in early or middle March.

Longleaf pine seed should be sown earlier than slash pine seed, because the seedlings grow somewhat less rapidly and need a longer season to develop into grade 1 stock.

The higher and more northerly the location of the nursery, the earlier should the seed be sown. The farther south and the nearer sea level the nursery lies the better is the growth rate adapted to late sowing, but, on the other hand, the more likely is late sowing to result in poor germination and to subject the seedlings while they are still in the cotyledon stage to heat and drought severe enough to prevent their best development. Data from several nurseries in the southern part of the region indicate that sowing should not be postponed beyond April 1. Detailed data from experimental sowing in two such nurseries at intervals throughout the winter and spring are given in table 13.

TABLE 13.—*Germination percentages, and size of 1–0 stock, in 2 nurseries at Bogalusa, La., by season of sowing*[1]

Nursery and date of sowing	Longleaf pine				Slash pine			
	Total germination	Final tree production	Average length		Total germination	Final tree production	Average length	
			Needles	Roots			Tops	Roots
	Percent	*Percent*	*Inches*	*Inches*	*Percent*	*Percent*	*Inches*	*Inches*
Nursery A:								
Nov. 13, 1924	80.4	61.8	16.2	23.3	33.1	18.9	11.2	18.3
Dec. 15, 1924	84.2	70.2	15.2	20.6	30.3	20.1	8.6	12.8
Jan. 17, 1925	78.4	64.6	15.2	20.9	25.1	20.1	7.4	13.5
Feb. 13, 1925	76.2	69.8	11.5	19.2	15.2	14.5	7.3	17.6
Mar. 12, 1925	72.4	56.6	7.8	16.8	13.9	8.0	5.6	11.6
Apr. 18, 1925	10.4	2.8	7.2	17.2	1.7	0.0	----	----
Nursery B:								
Dec. 4, 1925	85.0	66.4	14.0	21.9	30.2	32.3	7.7	16.5
Mar. 11, 1926	80.4	72.2	----	----	49.5	41.1	----	----

Nursery and date of sowing	Loblolly pine				Shortleaf pine			
	Total germination	Final tree production	Average length		Total germination	Final tree production	Average length	
			Tops	Roots			Tops	Roots
	Percent	*Percent*	*Inches*	*Inches*	*Percent*	*Percent*	*Inches*	*Inches*
Nursery A:								
Nov. 13, 1924	57.5	53.3	7.7	11.6	23.5	22.0	6.1	14.3
Dec. 15, 1924	57.9	53.0	8.8	12.2	23.9	22.5	5.4	13.6
Jan. 17, 1925	49.1	47.5	5.0	14.0	20.6	18.8	4.5	10.5
Feb. 13, 1925	33.2	30.4	5.1	15.6	19.0	17.4	4.6	12.4
Mar. 12, 1925	17.1	16.8	4.2	14.3	13.0	11.5	3.4	13.3
Apr. 18, 1925	2.0	0.5	6.8	14.3	8.8	6.5	4.1	12.2
Nursery B:								
Dec. 4, 1925	63.7	59.9	----	----	48.3	44.8	----	----
Mar. 11, 1926	46.8	42.9	----	----	38.4	34.9	----	----

[1] Seed was covered with sand to a depth of from ⅛ to ¼ inch. Shade removed June 20, 1925, in nursery A, and June 24, 1926, in nursery B. Basis of table: Germination percentages, 5 drills each 4 feet long; lengths, 50 or more seedlings in each instance except for the Apr. 18 sowing in nursery A, from which the longleaf average represents 13 seedlings and the loblolly average represents 3 seedlings. "Final tree production" is the percentage of seeds sown. "Average length" is at end of growing season.

Other things being equal, seed should be sown earlier on poor soil than on rich soil, so that lower fertility will be offset by a longer growing season. This is particularly true of longleaf and shortleaf pines. Since slash pine seedlings on fertile soil tend to grow in one season beyond the size suitable for planting, in especially fertile nurseries it is sometimes necessary to postpone sowing of slash pine seed to the latest date consistent with safety from drought and heat.

Control of practically all pests and weeds is favored by late sowing rather than very early sowing. The briefer the period during which the stock is in the seed beds the less opportunity pests have to injure it. In particular, moderately late sowing shortens the period during which the seedlings remain in the cotyledon stage, in which they are especially subject to insect attack and damping-off. If sowing is postponed until fairly late the first crop of weeds starts before the pine seed is sown, and can be gotten rid of by harrowing or hoeing instead of by the more expensive hand pulling.

Moderately late sowing simplifies nursery administration because it allows time for making up, settling, and resowing the beds in the same season in which one crop of seedlings has been lifted from them for planting, and because it spreads nursery work over a long period instead of making the work of sowing coincide with that of lifting.

In starting a new nursery, it is a good plan to lay out a series of small experimental beds and sow 1 or 2 each month from January to April, inclusive, in order to determine what month is preferable for sowing the main crop.

Theoretically, broadcast sowing results in greater uniformity of stock and in better use of all available plant nutrients, soil moisture, growing space, and light, than drill sowing. Certainly some of the finest nursery stock so far produced in the South has been grown from seed sown broadcast. In general, however, in the southern pine region the rapid growth and early removal of the seedlings, the class of labor frequently employed for nursery work, and the luxuriant growth of weeds give drill sowing a slight advantage in economy of operation and quality of stock. In particular, drill-sown seedlings are much easier to thin than broadcast seedlings. Drill-sown stock requires ordinarily about 20 percent more seed-bed area, and in extreme cases as much as 50 or 60 percent more. Ordinarily, however, the cost of clearing, fencing, and preparing extra land, and the taxes on extra land, appear to be more than compensated for by the difference in cost of weeding, particularly if the drills are far enough apart to permit hoeing out most of the weeds.

In the South broadcasting is usually done by hand. In preparation for broadcasting by hand it is best to weigh out the quantity of seed needed for each bed and divide it in halves or quarters, so that each half or quarter of the bed can be sown separately. It is well to divide the seed set aside for a given portion of a bed into two lots of unequal size, and after sowing the larger lot as evenly as possible to fill in with the remaining lot all spots missed the first time. These practices not only result in a more uniform distribution of seed, but enable the sower to work more rapidly.

In drill sowing, the first step is to determine carefully the number of seeds to be sown in each drill, and their volume. It is then

possible to make a measuring cup that will hold almost exactly that quantity of seed. An aluminum gelatine mold cut down with tin snips is good for measuring longleaf pine seed, and a 10-gage or 12-gage shotgun shell cut down with a knife is good for measuring seed of the other species.

In small operations, particularly if skilled labor is available and there is no great need of haste, sowing in drills may be done by hand, either with the fingers or directly from the measuring cup. In a nursery with a capacity of more than 100,000 seedlings, it is commonly much more desirable to use a seeding trough.

Many devices have been designed for sowing seed, some of which permit sowing several drills at a time. In regard to the design of such devices, one important point is the extreme fatigue involved in squatting down to manipulate a low trough that must be opened

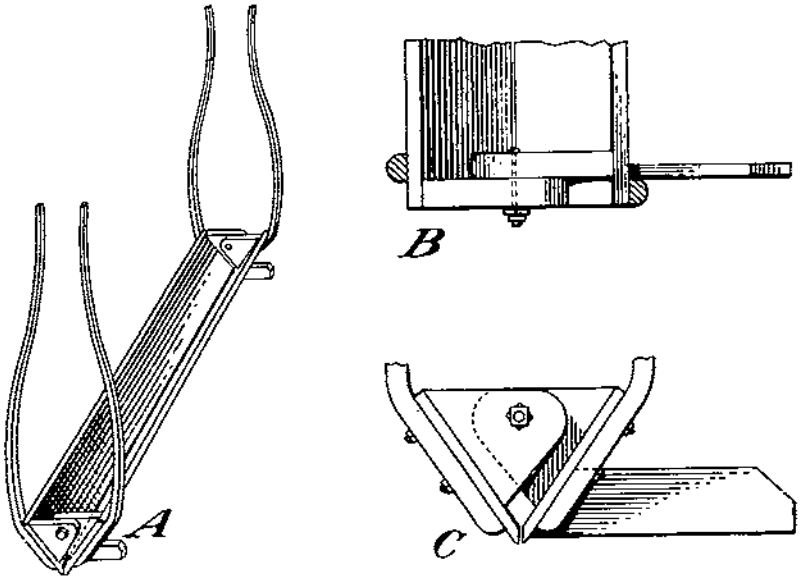

FIGURE 8.—*A*, Trough used for sowing seed in drills in the nursery, showing also top view (*B*), and side view of end (*C*).

and shut 100 or more times in the process of sowing a 50-foot bed. Another is the fact that seeds are very likely to get between any sliding parts, such as the layers of the triple-bottomed Michigan drill seeder, and jam them.

A difficulty in using any of the more common seeding machines with longleaf pine seed arises from the fact that the wings of seeds of this species make them very bulky and prevent them from sliding through easily.

A seeder that is perhaps more effective than any other developed in the South is shown in figure 8. It consists of a trough constructed to open at the bottom. Two 6-inch boards 4 or 5 feet long, according to the width of the beds on which the seeder is to be used, are joined at the ends by triangular wooden blocks screwed to them and bolted to each other, which rotate when the upper edges of the

boards are pushed toward each other. The trough is equipped with two pairs of curving handles about 3 feet tall. At its ends are horizontal markers of such length that when their ends are set in the first drill the trough is in correct position to sow the second drill.

The two men operating the trough are each equipped with a bucket of seed and a measuring cup that holds enough seed for half a drill. They set the closed trough down on the freshly prepared bed, on the surface of which the trough, by its own weight, makes a shallow drill. Each man fills his measuring cup with seed and distributes it along the trough from his end to the middle, then each grasps the handles at his end of the trough and pushes them together, opening the trough at the bottom and depositing the seed in the drill. With this device 2 men can easily sow 20 drills 6 inches apart, or 100 linear feet of bed, in an hour. Sowing at this rate, if it results in production of 15 seedlings per foot of drill, requires only 0.167 man-hour per 1,000 seedlings in beds 4 feet wide and only 0.133 man-hour per 1,000 seedlings in beds 5 feet wide.

How many seeds should be sown per unit area of broadcast bed or per running foot of drill depends first of all on the seed-bed density most desirable for the species concerned, which in turn depends in part on the productivity of the soil.

Table 14 gives densities desirable during the latter part of the growing season for seedlings growing in nursery soil of average quality in broadcast and drill-sown beds, respectively. On especially fertile sites seedlings can be grown satisfactorily a trifle closer than indicated in the table; one nurseryman in South Carolina produces unusually good longleaf pine seedlings at a density of approximately 40 per square foot. On soils less productive than the average—particularly on dry sites or in localities of high temperature and low rainfall—or in nurseries lacking a liberal supply of water, it is frequently necessary that the densities be one-third or even one-half less than those shown in the table. In a comprehensive series of tests at the University of Georgia in which seedlings were grown from broadcast sowing at densities varying from 10 to 80 per square foot, the largest and best longleaf pine seedlings obtained were those grown at a density of 10 per square foot, and the largest and best slash and loblolly seedlings were those grown at a density of 30 per square foot.[8]

TABLE 14.—*Desirable final densities for seedlings grown in nursery soil of average quality*

Species	In broadcast-sown beds	In drills 6 inches apart
	Number per square foot	*Number per foot*
Longleaf	25–35	10–12
Slash	35–45	12–15
Loblolly	40–50	12–15
Shortleaf	55–70	15–18

[8] MAY, J. T. EFFECT OF DENSITY OF STOCKING ON THE GROWTH AND DEVELOPMENT OF LONGLEAF, LOBLOLLY, AND SLASH PINE SEEDLINGS. 55 pp. 1933. (Unpublished thesis, Univ. of Georgia.)

Since rent and charges for water and weeding are the same no matter how many trees are grown per unit of seed-bed area, the cost per 1,000 trees is unnecessarily high if fewer good trees are grown than the soil is capable of producing. In addition, isolated seedlings fail to shade the ground so effectively as those grown at optimum density, and this deficiency of shade or some factor associated with it results in poorer quality of stock. It is better to sow too much seed and obtain too dense a stand than to sow too little, because thinning is easy and inexpensive but to bring an understocked seedling stand up to normal is impossible. Seed-bed thinning should be done late in May or in June, after the period of heavy juvenile mortality but before the seedlings are large enough to crowd each other seriously. Snipping off the excess seedlings with small scissors is quicker than pulling them, and much less likely to injure the seedlings that remain.

The computations necessary to determine nursery requirements on the basis of the results of seed tests have been described in the section on seed testing (p. 31.) As a general rule when fresh seed of high quality, that is, seed with a germination percentage of 90 or more, is sown under conditions conducive to abundant and vigorous germination 40 to 50 trees are produced for every 100 seeds sown. Seed with a germination percentage much lower than 90, or seed sown during adverse seasons or under unfavorable nursery conditions, cannot be expected to produce more than 20 to 40 trees per 100 seeds sown.

COVERING, ROLLING, AND MULCHING

Seed requires a covering to keep it moist from the time it is sown until it germinates, to assist it in taking root, and to protect it from birds. The southern pines as a group react unfavorably to a soil cover of any considerable depth during germination, as has been noted in connection with germination tests. Experiments and experience in southern pine nurseries have demonstrated conclusively that the most favorable depth of soil or sand cover is approximately one-eighth inch, and that any covering deeper than one-quarter inch decreases germination seriously or prevents it altogether.

In many nurseries, rolling the seed beds makes easier the application of the covering, in addition to settling the beds; in few nurseries is the soil of such peculiar composition that rolling does more harm than good. Some nurserymen prefer to roll the beds before they sow the seed, especially if the seed is to be sown broadcast and covered with soil or sand; others prefer to sow broadcast on a freshly raked bed or in shallow drills and roll after sowing, thus covering at least part of the seed. Some who make use of a cover other than soil prefer to roll after sowing but before applying the cover, others prefer to roll after the cover has been put on. The most effective practice must be worked out for each nursery in accordance with its needs.

The roller should always extend the full width of the bed, and should be heavy enough to pack the soil uniformly and firmly. Weights of 300 or 400 pounds have been found suitable. A hollow roller the weight of which can be adjusted by pouring in water, to

suit different soils and different conditions of soil moisture, is particularly useful. The larger the diameter of the roller, the less rolling disturbs the seed by pushing up the soil. The Forest Service has obtained very satisfactory results with hollow wooden rollers 4 or 5 feet in diameter.

Burlap, preferably of the 10- or 12-ounce grade, is widely used for seed-bed covers, since it is easy to apply and is an effective protection against birds. It may be tacked to the bed curbs or pinned down to the ground with U-shaped wires. Care must be used in laying it, to avoid disturbing the distribution of seed; and in removing it, to avoid destroying seedlings.

Burlap cover usually should remain on the beds for 3 or 4 weeks after sowing. Earlier removal may leave a large portion of the seed unprotected. If it is left too long, many seedlings may be crushed or smothered, or become subject to damping-off, while others may work through the cloth and so be destroyed. If germination is prompt and vigorous, the burlap usually may be removed when counts on small areas chosen at random show that about two-thirds of the expected germination has taken place. If germination is slow and irregular, and sometimes even if it is fairly prompt, the burlap should be left on until seedlings begin to smother beneath the cloth or to push up through it. Longleaf pine seedlings seldom push their way through burlap, because their stems are too short and their cotyledons too thick. If other seedlings push through, some of them may be saved if the burlap is removed in the afternoon, when the seedlings have wilted a trifle and are pliable.

The use of burlap is not entirely satisfactory, because some soils pack badly under it during heavy rains; also it tends to rot in storage during the summer unless it is dried with great care after being removed from the beds.

A thin layer of pine needles (locally called pine straw) is coming into general favor as a combined cover and mulch. Usually, it costs less than burlap. Seed-bed soil is less subject to packing by rain under the straw covering than under burlap, and germinating seedlings suffer less from crushing or smothering under straw.

Pine straw for use as cover and mulch is raked from the ground under young stands. An effort is made to keep it relatively free from twigs, bark, and cones. It is scattered over the freshly sown bed in a layer one-half to 1 inch thick. This layer settles rapidly, or may be rolled flat in the process of firming the surface of the seed bed. In its final form, it should just hide the seed from view. To prevent injury to the seedlings, it must be removed from longleaf pine seed beds when germination is not quite complete; on seed beds of the other species, it may be removed at that stage or one-half to two-thirds of it may be removed then and the rest left in place for weeks or months, according to the kind and abundance of weeds in the bed.

In the Forest Service nursery at Russellville, Ark., where shortleaf pine seed is sown in January, a mulch of clean wheat straw is used on top of a light covering of sand to prevent frost heaving. Need of such mulching is not usual in southern pine nurseries.

Several trials of paper mulches have been made in southern-pine nurseries, but with unsatisfactory results. Such mulches are not well

adapted to small plants grown in great numbers and in even, close distribution. It is difficult to sow seed between strips of paper mulch, and if the seed is sown first it is likely to be covered. The mulch is hard to anchor. Because of the nature of the crop, as much as 20 or 30 percent of the soil must be exposed; and this gives the weeds plenty of chance to come up among the crop plants. In the few instances in which a paper mulch has been put in position and kept there, no appreciable improvement in the quality of the pine seedlings could be observed.

EARLY PROTECTION

Agencies that may injure southern pines between the time of sowing and the time when the seedlings are well out of the cotyledon stage and have put on considerable juvenile (single needle) foliage, that is, from February or March until May or June, include frost, birds, rodents, moles, cutworms, and damping-off. Frost does little or no harm in most southern nurseries, but occasionally causes some damage in winter-sown beds, especially in the northern part of the region. In localities where frequent freezing and thawing of the ground is known to occur, sowing should be postponed until the danger of frost has passed in the spring or, if winter sowing is necessary, the beds should be mulched with needles or grain straw or the seed should be covered with one-eighth to one-fourth inch of pure sand.

Birds are among the greatest destructive agencies, particularly to longleaf pine and on areas near gathering points of migrating flocks. A large flock of birds can practically ruin a small nursery in the early morning hours of a single day. According to reports from a dozen nurseries the most injurious species are, in order, doves, meadow larks, bobolinks (reedbirds), domestic pigeons, and cardinals. Other species may exceed these in destructiveness in some places. Bird screens made of fine chicken wire on light wooden frames are effective, but are expensive to build and handle and do not last many seasons. The use of screens is not generally recommended. If bird damage is known to be only moderate in quantity, the seedbed cover used during germination can frequently be depended on for protection. Burlap cover is better than pine straw in this respect. If birds are very numerous, the most satisfactory protective measure is to employ reliable laborers to patrol the beds with sling shots, air rifles, or shotguns, from just before dawn until after dusk. Damage by birds ceases once the cotyledons are free from the seed coats; therefore 2 months is the longest period during which a patrol is likely to be needed. Care must be taken to avoid coming into conflict with the Federal Migratory Bird Treaty Act and with State laws, which protect many of the bird species that commonly injure seedlings. In a few instances it has proved effective to feed the birds oats or cracked grain at one side of the nursery. Coating pine seed with red lead or other repellents seems to have no effect in the South, and scarecrows and similar devices have proved useless.

A sharp lookout should be kept for signs of injury by rodents. An effective mode of control is to scatter poisoned bait on the nursery

and adjacent areas before seeding. A formula for a bait for field mice is given in the appendix (p. 111).

Moles, tunneling in the nursery, sometimes cut up the soil so seriously as to destroy considerable quantities of seedlings. Their food, however, consists entirely of animal matter, including white grubs and many other insects. It may be, therefore, that their presence on areas near the nursery, and in portions of the nursery temporarily in soiling crops, is definitely beneficial. If their tunneling damages the seed beds excessively, systematic use of any of the standard mole traps is a satisfactory method of control in commercial nurseries. Detailed instructions for controlling moles are given in Farmers' Bulletin 1716 (*27a*).

Cutworms, the caterpillars of several very common species of moths, sometimes attack seedlings in the cotyledon stage. Cutworm injury first becomes noticeable as a sudden thinning of the very young seedling stand, and is likely to be confused with the effects of damping-off. Close examination shows that the stems of the seedlings have been bitten completely or part way through. Cutworms are ordinarily easy to control by using a poisoned bait described in the appendix (p. 112). As the worms feed principally at night, the bait should be scattered through the nursery just about sundown, so that it will have no time to dry out before the worms begins to feed.

Seedling diseases of the group known as "damping-off", caused by fungi of various species, are neither so general in occurrence nor so severe and persistent in the South as in the North and West. This may result partly from the greater acidity of southern nursery soils, as most of the fungi causing the diseases prefer nearly neutral or even slightly alkaline soils, or it may result from the greater resistance and more rapid initial growth of southern pine seedlings.

In its most typical form damping-off occurs in seedlings in the cotyledon stage and causes the roots to die and turn watery brown and the stems to topple over and become so limp that they drop into any depressions in the soil surface. Freshly germinated longleaf pine seedlings, having stems too short to topple over easily, when attacked by damping-off fungi often flatten out on the ground like little rimless wheels. In its more obscure form, damping-off occurs in germinating seed before the seedlings appear above the surface of the ground and often remains a good deal of a mystery to the nurseryman. This phase of the disease may account for the lack of success in beds and germination tests in which the seeds are covered with soil more than one-fourth inch deep. An infrequent form called "top damping-off" occurs in the tops of the seedlings as late as May or June.

Factors contributing to damping-off are overcrowding, poor drainage, too much rainfall or artificial watering, the addition of too much organic matter or of lime or wood ashes to the soil, and too much shade. The infrequent top damping-off can be controlled by providing ventilation; thinning may be needed in extremely dense stands. The so-called "late damping-off", really a root rot caused by the damping-off fungi after the stems are too stiff to fall over, has not been observed in the South. To protect sprouting seed and very young seedlings from the usual type of damping-off, acid

treatment, either with sulphuric acid or with the more convenient aluminum sulphate (*17*), is the most generally successful. At nurseries where damping-off is feared and where the soil acidity is materially less than that represented by pH5, such treatment should be tested on a small scale. Either material may be applied to the beds just after they are sown and covered; the amount to use per square foot varies from one-eighth to three-eighths fluid ounce for sulphuric acid, and one-fourth to 1 ounce for aluminum sulphate, the largest amounts being needed or tolerated only on heavy or alkaline soils. For such surface treatment, the materials should be dissolved in water at the rate of 1 to 2 pints per square foot (the smaller amount only if the soil is already moist), and the beds should be promptly sprinkled. Modifications of the acid type of treatment are now being made, and the most recent information can be secured by application to the Division of Forest Pathology, Bureau of Plant Industry, at Washington. Because different soils differ in their requirements and tolerance for acid treatments, they should not be used on a large scale until after small-scale local tests.

Where it is very essential to insure against failure of first-year seedling production on an untried nursery area, the formaldehyde treatment may be used without previous trial. The treatment is applied at the rate of two-thirds fluid ounce of the strongest (37-percent) liquid formaldehyde per square foot of bed, dissolved in approximately 2 pints of water per square foot. The beds must be exposed to evaporation for a week, or, if the weather is cold, for 2 weeks, before the seed is sown. The soil should not be turned over deeply after treatment; no soil cover other than treated soil, or clean river or subsoil sand, should be used on the treated beds. The treatment is more expensive, and usually less effective against either disease or weeds, than a proper strength acid treatment, but can be counted on to be of some value on almost any soil type.

Another still more expensive but usually safe method is that of steaming. The Maryland State Department of Forestry has successfully controlled damping-off fungi and greatly reduced weeds in beds of loblolly pine and other species by a modification of this method in which a 4- by 12-foot inverted pan supplied from a small portable steam boiler is left in place 30 minutes, with steam at 40 to 60 pounds per square inch, heating the soil at a depth of 4 inches to a temperature of from 160° to 180° F. Loblolly pine has grown better in beds steamed by this method than in adjacent unsteamed beds. Scheffer (*24*) has found it effective to use very low pressure steam for the same purpose, and describes the procedure in some detail.

SHADING

Shades over seed beds are seldom necessary in southern pine nurseries, because of the exceptional resistance of southern pine nursery stock to high surface-soil temperatures.[9] Need of shades is least for seedlings growing at correct densities and for seedlings large enough to shade the ground around their root collars.

[9] Studies in California, the Northeast, and other forest regions of the United States have shown that surface soil temperatures higher than 120° F. are generally dangerous to small coniferous seedlings in those regions.

In a nursery at Bogalusa, La., the maximum surface soil temperature of 1928 in an unshaded bed was 132° F., recorded on July 9. The corresponding surface-soil temperature in an adjacent bed under a lath "half shade" was 114°. In this and in two other nurseries at Bogalusa in which shading experiments were made, the results were distinctly better in the unshaded beds except that the smaller seeded pine species (loblolly and particularly shortleaf) tended to germinate and occasionally to survive better under shade. Longleaf and slash pine in unshaded beds germinated and survived as well as they did in shaded beds, and in several instances much better. All four species developed markedly stouter, heavier seedlings in the absence of shade.

On the Ozark National Forest, Ark., unshaded shortleaf pine 1-0 stock planted in the spring of 1932 survived far better than corresponding shaded stock.

Use of shade sometimes causes considerable injury. It apparently increases very greatly the loss from damping-off. It also causes rapid elongation of the stems of the surviving seedlings and makes the plants tall and spindling. Shaded seedlings continue to develop juvenile foliage long after similar plants grown in unshaded beds have put out abundant fascicled needles. Not only are they undesirable in form but they lack hardiness, because of delay in developing woody tissue. Moreover, shading seems to prevent the root systems of the seedlings from developing as well as those of seedlings grown without shade.

Omission of shade is necessary in the latter part of the season to induce the hardening of the tissues that makes dormancy more complete and renders the stock better able to endure the shock of being transplanted.

Shades are occasionally needed during very hot dry weather to prevent heat injury to seedlings that have begun to germinate but have not yet formed true bark on the stems, or to prevent retardation of growth. Exotic conifers are much more likely than native pines to require shades when grown in southern nurseries.

Burlap makes entirely too heavy a shade. Light cotton fabrics such as the cheesecloth or netting used over truck crops and tobacco might serve the purpose. The material most commonly used is lath or similar narrow strips of wood. These strips are nailed on light wooden frames, tacked to wires, or connected by means of wires interwoven around their ends. Each lath in the shade is separated from the next by a space equal to its own width, which gives 50 percent density. The shades are made the same width as the seed bed, and of any length desired; those on wooden frames are usually 10 or 12½ feet long, and those on wires 25 or 50 feet. Wire-mounted lath shades are particularly convenient because they can be rolled up from either end and can be picked up and carried by one man.

Shades are best supported on rails paralleling the edges of the beds and about 20 inches above them. These rails can be made of low-grade 1-by-3's or similar inexpensive material nailed to stakes. Shade frames are more effective against heat injury if they are high enough to permit good air movement under them.

WATERING

Nearly all the more successful of the large nurseries in the southern pine region use overhead sprinkler systems, the pipes of which rest in roller sockets on the tops of posts. Each line of pipe is rocked backward and forward in its roller sockets by a water motor, in such a way as to swing fine lines of spray back and forth over a strip 25 to 30 feet wide on each side of it. Several large nurseries use small rotary sprinklers or ordinary hose and spray nozzle, but without obtaining entirely satisfactory results. Several small nurseries water at reasonable cost and in sufficient quantity by means of hose. Irrigation in the paths was tried in one nursery, but was abandoned because too little water penetrated to the centers of the beds.

The quantity of water to be applied, and the frequency with which watering is needed, vary greatly with soil, rainfall, and number of hot, cloudless days. During any one week, rainfall and artificially applied water should ordinarily total at least as much as the average weekly rainfall of the locality in which the nursery lies. In a rainless week water equivalent to at least 1 inch of rainfall should be applied artificially, even though there have been abundant rains earlier in the season.

During germination the surface must be kept almost continuously moist, although preferably it should not be extremely wet. At other times, it is better to soak the nursery thoroughly at intervals of several days than to moisten merely the surface of the ground every day.

No authentic cases of injury to southern pine seedlings from watering in the daytime instead of at night have come to the attention of the Southern Forest Experiment Station. On the contrary, heat injury may sometimes be warded off by starting an overhead sprinkler during the hottest part of the day. Ordinarily, it is preferable to water at night, because the higher humidity and lower temperatures of night reduce the rate of evaporation and the water applied has a correspondingly greater chance to soak into the ground.

It is generally considered good practice, and in some nurseries in the most southern part of the region is essential, to stop all watering in August or September except in seasons of extreme drought. By August or September the seedlings should be so far advanced in development that a reduction of the water supply will not leave them too small for planting, but will merely cause the tissues to harden. Particularly on the better soils, reduction of the water supply toward the end of the summer is in some instances necessary not only to harden the stock but to keep it from becoming too large to plant economically with the tools ordinarily used.

WEEDING

From 4 to 7 weedings a year are necessary in even the cleanest of southern pine nurseries, and a dozen or more may be required where weeds are abundant at the start. The cost of hand weeding ordinarily makes up 20 to 40 percent of the total cost of 1–0 nursery stock.

Certain general control measures reduce greatly the labor and expense of weeding even during the first year of application, and help still more to restrict the weed crop of the following season. Among the most important of these measures, particularly if the principal weeds are running grasses like Bermuda, is very thorough hand working of the seed-bed soil before sowing. Going over a bed thoroughly from end to end with a potato hook and then a rake takes less time than one hand weeding, and such a cleaning of the soil in advance of sowing may save half a dozen weedings.

If coco grass is present, working with spike-toothed or spring-toothed harrows to eliminate weeds does more harm than good because such harrows spread the bulbs of this particularly obnoxious weed. Bermuda grass and Johnson grass can be worked to the surface with toothed harrows; and as these weeds spread by rootstocks more than by seed, to destroy most of their overwintering rootstocks is more than half the battle.

Other general measures include late sowing, with one working of the soil before sowing to kill the weeds already started; drill sowing, to permit hoeing out some of the weeds and pulling the remainder by hand more easily than is possible in broadcast-sown beds; cutting weeds on the margins of the nursery and on surrounding land, to keep them from going to seed and scattering their seed over the beds; and growing heavy cover crops on portions of the nursery not being used for seedlings. It is important, also, to avoid bringing in from outside the nursery any soil or barnyard manure that may contain weed seeds, or using compost made of weeds that may have gone to seed before being pulled.

Aside from these measures, weed control depends largely on weeding by hand. To be effective, hand weeding must be done early and must be clean. The cost of early, clean, hand weedings, although sometimes very high, is almost invariably compensated for by a reduction in weeding costs later in the season and a great decrease in costs in following years.

Every man assigned to hand weeding must be taught never to weed on dry ground, never to break off weeds at the surface, and not to injure the seedlings in any way. He should not be allowed to break down the edges of the beds, or to rest his weight on his hands at any point within the bed. He should be taught to reach down to the weeds from above, instead of sliding his hands to them from the side among the seedlings.

Various devices such as knee pads, small stools, or benches, and hand tools such as small knives or teaspoon handles, make weeding easier and more efficient.

WEEDS PARTICULARLY SERIOUS IN THE REGION

The history of a dozen nurseries in the southern pine region indicates that crabgrass (*Syntherisma sanguinale* (L.) Dulac) and Bermuda grass (*Capriola dactylon*) are about equally wide-spread and troublesome. Coco grass (*Cyperus rotundus*), also commonly called nutgrass, although less common, is fully as serious in some nurseries and is perhaps the hardest of all to eradicate. Goosegrass (*Eleusine indica* (L.) Gaertn.) and crowfoot grass (*Dactyloctenium aegyptium* (L.) Richt.) are perhaps the next most important species. All other

grasses put together take a minor place. Except in a few nurseries, weeds other than grasses present relatively little difficulty.

Both Bermuda grass and nutgrass spread by means of creeping underground stems, reproduce from underground rootstocks or tubers, and are difficult to eradicate by pulling. The "nuts" of coco grass are readily killed by severe cold, and the rootstocks of Bermuda grass by cold and by drying. Plowing in the fall and leaving the land rough during cold weather greatly reduces the survival of plants of these two species, especially in the more northerly nurseries, and turning up Bermuda grass before a dry season is helpful. Geese eat the leaves of coco grass and thus help exhaust the food stored in the tubers, and can be allowed to feed on infested areas where soil-improving crops are being grown. Hogs eat the tubers, and can be turned into the nursery between lifting time and sowing time. Neither coco grass nor Bermuda grass can endure heavy shade; a heavy soil-improving crop, such as velvetbeans, in a season during which the soil is not occupied by pine seedlings should considerably reduce the numbers of both weeds.

CHEMICAL WEEDING

Zinc sulphate treatment, which has given good results as a method of weed eradication in other regions, has been tried on three different nursery sites for several years without satisfactory results. The chemical is inexpensive and easy to apply to the soil, and gives good control of weeds other than grass even when used in quantities so small as to cause little or no injury to any species of pine. The grasses, however, especially those that arise from rootstocks already in the ground, seem to resist it as successfully as the pines; and, since the grasses are the principal weeds in most southern nurseries, this renders the treatment generally useless. In nurseries in which the weeds of major importance are not grasses—particularly if the pines grown are longleaf and slash, which are more resistant to injury by the chemical—zinc sulphate should be tried. The chemical should be applied at the rates of 6 g, 8 g, and 10 g per square foot in small beds, preferably in two or more separate beds for each treatment. Check beds should be left between the treated beds and should be hand weeded; it might be instructive to leave one check bed entirely unweeded. Not until successful control of weeds has been demonstrated in the test beds, at reduced cost and without injury to the soil, should the chemical be applied to the nursery as a whole.

Weed killers applied to the foliage have not been tried in southern nurseries. Some of these, such as ferric chloride, roll off the leaves of grasses too soon to injure them, and consequently seem to offer little promise in such nurseries. Others, such as sodium chlorate solution, and acid solutions containing compounds of arsenic, may be expected to kill all plants on which they are sprayed, and are therefore unsuitable for application upon weeds growing among pine seedlings, whatever their usefulness in destroying patches containing weeds alone.

LATER PROTECTION

Between the end of the moist, cool weather of March and April and the onset of hot, dry weather, usually sometime in June, there

may be a slight lull in the activities of nursery pests. With the coming of summer, a new series of injurious agencies attacks the nurseries, the most harmful of which are usually insects, fungi, and drought.

INSECTS

Insects injurious to young southern pines may be grouped in three general classes. The first includes chewing or biting insects that feed on external surfaces of the plant. Many insects of this class, such as sawfly larvae and the adults of certain beetles, succumb readily to stomach poisons, such as arsenate of lead, applied to the plant. The second class includes sucking insects, such as aphids and scales, living on exposed surfaces of the plant but getting their food by thrusting slender mouth parts through the epidermis of the plant and sucking the inner juice. Insects feeding in this way are unaffected by stomach poisons on the outside of the plant, and can be controlled only by applying contact insecticides, such as nicotine sulphate or oil emulsion, to the insects themselves. The third class includes insects of several types that work underground or burrow within the tissues of the plant, out of reach of ordinary sprays. Examples are the adults and larvae of bark beetles, the larvae of pine tip moths, leaf miners of all kinds, and white grubs (May beetle larvae) working underground. In many instances, control of insects of this third class can be effected only indirectly, as by various cultural methods, or is entirely undeveloped.

Among the most persistent and destructive nursery pests, and likewise among the most difficult to combat, are the larvae of June bugs or May beetles (*Phyllophaga* spp.), commonly referred to by nurserymen as grubworms or white grubs. The exact life histories of the southern species of these pests are not known in every instance. In some regions it appears that the eggs are laid in the spring and that the larvae which hatch from them feed on dead vegetable matter in the soil until the following winter (*11*, *18*). In such cases, the larvae are small during this first year of their underground existence, and comparatively or entirely harmless to pine seedlings. Recent studies by the Bureau of Entomology and Plant Quarantine, however, indicate that in the South the larvae do not feed on dead vegetable matter the entire season, but become a menace to young pine seedlings. During their second year, after remaining more or less dormant through the winter at a considerable depth, they return to the top 6 or 8 inches of soil, the zone containing most of the feeding roots of the pine seedlings, and attack the roots voraciously. They feed throughout the summer and late into the fall, usually doing their most conspicuous damage during the hot summer months. Working singly or in groups, and moving back and forth in small tunnels, they cut off the seedling roots from 1 inch to 10 inches below the ground. The seedlings die in small patches, which increase in size and in irregularity as the grubs work outward from their starting points. Typical white grub injury is easily recognized by the color of the dying foliage, which changes from faded green to brown, and often by the patchy occurrence of the damage. The injured seedlings are easy to pull up, and show a characteristic pruning of the roots. If the roots are cut off 6 or 8 inches below

the surface of the ground they often heal over, and in that case the seedlings may recover and develop into satisfactory planting stock. Roots cut off 2 or 3 inches underground may begin to heal, but with the first water shortage the small quantity of moisture supplied by the reduced root system is exhausted and the seedlings die. Digging in the patches of injured or dead seedlings usually reveals one or more of the grubs. In general they are whitish in color, with hard brown heads and almost transparent abdomens, and bend double when disturbed. In addition to white grubs there may be present other forms which resemble these very closely but which are not injurious. This is apt to be the case where compost is applied to the soil. Information on methods of distinguishing these forms is obtainable from the Bureau of Entomology and Plant Quarantine.

It is rare for a nursery to be entirely free from white grubs. Even a light infestation may result in a steady drain on the nursery throughout the season, and a loss of 10 to 20 percent of the plants. When a heavy flight of adults has been followed by two seasons of weather favorable to the development of grubs, the grubs have destroyed as much as 60 percent of all the stock in a nursery.

No thoroughly satisfactory control for white grubs has been demonstrated in the southern pine region. Control by indirect or cultural methods should be applied whenever practical. These methods include locating the nursery as far as possible from pecan groves and hardwood stands and even from longleaf pines, on which the adults feed; avoiding establishment of the nursery on sites which have been in grass for more than one season, particularly without taking precautions to free the ground of white grub larvae; keeping beds, paths, and fallow areas as free as possible from vegetation during the flight of the adults in the spring, to make the ground less attractive for egg laying; practicing a rotation of crops; turning hogs or chickens into the nursery after the old stock has been lifted and before the new beds are sown, especially during plowing; and killing all white grubs found at any stage of cultivation, weeding, and lifting. More direct methods of control include the application of poison, both when the beds are made up and when damage becomes conspicuous.

In the Northeast and in Australia the application of 80 pounds of white arsenic (arsenic trioxide) per acre, in mixture with enough sand to make spreading easy, gave good control. Use of white arsenic in this manner in midsummer, followed by thorough wetting to wash the poison well into the soil, gave partial control in one nursery in Texas even after damage had become severe. A systematic trial of this method by the Southern Forest Experiment Station at Bogalusa, La., failed entirely. The Bureau of Entomology and Plant Quarantine reports it ineffective also in Nebraska and South Carolina, and, on the basis of recent investigations, warns against its use in certain light, sandy coastal plain soils until more is known about them lest severe damage to seedlings result and the site be rendered unproductive for a number of years.

The Bureau of Entomology and Plant Quarantine has tried arsenate of lead also in concentrations varying from one-half pound to 10 pounds per 100 square feet, for control of white grubs in seed beds of southern pine on several different soils in Maryland and the

Carolinas. Some of the results have been unfavorable. The chemical not only injured or killed the seedlings grown on the soil immediately after the treatment but remained in the soil and, in all but the lightest applications, caused severe burning of the foliage of seedlings grown 1 or more years after the treatment.

Carbon disulphide emulsion applied to the surface of the soil has killed seedlings as well as grubs in three nurseries in which it has been tried. In one of these nurseries, a trial was made of carbon disulphide in liquid form poured into holes in the soil. Wherever the nurseryman found seedling tops wilting or fading he pulled 2 or 3 of the apparently injured trees. If their roots had been eaten by grubs he pulled all other apparently injured trees in the same spot, made a hole 2 inches deep with the end of a broom handle, poured in a teaspoonful of carbon disulphide, and plugged the hole with earth. This treatment seemed to succeed uniformly in stopping injury in the particular spots treated, and had no harmful effect on the trees.

Ordinarily less serious than white grubs, but occasionally far more dangerous to an individual nursery or block of stock, are cutworms. The different species appear and attack suddenly at various times of year. The worst attacks on record have occurred in midsummer. In one longleaf pine nursery more than a million seedlings were killed in approximately 1 week.

If discovered when they first begin working, cutworms are easy to control. A recommended method of control, as was stated earlier, is to prepare a bran bait according to formulae given in the appendix (p. 112) and scatter it through the nursery about sundown. The poison should be kept on hand at all times for use in emergencies.

Scale insects of the genus *Toumeyella* are another group of dangerous nursery pests. These are plump, grayish-brown scales the diameter of which varies from that of a small pencil lead to that of a BB shot or a little larger. Frequently their presence is marked by a sooty coating on the needles and stems of the infested seedlings. This coating is a harmless mold that grows on a honeydew exuded by the insects. The seasonal life history of the scale insects is not well known, but the rate of seedling development tends to confine their attack to the middle and latter part of the summer. Scale insects of the genus *Toumeyella* have been reported most commonly on slash and loblolly pines. So far as is known, they do not attack longleaf pine seedlings in the nursery, although they have been found on the needles of naturally reproduced longleaf pines 3 or 4 feet high.

Prompt application of a miscible oil emulsion is effective in controlling scale. Miscible oils ordinarily can be obtained from dealers in seed, fertilizers, and gardeners' and farmers' supplies. These oils emulsify immediately upon contact with water, without heating or other special preparation, and therefore are simple and easy to use. They should be mixed and applied according to the manufacturer's or dealer's recommendation for summer (nondormant) sprays. If miscible oil cannot be obtained, kerosene emulsion (described in the appendix, p. 112) may be substituted fairly satisfactorily, although it is much less convenient to apply and must be made with great care lest it injure the foliage.

Seedlings infested with *Toumeyella* scale are useless for field planting. Although seedlings attacked by the scale may appear fairly healthy and although a late-season spraying may have freed them of the insects, because of loss of stored food or for some other reason practically all of them fail to survive transplanting. If the scale has been destroyed before the end of the growing season, however, and the trees have made some growth since the infestation came to an end, successful transplanting appears to be possible.

A pest somewhat less serious than the scale insects is the mite *Tetranychus telarius* L., the common red spider. Particularly during very hot, dry weather, this pest attacks pine seedlings and causes them to stop growing and turn yellow. The mites can hardly be seen without a magnifying glass. As adults they migrate by crawling rapidly. They spend the winter on the leaves of the common violet and other evergreen plants.

In localities where red spiders are abundant on agricultural crops, special care should be taken to keep the surroundings of the nursery as free as possible from plants with heavy foliage that remains green the year around. Red spiders are easily controlled by the use of bordeaux mixture, nicotine sulphate, one of the oil emulsions recommended in the foregoing for controlling scale, or dry sulphur. Either spraying or dusting should be repeated after an interval of 10 days or 2 weeks. The spray should be very fine and penetrating.

A conspicuous nursery pest, potentially serious but very easy to cope with, is the larvae of LeConte's sawfly (*Neodiprion leconteï* Fitch) (*21*). Other sawfly larvae attack southern pine nursery stock, but less commonly. Sawfly larvae resemble very closely the caterpillars of butterflies and moths, but differ from them in having 8 instead of 10 pairs of false legs (stubby, fleshy, unjointed appendages on the rear two-thirds of the body). They have a striking habit of rearing back, when startled, from the leaves on which they are feeding. Usually they feed in groups. Their bodies are greenish or yellowish, usually with rows of black dots along the sides, and their heads mahogany colored, brownish, or blackish. Like many other leaf-chewing insects, they are easily killed by means of lead arsenate (p. 112) or other arsenical sprays.

One or more species of *Tetralopha*, a soft-bodied moth the larvae of which live in a loose tube of webbing and frass, has appeared in nurseries in Florida, Mississippi, and Texas, and to a slight extent in Louisiana. It apparently does no serious damage, confining its feeding to a few needles on each tree. The Nantucket tip moth (*Rhyacionia frustrana* Comst.) (described on pp. 96–99) occasionally infests 1 to 5 percent of the slash and loblolly pine seedlings in a nursery, but does no appreciable harm. Other insects that have appeared from time to time in southern nurseries are various species of aphids, which can ordinarily be controlled with nicotine-sulphate spray (p. 112); grasshoppers, for which bran bait is recommended (p. 112); mole crickets, which can be poisoned by means of cottonseed meal and paris green (p. 111); and various species of mound-building ants.

FUNGI

The only serious disease of nursery stock so far encountered on southern pines is the brown-spot needle blight, caused by *Septoria*

acicola (Thum.) Sacc. (*25*). This is primarily a disease of longleaf pine seedlings. It occurs also on slash pine, particularly in nurseries that lie outside the natural range of the species or that are subjected to extreme drought. The first symptom is formation of small spots on the foliage. These spots soon develop into narrow brown bands, with definite margins, encircling the needles. The first signs of the disease are likely to appear in July or August, but infection may take place even in midwinter. Nurseries far removed from any infected stands of young longleaf pine seldom or never suffer seriously from brown spot. Infection is often heavy in nurseries in the immediate vicinity of infected young longleaf, and may take place very suddenly when weather conditions become favorable. A detailed study[10] by Verrall of spore production and dissemination during a period of nearly 6 months has indicated that slight infection takes place at considerable distances through the medium of windblown spores, but that serious infection is usually traceable to spores produced in fruiting bodies during prolonged warm rains and carried only so far as they can be spattered by rain.

Control of brown spot is simple, certain, and inexpensive. The infection is checked immediately by spraying with bordeaux mixture, lime-sulphur, or zinc sulphate-lime mixture, with casein or fish-oil soap as a spreader. Reinfection necessitates fresh sprayings, but there is no excuse for letting brown spot make any serious inroads in a nursery. From 75 to 85 gallons of bordeaux mixture or other fungicide should suffice for 20,000 square feet of seed bed. A man equipped with a 4-gallon knapsack pump can ordinarily spray this area in 8 hours, provided he does not have to walk an average of more than 300 feet to refill, or stop to prepare additional mixture.

OTHER NURSERY PESTS

Seedlings on very sandy soil, particularly on soil previously used for agricultural crops, sometimes become infested with nematodes. These cause knots on the roots and check growth almost entirely, soon causing an unhealthy appearance and high mortality. It is bad procedure to plant trees known to be hosts of the root-knot or other nematodes on land infested with these pests. Species or varieties of trees known to be immune to the nematode involved should be planted exclusively, or the land should first be cleaned of the pest. Treatments for nematodes are described in the appendix (p. 111).

"Salamanders", pocket gophers of the genus *Geomys*, tunnel and burrow through nurseries on sandy soils, throwing up little mounds of earth and destroying many seedlings by eating the roots. They are readily controlled by persistent trapping with any of the several kinds of burrow trap commonly found on the market, or by placing poisoned bait (p. 111) in the burrows.

DROUGHT

Extreme damage from drought takes the form of heavy mortality throughout the seed beds. Under milder drought conditions, conspicuous mortality is confined to the soils less retentive of moisture.

[10] VERRALL, A. F. INVESTIGATIONS OF SOME OF THE BIOLOGICAL ASPECTS OF THE BROWN-SPOT NEEDLE BLIGHT OF LONGLEAF PINE SEEDLINGS. U. S. Dept. Agr., Bur. Plant Indus. Manuscript report. 1933.

Even moderate drought may cause considerable losses in a nursery by gradually killing a few seedlings here and there.

Failure of seedlings to make sufficient growth during the summer is another serious after effect of drought. This may make the stock partly or wholly unsuitable for planting, and thus not only result in waste of much of the money and effort spent on a nursery during the summer but delay seriously an entire planting program.

Visible drying of surface soil to depths exceeding 1 inch, particularly in the centers of the beds, is a sign of serious danger. When seedlings are very young, they sometimes show need of water by temporary wilting. At a later age they do not wilt visibly even when about to die from drought.

Aside from direct watering and the use of shade, already discussed, means of forestalling drought killing are reducing beds to the levels of the paths, terracing to prevent rapid run-off of rain water, increasing the organic content of the soil, adding loam or clay if the soil is very sandy, and growing the seedlings at relatively low density.

An after effect of drought that often gives the nurseryman warning to change his practice the following year is "troughing" of the beds, or markedly inferior development of the seedlings in the center of a bed as compared with those along the sides. The inequality in growth results usually from the fact that the border seedlings can draw on otherwise unused water in the soil included in the paths, in which case the nurseryman should provide more water for the beds and should decrease the seedling density unless it is already very low. Troughing may be caused also by impoverishment of the soil.

CHARACTERISTICS OF NURSERY STOCK

Longleaf pine seedlings, unlike almost all other tree seedlings, develop practically no stem during the period spent in the nursery. Their height is therefore no index to the success of the nursery treatment or to the fitness of the stock for planting.

Seedlings of slash and loblolly pine are typical of pines in general, except that they grow much more rapidly and vigorously than northern and western species. Shortleaf pine seedlings are somewhat smaller and usually have one conspicuous characteristic normally lacking in other pine seedlings, namely, a crook at the surface of the ground that causes the stem to arise at a point one-half to 1 inch away from the root collar. This crook must not be mistaken for a defect or the result of an injury. It in no wise lowers the grade of the seedlings; in fact, it is seldom lacking except in seedlings grown so close together that they are too weak and spindly for field planting.

The size of high-quality southern pine seedlings varies considerably with species. Within a species, also, it varies considerably from nursery to nursery and even from season to season in the same nursery. The size of seedlings is less important than their quality. Sizes and other stem and needle characteristics of grade 1 seedlings are discussed in the section on planting (p. 77). Characteristics of lower grade seedlings are discussed in that section (p. 79).

A properly developed nursery seedling has a root system proportionate to its top. Root development of nursery stock varies strik-

ingly among species of southern pines, however, and varies greatly within any one species according to the quality of nursery soil and the method of cultivation and watering. Longleaf pine usually has a strongly developed taproot, although on certain soils and possibly under other influences it develops a somewhat diffuse root system. Slash pine and occasionally shortleaf pine tend to have one or more rather strongly developed central roots, but in the main their root systems are much more fibrous and diffuse than that of longleaf pine. Loblolly pine usually has the most diffuse root system of the four species. Loblolly and shortleaf pines have the greatest quantity of absorbing roots in proportion to the top. Longleaf pine has a relatively meager supply of lateral roots, but in total bulk its root system is greater in proportion to the top than that of any of the three other species. The stout, thick-barked longleaf pine taproot is thought to be important as an organ for storing food. Slash pine has perhaps the most meager roots in proportion to the top of all pines produced for planting purposes in the United States. Its striking dissimilarity to other southern pines in top-root ratio is shown in table 15. It usually makes better height growth in the nursery than any of the other species, however, and survives well in the field.

TABLE 15.—*Height and ratio of top weight to root weight of 1-year-old nursery-grown seedlings of southern pines*[1]

Location of nursery and grade of oven-dry material	Longleaf pine		Slash pine		Loblolly pine	
	Needle length	Top-root ratio	Height	Top-root ratio	Height	Top-root ratio
	Inches		*Inches*		*Inches*	
Bogalusa, La.:						
Grade 1	14.2	3.52	8.4	5.50		
Grade 2	12.9	3.90	6.9	5.56		
Grade 3	12.8	3.24	5.1	6.17		
All grades	14.0	3.56	7.7	5.53		
Athens, Ga.,[2] all grades	14.1	1.38	7.3	2.95	5.5	1.42

[1] Small ratios, showing that roots are large in proportion to tops, theoretically indicate better quality of planting stock. Basis of table, in number of trees, as follows: Bogalusa nursery, longleaf pine, 67 grade 1, 14 grade 2, 2 grade 3; slash pine, 113 grade 1, 47 grade 2, 14 grade 3. Athens nursery, longleaf pine 50, slash pine 50, loblolly pine 88.

[2] MAY, J. T. See footnote 8, p. 46.

Although in the course of 10 months in the nursery individual roots of loblolly and shortleaf pines frequently penetrate to a depth of 20 inches and longleaf pine roots not infrequently go down 30 or 40 inches, most of the roots essential to the welfare of the seedlings are in the top 6 or 8 inches of the soil.

As the result of an apparently symbiotic relationship, known as "mycorrhizal", between the pines and certain soil-inhabiting fungi, minute fingerlike or clublike growths almost invariably occur on the roots of southern pine nursery stock. These growths, or mycorrhizae, are a combination of root and fungus tissues. They are most abundant, and reach their best development, on the best stock. In troughed beds, where the edges appear markedly higher owing to faster growth there than in the center, mycorrhizae are usually abundant on the border seedlings and almost entirely lacking on the stunted seedlings in the center. In seed beds surrounded by

partly decayed wooden curbs, frequently they develop in astonishing profusion and luxuriance on the roots in contact with the rotting wood. Most of these growths are white, but frequently those developing in contact with curb boards are yellow.

To summarize the normal course of development of nursery stock through the season, germination should be at its height not more than 3 weeks after sowing, and should be practically complete within a month or 5 weeks at the latest. Much more rapid germination frequently occurs and is greatly to be desired. By the time germination is complete, juvenile needles should be plainly evident in the seedlings that were first to free themselves from the seed coats. By early or middle May the cotyledons should have outlived their function as leaves and have given way to small but thrifty crowns of juvenile needles, that is, needles occurring singly. By the middle of June the juvenile needles of longleaf pine and the seedling stems of the three other species should have elongated considerably, and the tender epidermis should have given place to the first thin layers of real bark. Secondary, or fascicled, needles should begin to appear on longleaf pine seedlings early in July, and on seedlings of the three other species not later than the 1st of August. By the end of the growing season the secondary needles should have taken over the function of the primary needles almost entirely. When cold weather begins, stock of the very highest quality has no living primary needles left.

Characteristics of nursery stock as to dormancy are discussed on page 77.

Color changes other than the yellowing or browning caused by insects, disease, or drought sometimes take place with changes in season or in treatment. Slash pine frequently turns bronze-red or purplish bronze when struck by frost. In beds treated with fertilizers, stock has been observed to turn every color from orange to blue when the first frost came. Shortleaf pine often takes on a bluish purple tinge late in the fall, and loblolly pine sometimes changes color to a lesser extent; longleaf pine is the least likely to undergo such changes. These changes do not seem to be accompanied by the least change in the quality of the stock.

SUMMARY OF ESSENTIALS OF NURSERY PRACTICE

The first essentials of forest-tree nursery operation in the South are an adequate supply of water and a favorable site.

The usual sequence of nursery operations, and of dangers to nursery stock, throughout the year is somewhat as follows:

Late January through early February.—Plow, harrow, and make up the beds.

Late February through early March.—Finish making up beds, or freshen surface, and sow. Great danger of damage by birds. Beds must be kept moist during germination.

Middle to later March or early April.—Finish removing burlap cover from all species, or pine-straw mulch from longleaf pine. Danger of damage by birds until seeds have dropped from cotyledons. Danger of cutworm attack and damping-off. Possibly, first hand weeding.

Middle to end of April.—First, or possibly second, hand weeding. Still some danger from cutworms and damping-off.

Middle to end of May.—Second, or possibly third, hand weeding. At this period regular weekly watering may become necessary. [Watering may, of

course, become necessary earlier, and may be necessary at shorter intervals.) Some danger of heat injury.

June.—Third, or possibly fourth, hand weeding. Danger of heat injury.

July.—Probably another weeding. Possible danger of attack by cutworms and by red spider, especially during drought. Possible need of spraying in longleaf and slash pine nurseries exposed to brown-spot infection. Slight possibility that shade may be needed. Continued danger of heat injury.

August and September.—Watering usually needed through August, but preferably discontinued at beginning of September. Probably at least one weeding, much lighter than those earlier in the season. Possibly one or more sprayings to control scale insects. One or two sprayings for brown spot, if nursery is likely to be infected.

Middle to late November.—Earliest possible season for lifting.

Middle December to end of January.—Usual lifting season.

Continuing duties of the nurseryman include maintaining equipment, maintaining and if possible increasing the fertility of the nursery soil, and subduing the weeds. Addition of fertilizer, alternation of pine seedling crops with soil crops from season to season, and unremitting efforts to keep weeds from going to seed in or near the nursery, should be matters of course.

The nurseryman or a responsible subordinate should make at least a hasty inspection of the nursery once or twice a day. He should watch particularly for the first inconspicuous signs of drought, heat injury, cutworms, red spiders, scale insects, and brown spot.

COSTS

In nurseries in which only one species is raised at a time, under exceptionally good conditions as to personnel, climate, and soil, seedlings have been grown at a total cost of less than $1 per 1,000. The manager of one Gulf States nursery that produces approximately 1½ million trees a year quotes average costs, for 1928–30, of $1.50 per 1,000 for slash pine and $1.75 per 1,000 for longleaf pine. Smith (*28*), reporting on 5,204 acres of plantations established largely with stock grown by the company doing the planting, published figures indicating that 79 percent of this stock was grown at costs per 1,000 of from $1.06 to $1.22 only.

Other things being equal, nursery operation is very much more efficient if a large number of trees is grown than if a small number is grown. A nursery manager can exercise just as close supervision over a nursery producing 12 million or 15 million seedlings as over one producing 3 million seedlings, and general company overhead charged against the nursery can be reduced by distributing it over a larger output. Exceptions to this general rule are small nurseries maintained largely for instruction purposes at forest schools, and small private nurseries operated by farmers and other landowners in spare time.

Factors that increase costs far beyond those necessary for the species and site are the following: (1) Waste of seed, particularly through oversowing or through mismanagement resulting in incompleteness of germination. (2) Usurpation by weeds. Weeds must always be pulled before they go to seed, and for greatest efficiency should be pulled before they attain a height of 2 inches. (3) Inroads by birds, or attacks by insects such as cutworms, red spider, or scale. Heat killing. Drought killing. (4) Waste of motion.

Every operation carried out in the nursery, from plowing at the beginning to loading the stock in trucks at the end, involves many repetitions of a movement or series of movements which must be paid for at so many cents an hour. Nurserymen should constantly endeavor to reduce costs by simplifying processes, introducing labor-saving equipment, and abandoning useless treatment.

RECORDS

Successful operation of even the smallest nursery requires technical records. The details of nursery practices are too numerous to be trusted to memory, and written notes are necessary if the nurseryman is to make adequate use of his experience.

In large nurseries it is necessary to keep a detailed history of each lot of seed sown, each major treatment applied, and each compartment or soil block, together with a record of all costs. The records on seed lots are needed to determine suitability of individual strains for the site. The economy and usefulness of various procedures such as mulching, fertilizing, chemical weeding, and raising the level of beds cannot be determined without precise records of costs and results. A record of treatments given to any portion of the nursery soil is vitally important; for example, certain fertilizers must not be applied in rapid succession on the same soil lest they neutralize each other's effects or combine in a manner harmful to the plants. In a nursery operated by a business concern or a public agency, an itemized cost record is of course necessary as a guide in planning future treatment or expansion.

The following cost items should be kept separate: 1, Preparing the soil and making up the beds; 2, fertilizing; 3, mulch; 4, seed; 5, sowing (exclusive of 1 to 4 above); 6, protecting the beds from birds and removing the mulch; 7, weeding (total); 8, watering (total); 9, spraying (total, preferably itemized according to pests); 10, lifting; 11, equipment (initial cost plus cost of maintenance, prorated over expected life if equipment is to be used more than 1 year); 12, miscellaneous direct; 13, technical supervision by men other than those employed for nursery work alone (total); 14, shares of office or company overhead (prorated over items 1 to 13).

Either by means of small sample plots in representative beds or by means of periodic inventories of the entire nursery, the following data should be obtained each year for each species and principal treatment, as a guide in future operations:

1. Germination percentage of seed (for comparison with results of laboratory tests).

2. Number of trees still alive in May or June, expressed as percentage of seeds sown (as a guide in deciding how much seed to sow).

3. Average height and degree of development of the seedlings in May or June (as a guide in judging seedling development in later years).

4. Mortality between May or June and end of growing season (as a guide in efforts to reduce losses).

5. Mortality caused by any specific outbreak of insects or disease, or the like (as an index of the expenditure justified in combatting the pest).

6. Density of the stand at the end of the growing season (as an index of the effectiveness of nursery practice intended to produce a chosen density, and as an index of the effect of density on quality).

7. Average sizes, and percentages of different grades, of seedlings at the end of the growing season (as an index of effectiveness of methods and maintenance of soil fertility).

8. Total output exclusive of culls (as a basis for computing costs, planning plantations, and reporting production).

For recording unmistakably the results obtained in a nursery study, photographs of the deciles of a representative sample of the seedlings grown under any given conditions have proved excellent. A sample consisting of 100 or some other suitable number of seedlings is lifted and the seedlings are arranged in order from best to poorest. The arrangement is made by eye, but is checked as carefully as possible, preferably by more than one worker. The 9 seedlings that divide the array into 10 equal parts (if 100 are taken, the tenth, twentieth, and so on) are then separated from the lot, arranged in order against a ruled background, and photographed. It is well to include in the photograph a label unmistakably identifying the conditions under which the seedlings have been grown.

Usually it pays in the long run to have the man in charge of the nursery keep a daily journal of work done, of interesting developments, and of decisions reached concerning future practice.

It is an excellent plan to keep a photographic record of the nursery, including several series of well-selected views taken from fixed points, a series showing all regular nursery operations, and examples of whatever damage is done by nursery pests. A series of photographs of the deciles of representative lots of stock will form a valuable basis of comparison for stock raised in later years.

PLANTING

SITES AND SPECIES

In artificial reforestation in the southern pine region selection of the site to be planted and of the species to be used depends primarily on the forest type originally occupying the land, logging and fire history and subsequent natural reseeding, soil conditions, the presence or absence of various brush species, and the suitability of the different southern pine species [11] for the site and for available markets.

As has been seen in figure 1, the range of slash pine is the most limited, and that of shortleaf pine the greatest. Longleaf pine is widely enough distributed to fill most of the region's planting needs, and slash pine seems to be able to thrive considerably beyond its natural range and hence to be almost as widely available.

By far the greater part of the area needing forest planting in the South was formerly occupied by pure or nearly pure stands of longleaf pine. Several million acres of land formerly occupied by longleaf pine appear to be incapable of restocking naturally with any useful species in less than 40 years (*33*).

[11] Results of efforts at reforestation with exotics in the southern pine region are discussed in the appendix, p. 113.

Under present conditions much of this nonrestocking longleaf pine land cannot profitably be planted, because of poor soil quality or because of dense stocking with scrub oak and other undesirable species. Among the least favorable planting sites are those on which the soil consists of deep, coarse sand, very low in fertility and in capacity for holding moisture. Such sandy soils occupy extensive areas in western and central Florida, south-central North Carolina, and central South Carolina.

Over most of the nonrestocking longleaf pine areas of better quality the soils consist of a comparatively shallow stratum of fine sand or sandy loam overlying a stratum of rather stiff sandy clay. Such soils are classified as sandy loams. They have high moisture-holding capacity and considerable fertility, but they bake hard in dry weather and their subsoil seems to be too stiff to favor loblolly pine. On such lands longleaf pine thrives and slash pine gives promise of making excellent growth at least where the temperature and rainfall resemble those of its natural range. Such lands are not in great demand for agriculture.

Characteristic loblolly pine areas on which there is occasion for planting occur on the sandy coastal plain from South Carolina north to Maryland and in the piedmont area from Mississippi east to Georgia and thence northward into North Carolina. A large proportion of these areas do not appear to offer satisfactory growing conditions for slash pine, which grows less rapidly when planted far north of its native range and is subject to windthrow in regions of occasional sleet and snow. The areas on which loblolly pine should be planted are in many cases abandoned agricultural lands, often more or less eroded. Areas of that description outside the natural range of loblolly pine offer opportunities for planting shortleaf pine; these include some of the most badly eroded lands in the Eastern States, and much abandoned agricultural land toward the western edge of the pine belt, as in Arkansas and eastern Texas, where the rainfall is apparently too low for pine species other than shortleaf.

In the Georgia and Carolina piedmont areas, and especially in the silt loam uplands of northern Mississippi, abnormal soil erosion is widespread and appears to be accelerating. Of the millions of acres of land so affected, practically all should never have been cleared and practically all has been farmed injudiciously. Rainfall is heavy, frost action extremely severe, surface soil highly susceptible of washing, and subsoil highly subject to undercutting by frost and rain. Control methods include forest planting, preceded by plowing of gully banks and construction of check dams. The species preferred for this special purpose include black locust, shortleaf pine, and loblolly pine. Directions for erosion-control planting are available in several publications (*19*, *20*, *33*).

Other things being equal, among areas in need of planting those of highest potential productivity should be planted first. Land that gives promise of prompt natural restocking with species of possible commercial use and with stands of adequate density should be saved for the last, except under unusual circumstances.

Ordinarily, it is desirable to plant clear land before brushy land. It may be advisable to make an exception of brushy land, incapable of restocking naturally with valuable species, where pines, if planted

promptly, could get ahead of the scrubby hardwoods. A system called "skeleton planting" (*29*) has been suggested to combine production of merchantable timber with improvement of deteriorated sites occupied largely by nonmerchantable species. This consists in planting 200 or 300 trees of the desired commercial species per acre, in natural openings or on apparently favorable patches of soil. The cost per acre for planting stock is low, cultural methods such as liberation cuttings or prunings are concentrated on the few stems intended for the final crop, and the cost of early thinnings, such as must sometimes be made without profit in young stagnated pine stands, is avoided. Under this system, which has not yet been tried in the South, the natural succession of subordinate species continues to improve soil conditions and the crop trees put on wood of superior quality. That the method is desirable for the southern pines is indicated by the results frequently observed in natural stands in which loblolly and shortleaf pine have grown in mixture with hardwoods and in slash pine plantations established by ordinary planting methods in heavy oak brush.

In general, the best species to plant on a given site is the species that made up the bulk of the original stand. If for any reason this species is undesirable, or if conditions resulting from logging, fire, or the encroachment of brush make use of the original species inadvisable, it is best to use a species known to grow well on similar soils nearby. For example, slash pine often succeeds on brushy cutover longleaf pine land on which, because of the shade cast by the brush, the initially slow-growing longleaf pine would have little chance of success.

Other things being equal, the species chosen for planting should be that promising greatest resistance to insect or fungous enemies likely to cause trouble in the locality. For example, longleaf or slash pine should be planted instead of loblolly or shortleaf pine in localities where damage by Nantucket tip moth is severe. Another element in choice of species for site is comparative fire resistance, discussed on pages 94 and 95.

OUTSTANDING SPECIES CHARACTERISTICS

Of the four principal southern pine species, longleaf and slash produce the heaviest and strongest wood. Slash pine produces naval stores somewhat more abundantly than longleaf (table 2). Slash pine grows more rapidly than longleaf, and, for the first 25 to 30 years, faster than either of the two other principal species (table 1).

Loblolly pine produces wood less valuable than that of longleaf and slash pine or than that produced by shortleaf pine where the latter reaches its best development. It grows more rapidly, however, than any of the other southern pines in rotations up to 60 years. Its wood makes excellent pulp. In this respect both loblolly and shortleaf pine excel longleaf and slash pine under the methods of pulp manufacture thus far put into practice. The higher resin content of slash and longleaf pines places them at a certain disadvantage in the manufacture of kraft-paper pulp.

Slash and loblolly pine are the easiest to raise in the nursery; according to our present knowledge, longleaf pine is next. Slash is the easiest of the southern pines to plant, followed by longleaf.

In adaptation to different sites and ability to endure unfavorable conditions in the field, high-quality longleaf pine stock clearly stands first. In this respect slash pine bids fair to take second place, at least aside from climatic limitations. Less is known about shortleaf pine, but it seems to be adaptable to a greater variety of soils than loblolly pine.

MIXTURE OF SPECIES

Establishment of pure even-aged stands of large extent has proved a serious mistake in the case of loblolly pine, and is thought inadvisable in the case of the three other species. Mixed planting is desirable for four different reasons. (1) In the present state of uncertainty as to which species is best for any particular site mixed planting has, on the average, a much better chance of establishing a fully stocked and productive stand than single-species planting. Variations in soil and drainage cause differences in site quality within comparatively short distances. (2) Mixture of species reduces the danger of rapid spread of insect infestations or disease epidemics, and can guarantee to some extent the survival of a fair stand in any of the numerous cases in which the insect or fungus attacks one species only. For example, if slash pine is planted in mixture with loblolly pine tip-moth attack is less likely, because the slash pine is not a favorable host for the moth, and if the insect does attack the loblolly pine and destroy its value the slash pine can still form a full, healthy stand. (3) Mixture of species may lessen the potential fire damage; in particular, longleaf pine is desirable for planting in mixture with slash or loblolly pine even on a site where one of the latter species is most likely to yield a large financial profit, because after its first growing season in the field longleaf is much more resistant than the three other species to fire. (4) As years go by changes in demand or other market conditions may make a once popular species less profitable, with the result that a second species will advance in favor.

Two species planted in mixture may alternate by rows, or may alternate within each row. In planting slash pine and longleaf pine in mixture it is well to alternate three rows of the one species with three rows of the other, because slash pine makes so much more rapid growth than longleaf pine at the start that if single rows are alternated it is likely to overtop and suppress the longleaf pine between the fifteenth and twentieth years in the field.

SPACING

The choice of a spacing at which to plant a given species of southern pine is almost as important as the choice of species for a given site. It may affect the cost of establishing the plantation and the quantity and quality of lumber produced, and hence the profit from the first rotation, even more than choice of species.

The southern pines are relatively intolerant of shade. With the exception of longleaf, in even-aged pure stands they tend to grow uniformly in height. For these reasons, very close spacing of species other than longleaf is likely to result in stagnation soon after the crowns close.

Pure even-aged stands of longleaf develop very irregularly in height [12] from an early age. The contrast in height growth between both planted and natural stands of longleaf pine and planted stands of other species is shown in figure 9. The contrast in this respect between planted longleaf pine and planted loblolly pine is illustrated in figure 10. Because of the tendency of the species toward early differentiation in crown class, at any spacing the danger of stagnation is less for longleaf pines of a given dominant height than for other pines of that height. Hence a close spacing might be permissible for longleaf pine when it would not be so for the three other species because of the prospect that thinning would be economically impracticable.

The southern pines' remarkably rapid growth insures that even when spaced rather widely they will close their crowns at an early age and thus prune themselves naturally. Wide spacing has the fol-

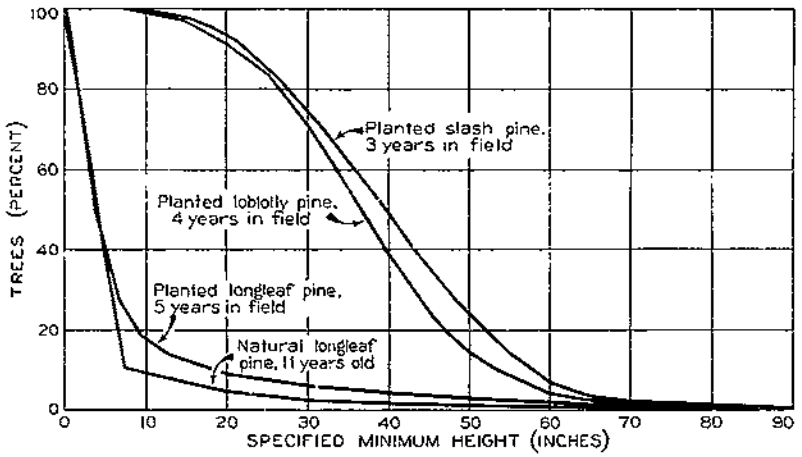

FIGURE 9.—Relative height distribution of planted and naturally reproduced longleaf pine and of planted slash and loblolly pine. (Basis, measurement of the following numbers of trees: Planted longleaf pine, 1,850; naturally reproduced longleaf pine, 2,168; slash pine, 2,778; and loblolly pine, 823.)

lowing principal advantages: (1) It reduces the cost of establishing the plantation. Cost of planting stock is reduced in direct proportion with number of trees planted per acre, and cost of labor involved in planting is reduced in a lower but considerable proportion. (2) It reduces the need of very early thinning to prevent stagnation, and frequently makes it possible to postpone the first thinning until the trees to be removed are large enough for pulpwood or other merchantable products. (3) It results in rapid diameter growth. If this can be brought about without sacrificing quality, it means earlier yield of merchantable products. Rapid diameter growth is especially important in plantations established for naval-stores production, since (as is shown in table 2) yield of gum increases with increase in diameter.

[12] A few plantations of longleaf pine almost as uniform in height growth as slash pine have been observed in South Carolina. All available evidence indicates that this unusual uniformity in height growth is the result of using vigorous stock very skillfully graded by the method described on p. 79.

Close spacing has these advantages: (1) It raises the quality of the product by causing earlier self-pruning, smaller knots, better recovery from attack of such insects as tip moth, and, usually, superior grain. (2) It decreases the probability that replacements will be needed.

Striking differences in habit of growth, together with differences in the purposes for which they are grown, make the southern pines differ somewhat as to space requirements in young plantations. Figure 11, based on drawings, to scale, of representative trees in plantations 7 to 10 years old illustrates essential differences in habit.

Longleaf pine and slash pine are sparsely branched. As trees of these species increase in height the lower branches weaken, die, and rot off before attaining any great size. The greatest crown width tends to move upward rapidly. Sidewise extension of the crown (marked by pairs of short lines at the bases of the trees in fig. 11)

FIGURE 10.—Planted longleaf pine (left) and loblolly pine (right) after 8 years in the field. The loblolly pines are approximately even in height, whereas more than half the longleaf pines have not yet emerged from the grass.

is decidedly moderate. Both longleaf and slash pines usually are entirely free of deformation resulting from insect attack and accordingly have straight main stems. Loblolly and shortleaf pines have more numerous branches, and after Nantucket tip-moth attack their branches subdivide prolifically. The lower branches not only persist longer than those of longleaf and slash pine but continue to grow vigorously, making large knots in the wood and producing the broad, somewhat conical crown shape shown in figure 11. The main stems of loblolly and shortleaf pine are frequently deformed as a result of tip-moth attack. Because of the habits of growth just described it is desirable to grow loblolly and shortleaf pines at somewhat closer spacing than longleaf and slash pines. The fact that loblolly and shortleaf pines are preferred for pulpwood, and that longleaf and slash pines are of value for naval stores as well as for wood products, is an argument in the same direction.

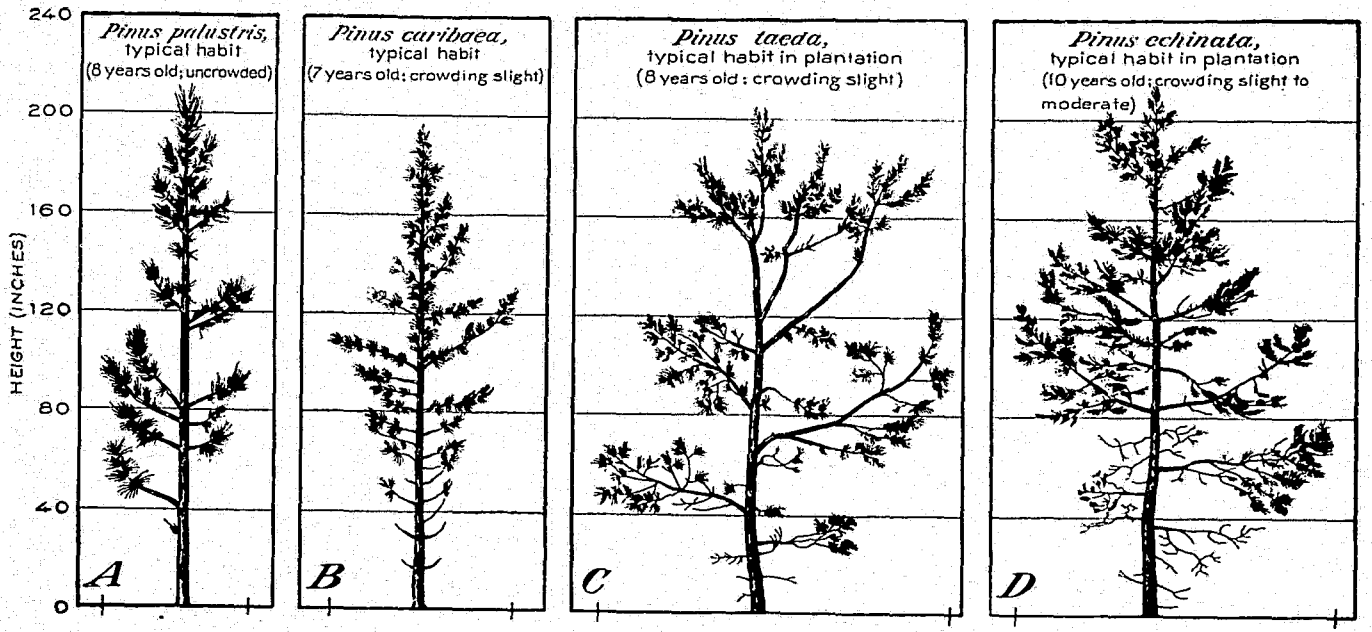

FIGURE 11.—Longleaf (*A*), slash (*B*), loblolly (*C*), and shortleaf (*D*) pines typical in form and branching habit of stock 7 to 10 years in the field. The longleaf and slash pines grew practically without crowding and the loblolly and shortleaf pines were crowded only slightly to moderately.

In an experimental planting of loblolly pine established in 1923, trees spaced 5 by 5 feet or 6 by 6 feet have tended during the first 10 years in the field to develop better form, with smaller knots, finer grain, and better recovery from tip-moth injury, than trees spaced 8 by 8 feet. The differences in spacing have had no significant effect on height growth. The plantation was established with 1–0 nursery stock on a site relatively poor for the species. Details of the results are given in table 16, and the plantations spaced 5 by 5 feet and

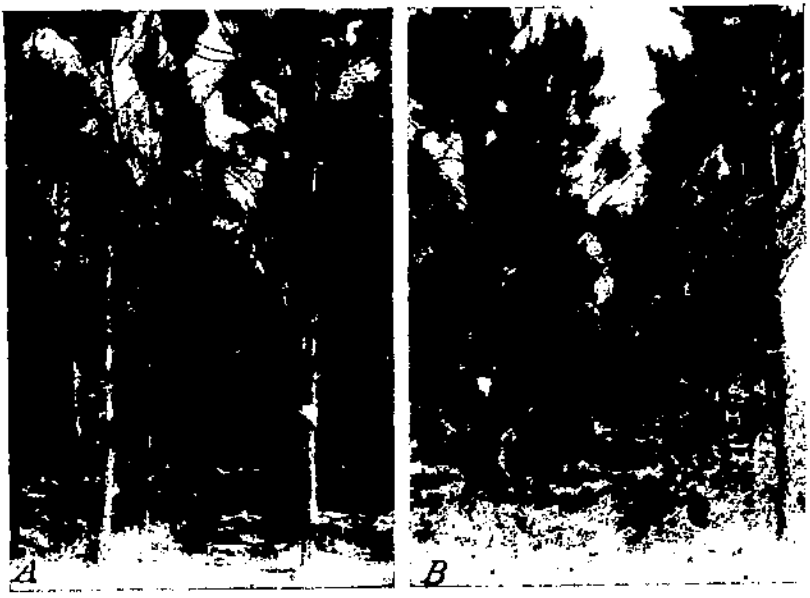

FIGURE 12.—*A*, Loblolly pine planted at spacings of 5 by 5 feet, 10 years after planting; *B*, loblolly pine planted at spacings of 8 by 8 feet, 10 years after planting.

8 by 8 feet are shown in figure 12. Practically no other systematic experiments to show the effect of spacing upon southern pines have been completed.

TABLE 16.—*Development of loblolly pine planted at different spacings, during its first 10 years in the field*[1]

Item	5 by 5 feet	6 by 6 feet	8 by 8 feet
Height.....feet	20.56	19.66	19.91
Diameter breast high.....inches	3.39	3.54	4.02
Crown diameter.....feet	6.45	6.94	8.41
Distance from ground to lowest live limb.....do....	7.14	5.58	4.62
Portion of total height below lowest live limb.....percent	34.06	28.38	23.20
Recovery from tip moth injury[2].....	2.79	3.40	3.56

[1] Figures presented are averages based on 600 trees, of which 200 were selected at random from the interior of each of three 1-acre blocks planted at the 3 spacings, respectively, on Ruston fine sandy loam near Bogalusa, La. The plantations were established in February 1923.

[2] 1=good recovery; 3=medium recovery, and 5=poor recovery.

In the southern pine region a very great part of the forest planting has been done not in the "square" spacings (6 by 6 feet, 8 by 8 feet, etc.) customary elsewhere but, with some slight irregularities, in rectangles, usually 6 by 8 feet.

Table 17 gives suggested spacings for southern pines under the conditions ordinarily encountered. The reasons for these spacings are fairly obvious. Where anticipated pulpwood production promises profitable thinnings or where thinning operations are contemplated as a part of the undertaking, spacing should be somewhat closer than where timber production cannot count on thinnings. Loblolly and shortleaf ordinarily may be spaced closer than longleaf and slash. For naval stores production, light and ground space are prerequisite. Where timber of good quality is to be the main crop and naval stores secondary, moderately close spacing is preferable even though it somewhat reduces the yield of naval stores.

TABLE 17.—*Suggested spacings at which to plant southern pines of various species, by intended use of plantations*

Species	Intended use	Suggested spacing	Species	Intended use	Suggested spacing
		Feet			*Feet*
Longleaf and slash	Timber production without thinnings.	6 by 8 7 by 7 8 by 8	Loblolly and shortleaf.	Timber production without possibility of early thinnings.	6 by 6 7 by 7
	Combined timber and pulpwood production.	6 by 6 6 by 8		Timber or timber and pulpwood production with probability of early thinnings.	5 by 5 6 by 6
	Naval stores production.	10 by 10 12 by 12		Erosion control	13 by 3 14 by 4

In "skeleton planting", discussed on page 68, the spacing would, of course, be not only irregular but also very wide, perhaps equivalent to a regular spacing of from 12 by 12 feet to 20 by 20 feet.

SITE PREPARATION

It has become increasingly common to plant southern pines without any direct preparation of the planting site. On some soils and in some cover types it is desirable to plow shallow furrows in which to set the trees. Plowing is particularly desirable on areas where the growth of grass is so luxuriant that it threatens to smother planted seedlings during their first summer in the field. It is likewise advisable on extremely dry, sandy sites, on which a slight furrow may serve to concentrate moisture. When a horse or team is used in plowing a middle breaker or a "scooter stock" is preferable to a turning plow unless longleaf pine is to be planted. If the middle breaker is used the furrows are less likely to require additional hand clearing with the planting tool, but more of the turned-out soil washes into the furrows and this "silting" tends to cover the bud of the stemless longleaf pine seedling and either kill the tree or delay the beginning of height growth. Where tractor plowing is feasible, satisfactory results can be obtained with a disk plow set to cut a very broad and shallow furrow. Furrowing, at 8-foot intervals, increases planting costs by from 5 to 15 percent; Smith (*28*) records an average of 32.4 cents per acre for 5,204 acres.

As a method of preparing a site for the planting of longleaf pine, clearing the grass from spots 12 to 15 inches square by means of heavy hoes is more satisfactory than plowing furrows. The spots should

be hoed during the summer, so that fall rains will wash in any loose soil and cause it to reach a permanent level before the planting season arrives. Longleaf pine seedlings properly set in such spots suffer little or no damage from "silting."

Either a plowed furrow or a hoed spot should be made as shallow as possible without leaving grass or other vegetation in it with sufficient roots to start new growth.

Some experiments have been made on adverse sites with plowing all over instead of in strips. In some instances the plowing has been followed by harrowing. Such treatment breaks up the native vegetation enough to prevent its competing seriously with the planted stock, and sometimes insures success where ordinary planting methods would fail; but its cost is entirely too high for general use. Where planting requires such thorough preparation, ordinarily it should not be attempted.

Sometimes it is necessary to clear land of brush either before planting or shortly after planting. The principal species to be cleared are usually oaks—blackjack, southern red, blue-jack, and post oak on the so-called sandy loam soils with a stiff sandy clay subsoil, and turkey oak and blue-jack oak on the deep sands. All these species sprout vigorously and even if cut in August or September may regenerate a dense cover from 12 to 24 inches high before cold weather sets in. If slash or loblolly pines can become established successfully under brush and grow a little under it in the first 2 years following planting, it is better to cut the brush after planting instead of before, because the pines take on a new lease of life when liberated and thereafter stay well above the oaks. If the brush cover is so dense that there is doubt of the pines' surviving under it, it is better to cut the brush before planting and if need be to return 2 or 3 years after planting to cut the sprouts actually interfering with the pines. On very brushy land, advantage should be taken of natural openings regardless of the resulting irregularity of spacing.

To plant longleaf pine under brush of any great density appears unwise. If the brush is cleared either at the time of planting or 2 or 3 years later, there is little or no chance that the pine will escape being overtopped by the resulting sprouts. If, on the other hand, the brush is left undisturbed until the pine has reached an age at which it ordinarily makes good height growth, there is serious danger that the shade cast by the brush and the competition of its roots for water and nutrients will entirely kill out the pine.

Burning of the planting site in advance of planting has often been advocated to facilitate planting by clearing the ground, to decrease vegetative competition with the young seedlings, and to transform the whole area into a sort of firebreak for the first season following planting. Such burning undoubtedly makes work easier for the planting crews if too long a rainy season does not intervene between burning and planting; but heavy or protracted rains harden the soil on burned areas more than on those protected by a cover of plants and litter. Evidence concerning the effect of fire on the chemical and physical condition of the soil is conflicting and inconclusive.[13]

[13] DEMMON, E. L. FOREST FIRES IN THE SOUTH. U. S. Dept. Agr., Forest Serv. Unpublished manuscript.

but burning the surface vegetation certainly increases sheet erosion, and this in the case of longleaf pine seedlings adds to the danger of injury to the trees from silting. Cattle tend to concentrate on burned areas in the spring and sometimes cause damage by trampling; and burning leads to more nipping of planted stock by sheep and goats. Except under extraordinary circumstances, therefore, burning of the planting site cannot be recommended. Several thousand acres of thrifty longleaf pine plantations show plainly that success does not depend on the use of fire at the time of planting.

SEASON AND WEATHER

To be consistently successful at reasonable cost, planting must be done during the dormant season. In the Gulf States this practically limits it to December and January, although early cold weather makes November planting possible in some years and a delayed spring sometimes makes it possible to work well into February.

In the more northerly part of the southern pine region freezing weather breaks the planting season into two parts. Although experiments in the Gulf States show a slight superiority of early planted over late planted stands both in survival and in height growth, especially for slash pine, farther north the latter part of the season appears to be preferable because of the danger of frost-heaving of stock set in the field before the midwinter freezes and thaws.

Certain skillful tree planters of the Gulf States prefer to postpone planting until at least one sharp frost or good freeze has "hardened" the stock in the nursery.

At least two instances have been recorded of successful planting of slash and loblolly pine in the spring, when the tops had put on 2 or 3 inches of growth and root development had reached a state of great activity. Great care was taken to keep the stock wet, and the planting was followed by very favorable weather. In the main, it is not wise to handle stock after growth has started in the spring.

The Southern Forest Experiment Station has no records of successful planting of southern pines during the summer on a scale and in a manner suitable for reforestation.

The Carolinas, Georgia, and Florida are likely to have a period of relatively low rainfall in October and November and another in April, with only a moderate increase during the midwinter months. The Gulf Coast States other than Florida are more likely to have only a very moderate rainfall deficiency in October and then to have distinctly heavy precipitation in February and March. Thus in the Gulf coast region west of Florida, as compared with the region to the east, the planting season is less likely to be delayed by fall drought and there is more likely to be plenty of moisture to help the newly planted trees get a good start in the beginning of their first growing season in the field. Favorable conditions of winter and spring rainfall ordinarily occur as far west as the third or fourth tier of Texas counties west of the Louisiana boundary. It must be emphasized that the general relationships just outlined by no means always hold true. The entire region is notably subject to droughts at almost any season.

Prolonged drought is the climatic factor most to be dreaded in connection with reforestation with southern pines. Fall droughts

sometimes leave planting sites so dry and hard that planting is impossible when the stock becomes dormant and must be postponed until the soil is softened by early winter rains. Drought during the usual planting season may make it necessary to postpone planting until dangerously close to the beginning of the growing season. Severe drought early in the growing season is to be dreaded most of all, because it catches the trees before they have had time to establish their root systems in the new environment and they lose water by transpiration faster than the roots can supply it. Spring droughts result in high mortality.

Planting in cloudy or even rainy weather is more likely to succeed than planting in clear and particularly in clear windy weather. Lack of sunshine and presence of considerable quantities of moisture in the air are helpful in keeping the roots of seedlings from drying out during planting. Rainy weather also insures sufficient soil moisture.

Warm weather has a tendency to bring seedlings out of their dormancy and thus decrease the likelihood of their survival. Very cold weather makes work more difficult, thus unduly increasing planting costs or seriously reducing survival. Instances have been reported in Louisiana and eastern Texas of slash pine being killed by freezing of the roots during planting.

STOCK

GRADES

At the end of the first growing season grade 1 seedlings of slash, loblolly, and shortleaf pines, as defined by the grading system devised by the Southern Forest Experiment Station, have greater average height than grade 2 or 3 seedlings of those species. (A few grade 2 seedlings may be taller than part or even all of the grade 1 seedlings.) Grade 1 seedlings of slash pine are ordinarily from 10 to 16 inches high, those of loblolly pine from 8 to 14 inches high, and those of shortleaf pine from 6 to 12 inches high. Development, rather than size, however, is usually the determining factor in grading. Grade 1 seedlings of these three species have stout, woody stems with well-developed bark. Their foliage consists largely or entirely of secondary (fascicled) needles. Winter buds are well developed on a large percentage of them, unless an unseasonable warm spell has caused the buds to open and a little new wood to form. Such new growth may become dormant in its turn and a second, somewhat less heavily scaled winter bud develop. Seedlings developing in this way are not quite so desirable as stock that remains dormant all winter, but with reasonable care can be planted as successfully as any others.

Grade 3 seedlings of slash, loblolly, and shortleaf pine have weak, slender, succulent stems, sometimes almost wholly lacking in true bark. Except in rare instances the foliage consists entirely of juvenile (single) needles. Winter buds are never present. At least in the southern part of the Gulf Coastal Plain, grade 3 stock does not become dormant, but continues to grow practically throughout the winter.

Grade 2 seedlings may have fairly stout stems but no fascicled needles, or a few fascicled needles but poorly developed stems.

Winter buds are more likely to be lacking than either secondary needles or satisfactory stem development. Such seedlings are less likely to continue growth throughout the winter than those of grade 3, but may not attain the complete dormancy ordinarily characteristic of grade 1 stock.

Seedlings of longleaf pine cannot be graded on the same basis as those of the three other species, since they develop practically no stems while in the nursery. Grade 1 longleaf pine seedlings have vigorous and abundant fascicled needles 10 or 12 to 18 inches long. They have very thick, stout taproots, usually from three-sixteenths to one-half inch thick at the surface of the ground. In ordinary seasons a high percentage of grade 1 longleaf stock has winter buds covered by well-developed white or brownish scales. Grade 3 longleaf pine seedlings are small, with few if any fascicled needles and with short primary needles. The taproots are very slender at the surface of the ground and buds are wholly lacking. On grade 2 longleaf seedlings the foliage is ordinarily fairly vigorous and may contain secondary needles up to 15 inches in length, but the needles are neither so abundant nor on the average so long as those of grade 1 stock. The taproots are not so thick as those of grade 1 stock. Buds covered with scales are generally entirely lacking, but a relatively high percentage of grade 2 stock may have naked buds consisting of very short needle tips closely packed.

The characteristics of the different grades are summarized, species by species, in table 18. Seedlings of various grades and species are shown in figure 13, *A*, *B*, *C*, and *D*.

TABLE 18.—*Characteristics of southern pine seedlings of different grades*

Grade no.	Usual heights[1]	Stems	Bark	Needles	Winter buds	Remarks
LONGLEAF						
1	12 to 18 inches	3/16 to 1/2 inch in diameter at surface of ground.		Abundant. Largely or entirely fascicled.	With scales usually abundant.	Usually become completely dormant.
2	Intermediate between those of grades 1 and 3	Diameters at surface of ground intermediate between those of grades 1 and 3.		Intermediate	Scales usually lacking; naked buds usually abundant.	In Gulf States, dormancy depends on weather conditions.
3	6 to 8 inches	Very slender at surface of ground		Scanty	Never present	Rarely dormant in Gulf States.
SLASH						
1	10 to 16 inches	Stout, woody	Well developed	Largely or entirely fascicled	Usually well developed	Usually become completely dormant.
2	Mostly less than those of grade 1.	Spindling to moderately stout.	Moderately developed	Few or none fascicled	Seldom present	In Gulf States, dormancy depends on weather conditions.
3	All less than those of grade 2.	Spindling, succulent	Sometimes little developed.	Usually none fascicled. Bluish in color.	Never present	Rarely dormant in Gulf States.
LOBLOLLY						
1	8 to 14 inches	Stout, woody	Well developed	Largely or entirely fascicled	Usually well developed	Usually become completely dormant.
2	Mostly less than those of grade 1.	Spindling to moderately stout.	Moderately developed	Few or none fascicled	Almost never present	In Gulf States, dormancy depends on weather conditions.
3	All less than those of grade 2.	Spindling, succulent	Sometimes little developed.	Usually none fascicled. Bluish in color.	Never present	Rarely dormant in Gulf States.
SHORTLEAF						
1	6 to 12 inches	Stout, woody	Well developed	Largely or entirely fascicled	Usually well developed	Characteristic crook at surface of ground. Usually become completely dormant.
2	Mostly less than those of grade 1.	Spindling to moderately stout.	Moderately developed	Few or none fascicled	Almost never present	Crook usually present. In Gulf States dormancy may or may not occur, according to weather conditions.
3	All less than those of grade 2.	Spindling, succulent	Sometimes little developed.	Usually none fascicled. Bluish in color.	Never present	Crook often lacking. Rarely become dormant in Gulf States.

[1] In the case of longleaf pine seedlings, needle lengths.

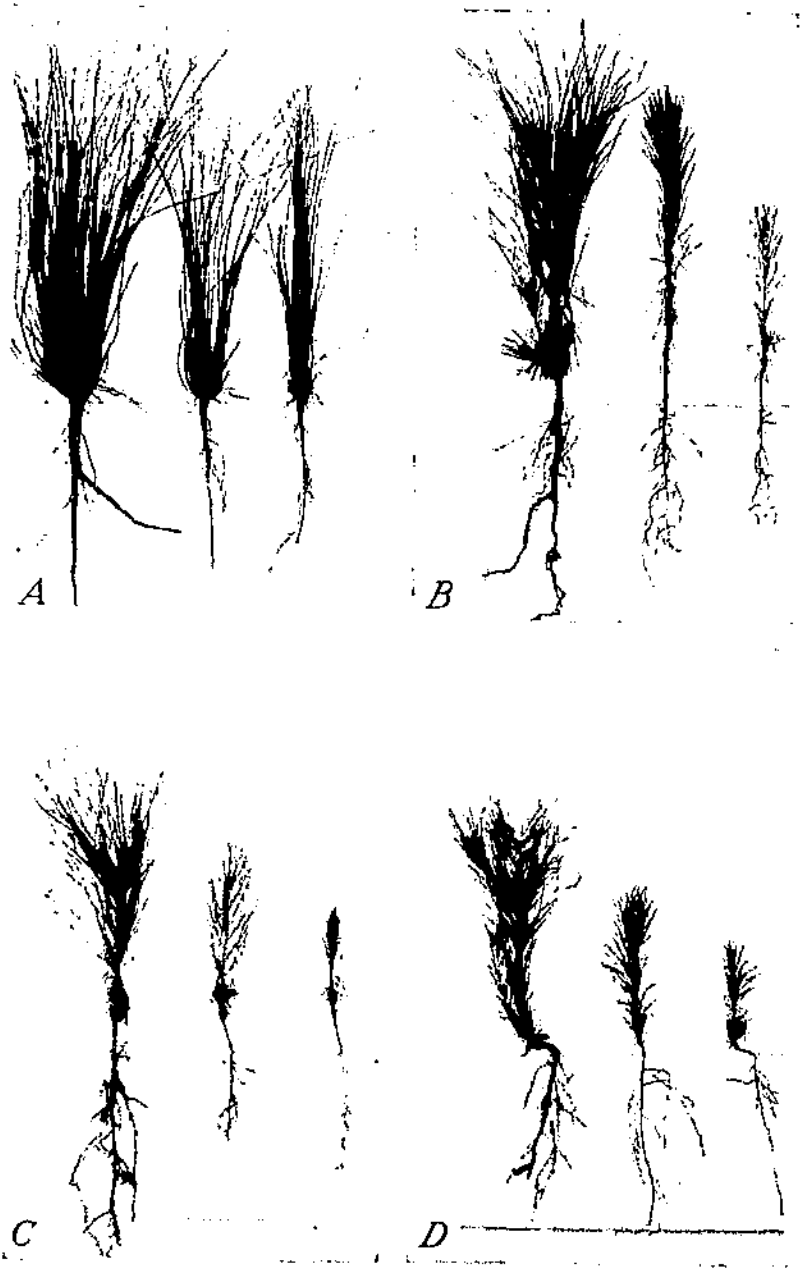

FIGURE 13.—Graded seedlings of southern pines, grades 1, 2, and 3 (from left to right): *A*, Longleaf; *B*, slash; *C*, loblolly; *D*, shortleaf.

The most clear-cut results obtained by the Southern Forest Experiment Station in its planting experiments have been those bearing on the use of various grades of planting stock. These results have been abundantly confirmed by general experience practically throughout the southern pine region.

In the station's principal grading experiments, conducted at Bogalusa, La., slash pine seedlings of grades 1, 2, and 3 were planted alternately by rows. Altogether, 200 seedlings of each grade were planted. A similar experimental plantation of loblolly pine was established at the same time. The following year the plantings of both slash and loblolly were duplicated on an area nearby. In analyzing the figures, all trees that had been subjected to injury not influenced by grade were omitted; consequently the conclusions are based not on the total 2,400 trees planted but on 2,136.

The results were practically the same with both species and in both series of plantations, the chief difference being that the benefits of grading showed more strikingly on the poorer site. After 1 year in the field, in 6 cases out of 8 a grade 1 or grade 2 group showed a higher percentage of survival than the corresponding group of next lower grade, with a maximum difference of 10.9 percent. After 5 years in the field, in 7 cases out of 8 a grade 1 or grade 2 group survived better than the corresponding group of next lower grade, with a maximum difference of 16 percent. The maximum difference in survival between grade 1 and grade 3 seedlings after 5 years in the field was 21.7 percent.

In the one instance in which survival (of loblolly pine) for a given grade was less than that for the next lower grade both after 1 year and after 5 years in the field, the higher-grade stock was discovered to be infested with scale insects.

In every instance, undamaged seedlings of grade 1 or grade 2 were taller than undamaged seedlings of the next lower grade. At the end of the second year in the field grade 1 seedlings were 33 to 112 percent taller than grade 3 seedlings, the difference varying with species and height, and at the end of the fifth year they were still 25 to 71 percent taller. The height relationship of the different grades of slash pine and of loblolly pine are shown in figures 14 and 15, for both uninjured stock and stock injured by rabbits the first year in the field. Figure 16 shows the appearance of the different grades of stock after 5 years in the field.

The experiments showed that high-grade stock, particularly in the case of slash pine, was less subject to rabbit damage during the first year in the field than that of lower grade. (Injury by rabbits during the second year was usually confined to nipping off side branches, and had little effect on vigor as shown by height growth.) In 6 cases out of 8 the higher the grade the lower the percentage of stock damaged by rabbits, with a maximum difference between consecutive grades of 14.1 percent. One group of grade 3 (slash pine) stock suffered 37.8 percent more damage from rabbits than the corresponding group of grade 1 stock.

The influence of rabbit injury on height growth of stock of different grades is shown in figures 14 and 15. Details of survival and rabbit damage, by grade, are given in table 19.

Studies of longleaf pine in experimental plantations and in commercial plantations indicated that high-grade seedlings not only suffered less from brown spot and silting but also began height growth at an earlier age than did low-grade seedlings. Indeed, grade 1 stock

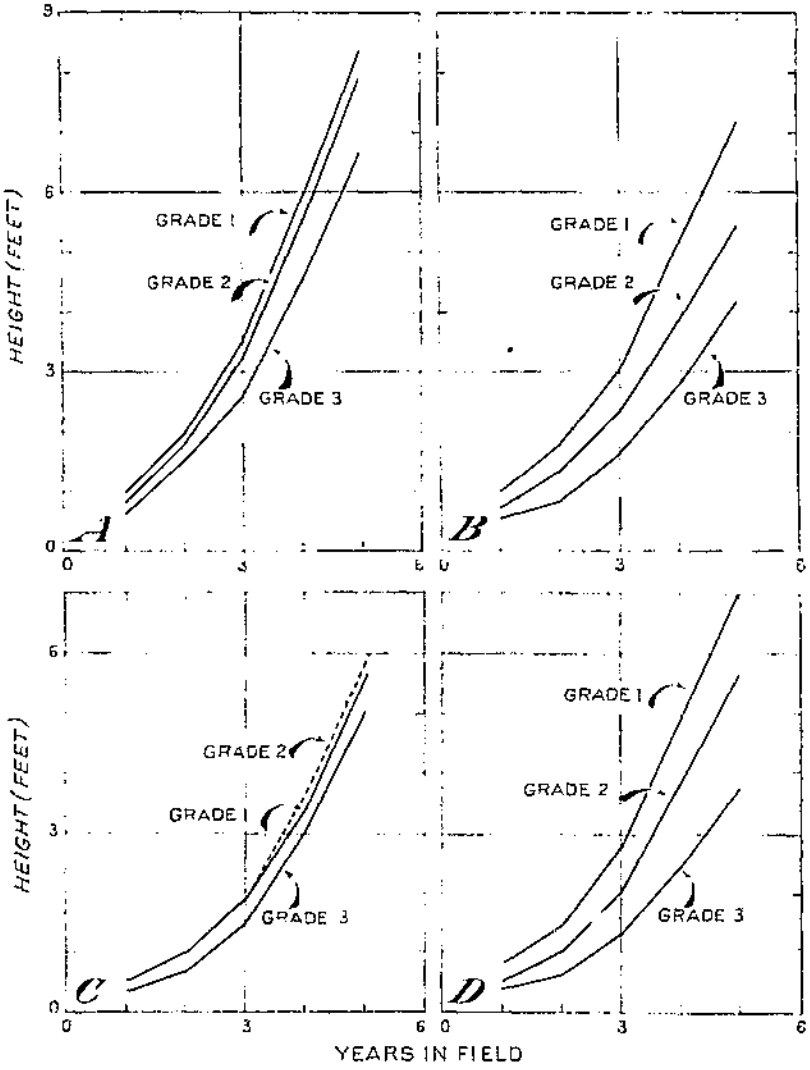

FIGURE 14.—Relative growth made by two successive plantings of slash pine stock (grades 1, 2, and 3) during the first 5 years in the field; *A* and *C* planted 1924–25 and *B* and *D* 1925–26. Effect, on growth, of rabbit injury at the beginning of the first growing season is shown in *C* and *D*; *A* and *B* show growth of *uninjured* stock.

that had been planted properly grew far faster than the best natural stands.

In 1928–29 the Great Southern Lumber Co. established an experimental plantation near Bogalusa, La., to test in detail the difference in survival and growth between grade 1 and grade 3 longleaf pine stock. Two plots of approximately one-fourth acre each were laid

out approximately 200 yards apart, on adjacent low ridges on a typical cut-over longleaf pine tract, and were planted with stock of the two grades, respectively. The growing conditions were nearly identical; if anything, the soil was slightly better on the plot planted with grade 3 stock. Four years later, the apparent survival on the grade 1 plot was 82 percent and that on the grade 3 plot was only 49 percent. It is possible that some of the surviving grade 3 seedlings were overlooked in the grass, because of their small size. On the grade 1 plot 22 trees out of 200 were 6 inches tall or taller, and the

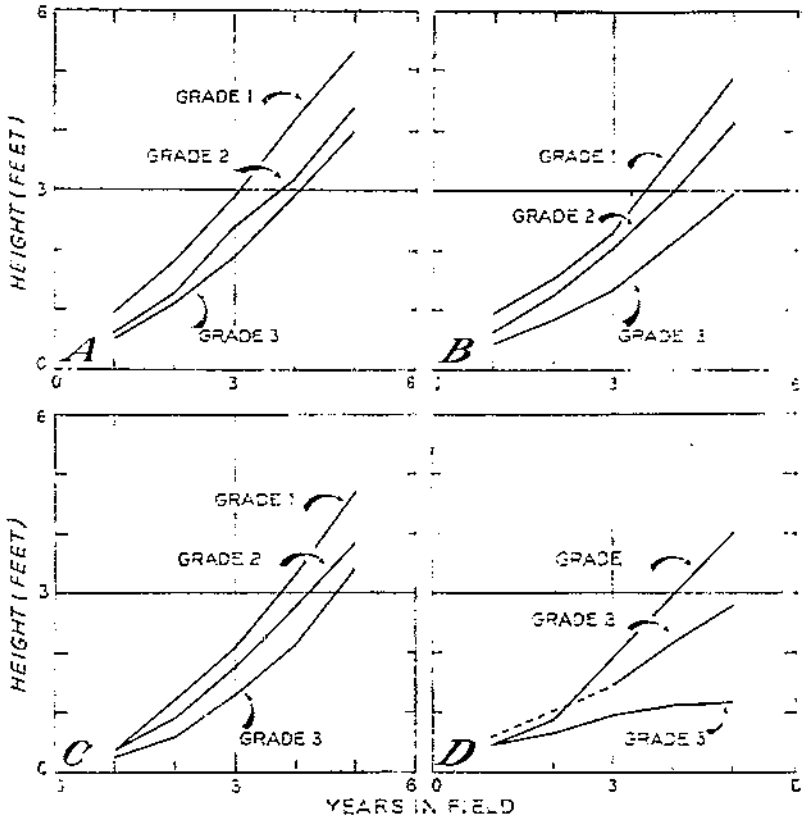

FIGURE 15.—Relative growth made by two successive plantings of loblolly pine stock (grades 1, 2, and 3) during the first 5 years in the field; *A* and *C* planted 1924–25 and *B* and *D* 1925–26. Effect on growth of rabbit injury at the beginning of the first growing season is shown in *C* and *D*; *A* and *B* show growth of uninjured stock.

tallest was 46 inches. On the grade 3 plot only 3 trees out of 112 had reached a height of 6 inches, and none exceeded that height. The exact distribution of seedlings by height classes is shown in figure 17, in terms of percentages of the total number of seedlings observed that attained specified minimum heights.

By the system outlined in the foregoing, the percentage of grade 1 stock can be determined without lifting the seedlings. This percentage, in connection with density determinations and other observations, is an index to the success of various seed-bed treatments.

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FIGURE 16.—*A*, Slash pine stock of three different grades after 5 years in the field. Grade 1 stock is on the right, grade 2 in the middle, and grade 3, including the small seedlings in front of and behind the man, on the left. *B*, Loblolly pine stock of three different grades after 5 years in the field, on a site poor for the species. Grade 1 stock is on the extreme right, grade 2 in the right foreground and center, and grade 3 at the extreme left by the man.

TABLE 19.—*Percentages of stock of different grades injured by rabbits, and percentages surviving, in slash pine and loblolly pine plantations*[1]

Species, date of planting, and character of site	Grade	Seedlings planted[2]	2-year-old seedlings injured		Stock surviving at end of—				
			In first year only[3]	Total	1 year	2 years	3 years	4 years	5 years
		Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Slash pine planted 1924–25, better site	1	202	16.8	22.2	93.1	91.6	90.6	90.1	89.6
	2	196	21.6	31.0	90.3	87.2	86.7	86.2	85.7
	3	191	21.5	27.3	88.5	86.4	85.9	84.3	83.8
Slash pine planted 1925–26, poorer site	1	130	3.3	30.6	93.8	93.1	93.1	90.0	90.0
	2	129	16.7	33.7	84.5	83.7	81.4	79.8	78.3
	3	133	41.1	57.9	82.1	77.2	70.7	69.9	68.3
Loblolly pine planted 1924–25, better site	1	194	10.7	11.8	96.9	96.4	95.4	95.4	95.4
	2	191	17.6	19.4	88.5	86.4	86.4	86.4	86.4
	3	188	11.8	13.6	91.0	89.9	88.3	86.2	85.6
Loblolly pine planted 1925–26, poorer site	[4]1	197	1.3	6.7	76.6	75.6	75.6	75.6	75.6
	2	199	1.6	5.5	93.0	91.5	91.0	91.0	90.5
	3	196	.6	3.9	82.1	78.6	77.6	76.5	74.5

[1] Table based on data for 2,136 seedlings planted at Bogalusa, La.
[2] Exclusive of a few trees rejected because of definitely determined injury not traceable to grade.
[3] Injury by rabbits the first year ordinarily involves cutting off the entire top of the seedling, and is more serious than later injury, which frequently involves only the clipping of side branches.
[4] The mortality in this grade was increased by action of scale insects, but the records were not sufficiently detailed to permit rejection of individual trees as described in footnote 2.

The most conspicuous differences between grades result from differences in seed-bed environment, in age, or in both. Low-grade seedlings result more often from overcrowding than from any other cause. Poor soil quality, abundance of weeds, and insufficiency of water are other important factors.

Trees from seeds germinating late in the season usually fall in grade 3, because of their disadvantage in competing for moisture and light. Insect injuries during spring or summer are another frequent cause of low grade. Another is undue delay in sowing the nursery as a whole.

Because grade is so largely a matter of seed-bed environment and of age, grade 2 stock may frequently be planted with perfect safety on favorable sites. On areas where site is more adverse, including those where there is much competition from other plants, grade 1 stock should be used whenever possible. Grade 3 stock, as here defined, cannot compete with native vegetation or stand up under the extremes of temperature or the fluctuations in moisture supply common throughout the region.

Seedlings infected with fungus or infested by insects at the end of the growing season, and seedlings injured in lifting, should be culled.

LIFTING

To date, most nursery stock grown in the South has been lifted by hand.[14] The usual practice, which produces satisfactory results so far as growth and survival are concerned, is to lift the stock with long-handled square spades, the edges of which are kept sharpened with files. Use of the highest-grade spades obtainable saves much

[14] The Forest Service and other agencies have developed for use in the North and West several types of mechanical seedling lifters (drawn by horses, tractors, or winches) that loosen the soil and prune the roots in a single trip down a standard seed bed (*33, 39*). The Forest Service is now adapting this equipment for use in the southern pine region.

time and cost in filing the edges, more than making up for the slight extra initial cost.

A trench about 12 inches deep is dug at the end of the bed. A spade is driven into the soil horizontally at a depth of 8 or 10 inches, cutting the roots fairly cleanly. The spadeful of soil containing the seedlings is then lifted out to the ground at the side of the bed. It is set down rather hard, to cause crumbling. One man does the digging in each bed. Two to four men follow each lifter down the beds, freeing the seedlings from the soil, culling the grade 3 seedlings and the injured seedlings of higher grade, and laying the good seedlings neatly together in readiness for the packers.

It is common practice to protect the piles of good seedlings by covering the roots with earth. Wet sacks could profitably be substituted.

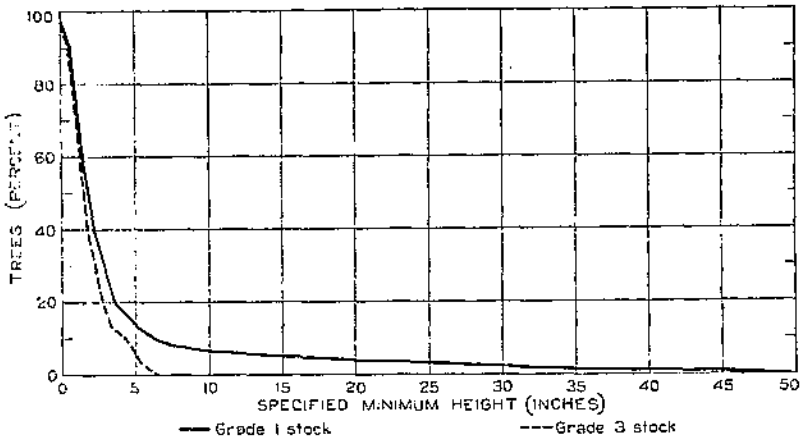

FIGURE 17.—Relative height distribution of grade 1 and grade 3 longleaf pine stock, after 4 years in the field, in experimental plantation established by the Great Southern Lumber Co. (basis, measurement of 200 grade 1 trees and 112 grade 3 trees).

The presence of many weeds in the nursery adds considerably to the cost of lifting, in extreme cases nearly doubling it. Bright, sunny weather somewhat increases the cost of lifting because it increases the frequency with which the sorters must stop to cover the roots.

In transporting the seedlings to the packers much waste of motion can be prevented by using two (or more) wheelbarrows, leaving one to be emptied by the packers while another is being filled at the beds. To protect the seedlings, wet moss should be used in the bottom of the wheelbarrow and wet burlap sacks over the top.

Counting the seedlings is necessary only if they are to be sold. If a count is required, usually it is made by the packers. Quantities of stock can be computed approximately by sampling representative beds before the stock is lifted. These computations can be checked by counting the seedlings in sample bundles and the bundles in sample crates, and further checked by totaling the area planted and computing an average of the number of seedlings planted per acre.

PACKING

In order that seedling roots may be kept moist at all times, the seedlings must be packed in some moisture-retentive material from the time they are lifted until they are heeled in or planted. This material should be the lightest and cheapest that will remain effective through the necessary handling.

One of the packing methods most common in the South employs sphagnum moss and light cardboard or waterproof paper. From 50 to 100 seedlings are wrapped in one bundle; 50 longleaf seedlings, or 75 grade 1 slash pine or loblolly pine seedlings, are about all that can be grasped and rolled efficiently. Another efficient method of handling seedlings is to bale them in burlap. Another is to pack them in the body of a truck lined with wet sacks and cover them with wet sacks and heavy canvas for direct transportation to the heeling-in bed. Small lots of seedlings may sometimes be transported economically by truck in washtubs full of water.

In wrapping seedlings in bundles, use is made of sections of light cardboard (known as "container lining") or waterproof paper, 16 by 16 inches to 18 by 24 inches. The wrapper should be long enough to project about 5 inches beyond the pruned ends of the roots and still extend to the tips of the stems of seedlings other than longleaf pine, or nearly to the ends of the needles of longleaf seedlings. Having laid such a wrapper on the bench or ground before him, the packer places on it a layer of sphagnum moss one-half inch thick and large enough to keep the paper from coming in contact with any of the roots or the lowest 2 inches of the stems. Next he lays a handful of seedlings on top of the moss, with their root collars all together. He then claps another ½-inch layer of moss over the mass of roots and begins to roll the bundle away from him, squeezing the roots tightly. After completing one turn of the wrapper around the roots he turns up the length of wrapper extending beyond them. The paper then forms a tube, closed at one end, that surrounds the seedlings and holds the wet moss in contact with them. When the wrapper has been rolled completely around the bundle, it is tied in place with light cord.

Longleaf pine seedlings are harder to pack than seedlings of the three other species, because of their lack of stems.

Shingletoes, the long stringy shavings left from sawing shingles, make very nearly as good a packing material as sphagnum moss. The light cardboard used for packing seedlings must be soaked in water to make wrapping easier. This is usually done in pits dug in the ground. Because the cardboard is weakened by soaking, it is better to use the grade in which a thick layer of board made from waste-paper pulp is backed by a thinner layer made from fresh kraft-paper pulp. The string used to tie the bundles should be soft so as not to cut the wrappers, and not so fine as to cut the packers' fingers. Tying the string with a slip knot instead of a hard knot saves the necessity of cutting or breaking it in the field.

Any desired number of bundles may be baled in burlap, with a reinforcement of cleats, for shipment by truck or rail, or bundles may be packed on end in large crates for trucking. Seedlings wrapped in bundles as just described ordinarily remain moist for from 3 days to a week even in open crates, if the crates are not exposed

to full sunlight. In bales, they may remain moist even longer. Seedlings in open crates can sometimes be kept in good condition for as long as 2 weeks, if the weather remains cool and if additional water is poured into the upper ends of the bundles.

Seedlings either in bundles or in loose masses can be packed safely and efficiently in a very light container by using the Olson baler, developed by the Forest Service. This is a box 18 inches wide, 15 inches deep, and long enough that two bundles of the tallest stock can be laid end to end in it with their roots overlapping only slightly. It has no top, and the front side is hinged so that it can be dropped to permit removal of the bale. The apparatus is raised to a convenient working height. The packer makes a loop at one end of each of two baling wires and lays the wires in the box, bending them to conform to its shape and hooking the ends over the front and back, with the loops at the front. He then lays two cleats in the box, and over them a layer of burlap and a layer of waterproof paper. Both burlap and paper are long enough to line the front, bottom, and back of the box and overlap on top. A layer of wet sphagnum moss 1 or 2 inches thick is placed in the bottom of the box, covering it completely. A layer of seedlings is placed on the sphagnum, with the tops toward each end of the box and the roots slightly overlapping in the middle. This layer is perhaps 4 inches deep. A ½-inch layer of sphagnum is placed over the roots, and sphagnum is tucked in between the seedlings and the front and back of the box. Successive layers of seedlings and moss are added until the box is full, the last layer of sphagnum being 2 inches thick. The paper is then folded over the moss, and the two ends of the burlap are brought together and rolled around a stick, 2 inches square, fitting into the box lengthwise. When the burlap has been rolled as tightly as is possible by hand, it is rolled more tightly by using a rolling handle (a large wooden socket wrench) on this square stick. Holding the rolling handle in place, the packer then slips the pointed ends of the wires through the corresponding loops and back through holes in a pipe fastened to the far side of the box. A few turns on a crank handle at one end of this pipe pull the baling wire as tight as its strength will allow. The wire by this time is so sharply bent where it passes through the loop that it can be cut off. After being given a turn around itself, it is tucked into the burlap.

The material used in packing seedlings with the Olson baler costs less than $0.15 per bale. Exclusive of the wet moss, it represents less than 5 percent of the total weight of the bale (*23*).

TRANSPORTATION

The need of getting seedlings to the planting site before they dry out usually requires that they be shipped by truck or by express; freight is too slow. As packed for shipment, southern pine seedlings weigh from 20 to 50 pounds per 1,000. Seedlings wrapped in paper in bundles of 50 to 100 run 6,000 to 10,000 to a crate measuring 2½ by 3 by 4 feet, the lower figure being for longleaf pine and the higher for small slash pine seedlings or for loblolly pine seedlings of average size. Three such crates are about as large a load as a 1½-ton truck can take onto an ordinary planting site.

HEELING-IN

If seedlings must be held before packing at the nursery, or held at the planting site, they should be heeled in. This process should be attended to with the utmost care. The best heeling-in ground is moist, easily worked soil exposed neither to full sunlight nor to excessive cold. If natural shelter is lacking some sort of brush, burlap, or canvas shelter should be provided. The seedlings are placed against the side of a shallow trench, their tops projecting above the ground slightly less than when they stood in the seed bed. They should be in a layer not more than 3 or 4 inches thick. The side of the trench against which the seedlings are placed may be nearly vertical or may slope as much as 45°. A slope simplifies the packing of a 3- or 4-inch layer of moist earth against the roots. A thicker layer of earth should be used if only one layer of seedlings is to be heeled in. Heeling-in beds should be kept moderately moist. Extreme wetness, however, makes it difficult to get the seedlings out of the trench again, and if water is allowed to stand in the trenches for any length of time it may cause injury to the plants.

REGULATIONS GOVERNING SHIPPING

Practically all States regulate in some way the shipment of nursery stock from other States, and a few States regulate shipment across quarantine lines within their own boundaries. In addition, Federal quarantines are established from time to time. No attempt should be made to ship stock by common carrier or across State lines by truck without obtaining from the State plant board or the State nursery inspector or other designated official information concerning the latest regulations and the mode of obtaining any certificate required. The present titles and addresses of such officials for the various Southern States are given in the appendix (p. 114).

Ordinarily no special quarantines affect southern pine nursery stock. Even in the absence of such quarantines, however, no agency should ever ship infected or infested nursery stock anywhere other than to its own plantations, and stock harboring insects or fungi capable of continuing their activities in plantations should be destroyed.

Express companies make a few simple requirements concerning containers for railroad shipments. Crated or baled material must be in such condition that it cannot injure other merchandise being shipped, and must be put up substantially enough to withstand ordinary handling. Material such as nursery stock should, of course, be marked as "perishable." Substantial crates or well-packed burlap bales are entirely satisfactory if they are not wet on the outside and if no points of wire project from them such as might tear the covering of other shipments. Small bales of seedlings wrapped in waterproof paper or heavy cardboard are ordinarily acceptable if moisture does not soak through and soften the wrappers. If the State to which seedlings are consigned requires nursery-inspection tags, shipping agencies refuse to accept the seedlings until the appropriate tags have been attached.

PLANTING TOOLS AND THEIR USE

TOOLS

The tool recommended for planting southern pine seedlings is the planting bar, known locally as the "digger" or "dibble." This tool is peculiarly adapted to southern soils and southern pine nursery stock. As originally developed, it has a wedge-shaped steel blade 3½ inches wide, 10 inches long, and three-fourths inch thick at the top, with a square or slightly rounded cutting edge. This is welded at the top to a straight ¾-inch iron rod ending in a D handle. A

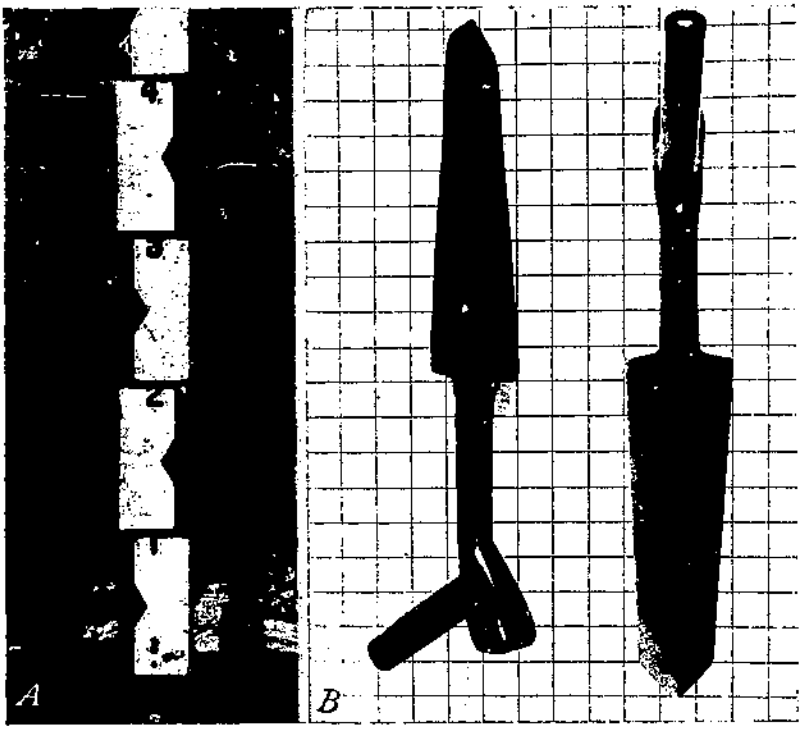

FIGURE 18.—*A*, Two types of the iron planting bar used in planting southern pine. That on the left has a detachable step. The scale in the center indicates feet. *B*, Choctaw-hatchee planting tool, designed for use by a man working alone on light soils, especially on brushy sites (background ruled in inches).

recent development is the addition of a 3- to 4-inch step welded or bolted to the top of the blade on one side, which enables the planter to drive the bar into the ground with his foot. The planting bar is shown with and without this modification in figure 18, *A*.

Planting bars can be made by any competent blacksmith at a cost of $1 to $2 each, or purchased from commercial concerns. The blade should be of good tool steel, and the joint between blade and handle should be strongly welded. The size of the grip should be such that a glove can be worn and there will be no danger of rubbing the knuckles across the lower part. In its most generally suitable form the tool is 45 inches long over all and weighs 10 pounds. A planting bar 47 or 48 inches long is very tiring to the arm of any

man less than 6 feet tall, except on very light, sandy soil, and one as short as 42 inches tires the back of a tall man. A weight of 12 pounds is excessive, but a weight much below 10 pounds is inadequate for most successful use except on unusually light soils.

A tool requiring only one hand and making a slit has been tried recently with encouraging results on light and moderately light soils, particularly where brush interfered with the handle and roots with the blade of the larger planting bar (*J-J*). It seems ineffective, however, on very hard or heavy soils. This tool is shown in figure 18, *B*.

The mattock, used commonly for forest planting in other regions, is not extensively used for this purpose in the southern pine region. It has been used to some extent on the piedmont soils and some of the Coastal Plain soils in the northern part of the region, and on the relatively stony soils in the Ozark Mountains in Arkansas. On the Ozark National Forest, Ark., however, the planting bar was tried by L. S. Gross in the spring of 1933 with success on all but the stoniest ground. On cut-over longleaf pine lands, which present the major planting problem in the South, the heaviness of the subsoil and its proximity to the surface prevent most efficient use of the mattock and give the planting bar a great advantage in speed. Longleaf pine planted by the mattock-hole method is especially subject to damage from silting.

Seedlings have been planted successfully with a great variety of makeshift home-made implements, but the use of such tools on large-scale planting operations results in unduly high costs.

METHOD OF PLANTING

Planters using the planting bar work in pairs. The man with the bar drives the blade straight down into the ground, making a slit at right angles to the direction in which he is facing. When he has driven the blade in to its full length, he moves the handle back and forth, with both hands, just enough to free the blade from the soil. It is bad practice to move the handle through an arc of 25° or more. To do so opens a hole somewhat like an hourglass in vertical section, which is extremely difficult to close properly about the roots. Skillful planters make a slit very little wider than the blade of the tool itself. Frequently a second stroke is necessary to make the slit deep enough.

As soon as the blade is withdrawn the second man slips a seedling into the slit, shaking it to spread the roots as naturally as possible and holding it upright at the desired depth (discussed in the fourth paragraph following). Care must be taken not to double up the root system or leave any of the roots projecting above the surface of the ground.

When the tree has been brought into position, the bar is driven forward into the ground at an angle of about 30° with the vertical, just far enough behind the seedling to insure that the edge of the blade will not strike the roots. This distance differs somewhat according to soil, but is usually about 4 or 5 inches. As the man with the bar completes the stroke he bears down on the handle. This movement, forcing the lower portion of the blade forward, effectively closes the lower part of the slit containing the tree. If the

movement is correctly executed, the man holding the seedling can feel the soil plucking at the roots. Next a slight upward motion of the handle frees the blade from the soil and to some extent closes the top of the slit. The man with the bar, as he follows the man with the trees to the next planting place, completes the closing of the slit by driving his heel against the loose earth.

Under ordinary conditions two men working together in the manner described can plant from 1,600 to 2,200 trees in an 8-hour day, or somewhat better than 3 trees a minute.

In using the modified planting bar all the motions are the same as those just described, except that the man with the bar, having brought it into place in an upright position by thrusting his arm well forward, completes his last stride toward the planting spot by bringing his foot down on the step at the top of the blade. He thus makes his weight and his leg muscles do much of the work done by arm and shoulder muscles when the stepless planting bar is used. The bar with the step is the less fatiguing of the two, except on very hard or heavy soils. In such soils impact, not pressure, is needed to make a slit, and it is necessary to drive the blade in by sheer strength of arm and shoulder.

The proper depth for planting southern pine seedlings is the depth at which they grew in the nursery bed, except in the case of longleaf pine. The difference in color between root bark and stem bark reliably indicates this depth. Longleaf pine seedlings make no height growth until they have been in the field at least one full season. In plowed furrows, on light sandy soil, or on sloping sites recently burned over, they are thus very likely to be covered by rain-washed soil unless they are set one-half to three-quarters inch higher in the field than they were in the nursery. Any man planting longleaf seedlings should be directed to grasp each seedling by the taproot, with the index and middle fingers, just at the root collar, so that the roots hang down below the fingers and the top lies across the palm and the wrist. When he inserts the roots in the slit made with the planting bar, the man with the seedling rests the knuckles of his first and second fingers on the surface of the ground, and the thickness of his fingers automatically "sets up" the seedling at just about the desired height. Even if soil wash fails to build up the level of the soil to the normal root collar of the seedling, the thick bark characteristic of longleaf pine seedling roots enables the trees to survive.

CONTAINERS FOR STOCK

The usual container for carrying planting stock is a pail. When pails are used, most planters prefer to keep the seedlings moist by means of sphagnum moss only, rather than be bothered by water in the bottoms of the pails. Care is necessary to keep the moss around the roots at all times.

Because pails are heavy and expensive and are likely to be stolen, one company has used two-compartment canvas planting bags in which, if need be, two species can be carried at one time, and has found them highly satisfactory. The trouble with both pails and bags is that in these receptacles stock as large as southern pine seedlings must be carried in an upright position. In pulling one upright seedling free from others, there is danger of stripping off part

of the root system. Ordinary market baskets are preferable because their length permits carrying the seedlings in a horizontal position. Seedlings so carried are not only easier to detach one at a time but easier to keep covered than seedlings carried in a pail or bag. The baskets are light, and their rigid handles make them easy to manage in tall grass and brush. They are generally inexpensive, especially when purchased in large quantities. The Forest Service uses watertight galvanized-iron trays similar to a market basket in size and shape. Although more durable than the baskets, these have a disadvantage in their greater weight.

ORGANIZATION OF SQUAD

The number of men needed for a southern pine planting operation is governed principally by the need of completing a season's planting program between the beginning of dormancy (or the occurrence of the first winter rains) and the beginning of the new growing season.

In planting with the planting bar, ordinarily 12 or 15 two-man crews are all one foreman should undertake to supervise. If the planters are experienced and highly reliable larger numbers may be supervised by one foreman, or individual planters may act as foremen of small groups and one boss or straw boss can supervise a considerable number of such groups. A boss can handle upward of 50 two-man crews; a good boss assisted by one or more straw bosses may be able to supervise 250 crews working in clear level country. Small squads are ordinarily preferable.

The boss is responsible for decisions as to laying out the job, for arrangements regarding seedling supplies, and for prompt movement from one planting area or portion of planting area to the next. He is responsible also for setting the standard of work. The foremen are responsible for spacing and alinement, proper setting of the trees, and promptness and efficiency in the work. More responsibility falls upon the foreman where planting is done without site preparation, because he must then set flags on one or both flanks of his squad to guide the end crews, and must see that the other crews remain at the proper spacing. He must also see that the proper spacing is maintained in individual rows.

A planter can satisfactorily carry 200 longleaf pine seedlings or slash pine seedlings, and as many as 500 small loblolly or shortleaf pine seedlings. To load planters' pails or baskets with quantities of stock much larger than these results in unnecessary fatigue and often leads to failure to keep the roots moist. On the basis that 200 trees spaced 6 feet apart will plant a row nearly one-fourth mile long, it is relatively simple to lay out an area to be planted so that by the time the planters have emptied their baskets they will have worked their way approximately back to the heeling-in ground or delivery point for seedlings or will have reached some place to which extra supplies of seedlings can be delivered.

A common arrangement is to load planting-stock supplies, and also supplies of drinking water, on a light horse- or mule-drawn cart and have this driven to meet the crews at suitable intervals. Frequently it is possible to have one cart supply two crews working from the same heeling-in ground. The hours at which addi-

tional supplies are needed by two crews working together can be staggered simply by starting one crew at the beginning of the day with only half the usual supply of stock.

Good alinement can be maintained by starting out with the more rapid and skillful planters at the left-hand end of the line and having the first pair guide on a series of two or more flags set in a straight line. The foreman must go ahead and set additional flags from time to time if the strip to be planted is extremely long. The flags must be set in such a position and close enough together so that the next two ahead are always in sight simultaneously. The remaining crews string off to the right of the guide crew at the chosen planting interval and the foreman checks their spacing now and then by pacing or by measuring with a pole. Better alinement is obtained if two rows of flags are used and the faster crews are assigned to the two ends of the line. In that case the right-hand row of flags is left in place to serve as a guide on the return trip. White or white-and-red flags on rods about 10 feet high are usually satisfactory.

RATES AND COSTS

On typical cut-over longleaf pine sites, two men working with the planting bar can ordinarily plant 1,600 or more trees per 8-hour day. A decrease in number of trees planted per day, and a corresponding increase in cost, results from any of these conditions: Uncomfortably cold weather, rain, water standing on site, sticky clay soil, clay subsoil within 6 inches of the surface, and heavy brush. Cost is increased also by using stock less than 10 inches or more than 18 inches tall or stock having very bushy root systems. Grade 3 stock of a given species is estimated to cost 10 to 20 percent more to plant than grade 1 stock. Slash pine seedlings of good quality are usually the easiest to plant correctly; longleaf pine seedlings are likely to be the second easiest. Planting in the rough does not seem to be appreciably slower than planting in furrows.

Large fluctuations in the total cost of planting are usually the result of fluctuations in the cost of nursery stock, and an upward tendency in total cost is almost invariably linked with high nursery costs.

As has been mentioned in connection with spacing, reduction of number of trees planted per acre reduces the per acre cost of stock and, in lower proportion, that of labor.

PLANTATION

INJURIES AND PROTECTION

No plantation should be established without natural or artificial firebreaks and an organized fire-control system. (This does not mean that artificial reforestation of a given area should be postponed until the fire-control system serving the area has been perfected in every detail.)

The susceptibility of southern pine plantations to fire varies greatly with species and age, and also according to vegetative state (active or dormant), weather at time of burning, and quantity of fuel present. Slash pine is more resistant than loblolly pine of the same age

and height. In one instance, at Bogalusa, La., a severe March fire in adjoining 7-year-old plantations of slash and loblolly pine killed 1 percent of the slash and 53 percent of the loblolly. Shortleaf pine is killed back by fire as easily as loblolly pine, but plantations of shortleaf are seldom killed outright by burning because the young trees of this species sprout from the root collar. Longleaf pine is the most fire resistant of the four species. Young plantations of longleaf pine, especially during the period when they are well established but have not yet begun height growth, sometimes endure hot fires in fall, winter, or even early spring without suffering serious losses; a 9-month-old plantation at Elizabeth, La., burned in September, two 2-year-old plantations on the Choctawhatchee National Forest, Fla., burned in December, and a 2-year-old plantation at Bogalusa, La., severely burned in March, suffered mortalities of only 10, 14, 5, and 5 percent, respectively.

Slash pine stands 5 years old or older, and longleaf pine stands that have begun height growth, frequently undergo partial defoliation by fire without suffering severe mortality, although they usually suffer a perceptible reduction in growth for a year or two. The burned portion of the 7-year-old slash pine plantation at Bogalusa, previously mentioned, increased in height an average of 2.2 feet the year after the fire; the adjoining unburned portion increased in height an average of 3.5 feet during the same period. The burned portion of a 6-year-old slash plantation at Bogalusa suffered 7 percent mortality as a result of a March fire and in the following year increased in height only 1.5 feet, as against an increase of 3.1 feet on the adjoining unburned portion. The burned portion of a 4-year-old slash plantation in Harrison County, Miss., suffered 8 percent mortality as a result of a winter fire, and in the following year made approximately 25 percent less height growth than the unburned portion. For longleaf pine plantations the diminution in height growth resulting from fire appears to be less serious than for slash plantations, although precise data on the subject are not available.

Planted longleaf pines that have begun height growth, and planted pines of the three other species at all stages of growth, increase rapidly in fire resistance with increasing age. Fire losses in three 2-year-old slash pine plantations, two at Bogalusa, La., and one on the Choctawhatchee National Forest, Fla., were 86, 100, and 99 percent, respectively, in contrast with 8, 7, and 1 percent, respectively, in the 4-, 6-, and 7-year-old slash plantations described in the foregoing. In planted loblolly pine at Bogalusa, 3 fires occurring when the trees had been from 1 to 4 years in the field caused 100 percent mortality, whereas the fire in the 7-year-old loblolly plantation already mentioned caused a mortality of only 53 percent.

Winter fires ordinarily injure the trees far less severely than fires during the growing season.

The ability of longleaf pine to survive fire and of shortleaf pine to sprout after being killed back by fire is a strong argument in favor of mixing these species with less fire-resistant species on suitable sites in localities where fire danger is high.

Longleaf pine suffers seriously from damage by hogs, particularly razorbacks and crosses between razorbacks and some of the domestic breeds. Purebred hogs of the best strains appear to do much less

damage. The hogs kill smaller seedlings and occasionally injure or kill trees up to 10 feet high by eating the thick bark on the taproots. Counts of longleaf pine seedlings eaten by hogs show clearly that one hog could destroy in a single day an entire acre of longleaf pine spaced 6 by 8 feet. Any planting program in which dependence is placed on longleaf pine must therefore include careful provision for fencing out hogs or for keeping them out of the plantations by agreement with the owners and by rigorous herding and hunting. Hogs destroy slash pine, also, but less often.

Sheep and goats are capable of doing much damage to slash, loblolly, and shortleaf pine plantations. No records are available of their injuring seriously longleaf pine seedlings that had not yet begun height growth, but they check the height growth of taller longleaf pine seedlings, sometimes for many years, by biting off the terminal buds. They should not be permitted to graze on planted areas.

Horses and cattle do no substantial damage to pine plantations except on limited areas where they concentrate because of shade or particularly good feed. A patch of carpet grass in a plantation in which most of the native vegetation consists of wire grass or broomsedge may cause such concentration. The damage is usually limited to trampling very young seedlings and to breaking older seedlings (in smaller numbers) by rubbing against them in an effort to get rid of insects.

Cottontail rabbits (*Sylvilagus* sp.) frequently do serious injury to plantations of slash, loblolly, and shortleaf pine. They bite off large numbers of freshly planted seedlings and occasionally bite off the smaller and more tender sprouts of seedlings beginning their second year in the field. In ordinary seasons many of the injured seedlings survive, but the mortality resulting from rabbit injury is too great to be ignored, and the height growth of the survivors is generally slower than that of uninjured seedlings. Why the rabbits bite off the seedlings is not known; the tops show little or no signs of parts having been eaten and are usually left lying beside the seedling stumps, which may be anywhere from one-fourth inch to 5 or 6 inches high. Figure 19 gives a comparison between the heights of uninjured high-grade seedlings of slash, loblolly, and shortleaf pine, and high-grade seedlings of those species set out at the same time but injured by rabbits. This type of damage can be reduced by hunting rabbits assiduously the winter before planting and by using high-grade stock or by planting only longleaf pine, which is rarely or never injured by rabbits. (Differences in rabbit damage corresponding with differences in grade of planting stock are discussed on p. 81.)

Some damage to seedlings by rats has been reported, and seedling roots are occasionally injured by "salamanders" (*Geomys* sp.), particularly on sandy soil; but damage of this sort is relatively unimportant through the southern pine region as a whole.

The Nantucket tip moth, previously mentioned as a nursery pest, is the most conspicuous example of insects injurious to young pine stands. This moth is a shoot-boring insect practically impossible to reach with poison except in the egg stage. It does serious damage to loblolly and shortleaf pines; in some instances it has caused aban-

donment of these pines for purposes of artificial reforestation. It attacks slash pine, but does relatively little damage to it and may not be able to reach maturity upon this species as easily as upon the two just mentioned. Only two records of its appearance on longleaf

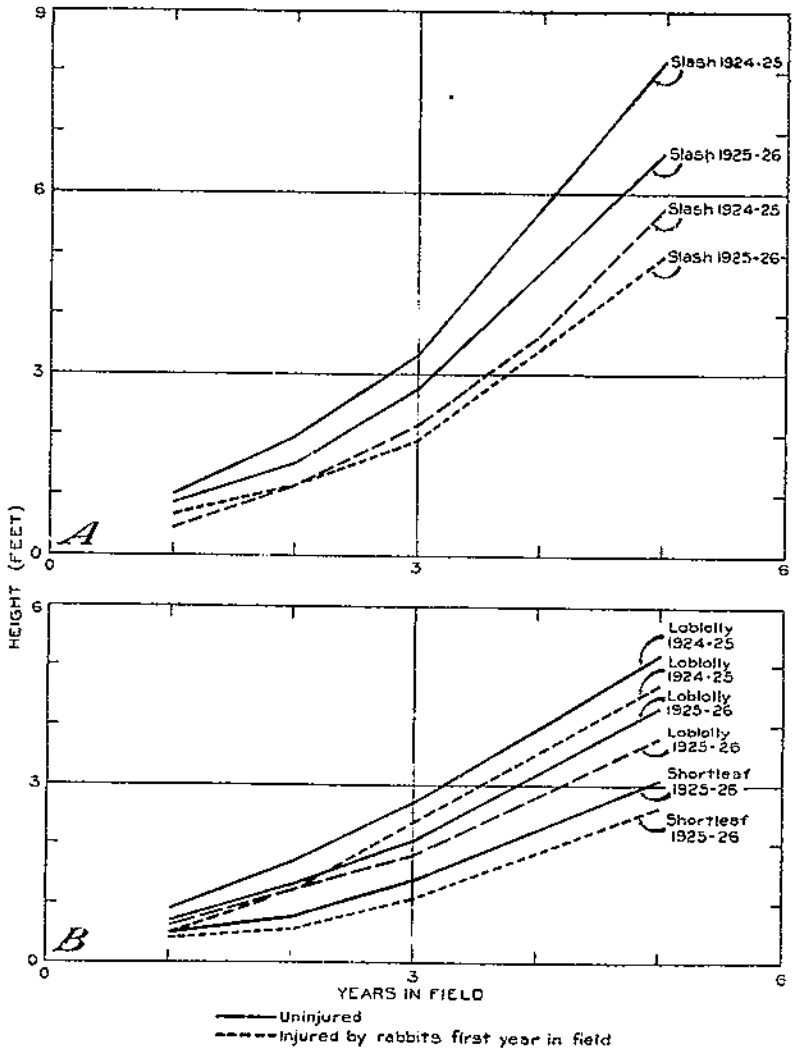

FIGURE 19.—Height growth of slash pine (*A*), and loblolly and shortleaf pine (*B*), planted in 1924–25 and in 1925–26, that was injured by rabbits at the beginning of the first growing season in the field, and of comparable stock not so injured. (Basis, in number of trees: 1924–25 plantation uninjured, 2,787 slash, 806 loblolly; injured, 740 slash, 240 loblolly. 1925–26 plantation uninjured, 518 slash, 826 loblolly, 749 shortleaf; injured, 208 slash, 32 loblolly, 94 shortleaf.)

pine have come to the attention of the Southern Forest Experiment Station, and neither of these was substantiated by collection and identification of specimens. It does great damage to Sonderegger pine, which is a hybrid between longleaf and loblolly pines.

The fact that longleaf and slash pines are practically immune to tip-moth injury apparently is due to their rapid flow of resin from injured tissues.

Infestation is usually heaviest on pines 1 to 8 feet high. In ordinarily dense stands, one attack upon leaders at points between 10 and 15 feet above the ground may deform the trees more seriously than several successive attacks at points below 8 feet. Open-grown trees are most heavily infested while 1 to 15 feet high.

The moths lay their eggs on the elongating shoots and newly exposed needles of the pines. The eggs hatch in a few days, and the larvae burrow first into the bases of the needles and then into the shoot itself, which they hollow out and kill. They pupate in the twig. When it is time for emergence the pupa works its way out of the twig, frequently through a pitch blister near the tip. During the

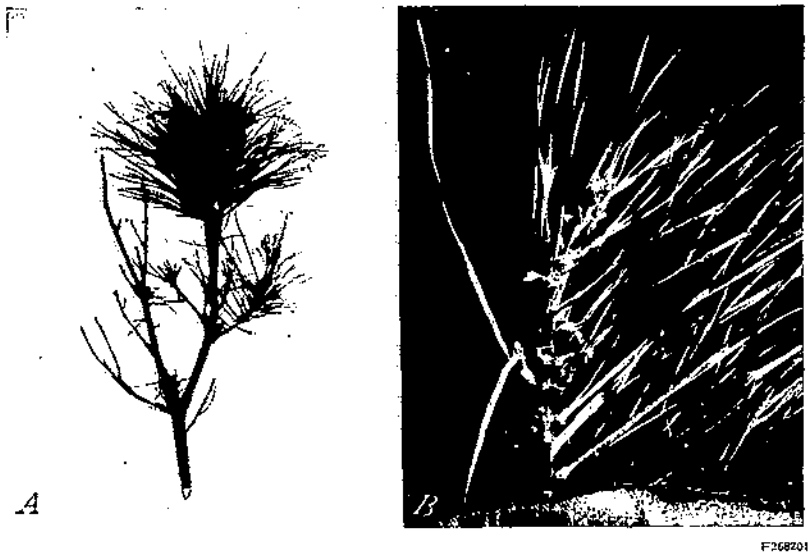

FIGURE 20.—*A*, Typical example of injury to loblolly pine by the Nantucket tip moth (*Rhyacionia frustrana* Comst.); *B*, adventitious buds of loblolly pine arising from the centers of the needle fascicles after injury to the twig by Nantucket tip moth.

flight of the adults minute, brown, empty pupae cases can be found clinging to the tips of many of the twigs. The adults are about one-eighth inch long; their wings are steeply sloping, fringed at the end, silvery in color, and irregularly crossbarred with brown. In color they match almost perfectly the sheaths around the bases of the needle bundles of loblolly pine, and they frequently hide upon these sheaths.

The insect produces four broods a year in the Gulf States, and possibly throughout the southern pine region. The combined work of these four broods may kill back young loblolly or shortleaf pines from 1 to 3½ feet each year. Notwithstanding their great vigor and rapid height growth these species cannot make much headway against such attacks, especially as much of the vigor of attacked trees is wasted in developing side branches and witches'-brooms (fig. 20, *A*). The trees would be killed back even more severely were it

not for the southern pines' remarkable faculty of developing new leaders from the centers of the needle fascicles at the highest portion of the twigs remaining alive (fig. 20, *B*).

It is commonly observed that tip-moth injury is greatest in large, pure, even-aged plantations, and in planted or natural stands on old fields, particularly those on soil which is not especially adapted to loblolly and shortleaf pines. On land formerly in longleaf pine where the subsoil is stiff and lies only a few inches beneath the surface, planted loblolly pines attacked by tip moth are so seriously killed back that planted or even naturally regenerated longleaf pines of the same age overtake them by the time they are 10 years old. On deeper and more penetrable soils, perhaps only a few feet away, loblolly pine planted or reproduced naturally makes much better height growth than longleaf pine in spite of tip-moth attack.

The effective methods of coping with tip moth, it appears, are to confine loblolly and shortleaf pines to the soils best suited to them, to keep pure, even-aged plantations of these species small and widely separated, and to plant at close spacing, 6 by 6 feet or closer, in order that side branches may be shaded off and stems straightened after injury. It appears desirable, also, to plant loblolly or shortleaf pine in brush or to mix with them species resistant to tip-moth attack, in order to force natural pruning and to reduce the food supply available to the tip moth. In small plantations the moth may be controlled in the egg stage by spraying the stock with either a 2-percent solution of Volck concentrate, or with nicotine oleate, using 1 part nicotine to 200 parts of water as recommended by the Bureau of Entomology and Plant Quarantine. Where nursery stock is dipped before shipment, care should be taken to prevent the solution from coming in contact with the roots.

Observations in plantations established by the Southern Forest Experiment Station in 1923, to study effects of various spacings, indicate great individual differences in the resistance of loblolly pines to tip-moth attack, even at the same spacing, and it may be possible to isolate a resistant strain.

Young plantations of all species of southern pine are sometimes defoliated by the larvae of LeConte's sawfly (described on p. 59) and other sawflies, and by adults of a small brownish beetle tentatively identified as *Colaspis brunnea* (Fab.). These insects appear over relatively small areas but in considerable numbers, and partly or entirely defoliate many trees. They are voracious feeders. Where spraying is feasible they are easily controlled by applying arsenate of lead according to the formula given in the appendix (p. 112). Outbreaks should be fought as soon as discovered, because a relatively small investment for spraying on areas up to 10 acres may prevent much more serious outbreaks later in the same season or in the following year.

Other insects to be guarded against in plantations are scale insects of the genera *Toumeyella* (described on p. 59) and *Chionaspis*. The *Toumeyella* scale appears largely on the twigs, and the *Chionaspis* almost exclusively on the needles. Large outbreaks have not yet been reported, but these insects are potentially dangerous to plantations and it is well to clear up any small, readily accessible infestations by spraying with miscible oils or nicotine sulphate.

Larvae of the genus *Tetralopha* (previously referred to as a nursery pest) frequently attack planted seedlings, particularly of longleaf pine. This insect has been noted most abundantly in Florida, but occurs throughout the Gulf States. It has done its greatest damage on the deep sands in western Florida and in the area of relatively low rainfall in eastern Texas. It lives in a tube of webbing and frass anchored to the top of the seedling. Ordinarily it injures only a few needles, but on small seedlings and under adverse conditions the loss of even a few needles sometimes prevents survival. No attempt has so far been made to control this insect on a commercial scale, but in view of its feeding habits, arsenate of lead is suggested as a possible means of control.

Among the most important diseases of planted southern pines is brown-spot needle blight, discussed on page 59 as a disease of nursery stock. Longleaf pine seedlings are highly subject to brown-spot attack, particularly between the time when the first fascicled needles appear and the time when the actively functioning foliage is 18 inches or more above the ground. Needles growing 8 or 10 feet above the ground sometimes show occasional or moderately abundant lesions. Slash pine also is attacked, particularly on dry sites or in localities outside its natural range where rainfall is lower and the evaporation rather higher. The hybrid Sonderegger pine is very severely attacked on some sites. Loblolly pine suffers from a disease that is thought to be brown-spot needle blight but has not been positively identified. Brown spot causes partial or complete defoliation, especially of longleaf pine, causes delay in height growth and sometimes severe stunting, and may cause serious mortality. It is least abundant on areas recently burned over (*26*), in exceptionally dry seasons, and on seedlings widely spaced. It is a moot question whether freedom from brown spot obtained by burning, even during seasons in which fire does little damage, completely offsets the damage done by the fires themselves. The disease is most severe on very densely crowded longleaf pine seedlings (200,000 to 300,000 per acre), where soil is too poor to support a protective covering of grass, and on seedlings that have not yet begun height growth.

In many localities brown-spot infection does not appear to be a great detriment to the success of longleaf pine plantations. If seedlings are kept free from the fungus in the nursery, those of high grade make such a vigorous start that infection during the first year or two in the field does not later prevent them from getting above the height—18 inches or a trifle more—beyond which danger from brown spot is negligible. In some localities and on some sites, however, where the disease is severe and seedling growth naturally poor, brown spot may cause high mortality and delay height growth of surviving trees for many years, unless artificially controlled.

In this connection it is significant that the better the quality of the longleaf pine seedling, as to development of taproot, foliage, and bud, the later it begins growth in the spring and the faster its needles develop once they have started. In a study of 200 seedlings of the same age at Bogalusa, La., in 1930, the seedlings possessing definite winter buds covered by white bud scales did not put forth new foliage until April, but the poorest seedlings, which had no bud scales at all, did so about the middle of February. Distinct brown-spot lesions

appeared on the new foliage of the poorest seedlings before the new needles of the best seedlings became visible. Thus the poorest seedlings suffered one complete cycle of the disease before the best seedlings were infected at all. The foliage of the best seedlings developed so much faster than that of the poorest that by the middle of June the average length of the needles on the best was greater than that of the needles on the poorest, despite the 2-month greater age of the latter.

What may prove to be a serious twig canker occurs on slash, loblolly, and shortleaf pines, but not, so far as is known, on longleaf. This disease first attracted attention in 1932, although examination of the cankers has shown clearly that it must have been in existence on southern pines at least as early as 1925 or 1926. In 1933 the disease was found in practically every State in the southern pine region. The worst infection thus far described has been in slash pine plantations in Georgia, where the disease has killed some trees outright and severely injured the crowns of many more. The fungus causing the disease has tentatively been identified as *Atropellis* sp.

FIGURE 21.—Gall of *Peridermium cerebrum* approximately 1 foot above the ground on trunk of 8-year-old planted slash pine.

Two other diseases to which planted southern pines, with the possible exception of longleaf, are somewhat subject are stem galls caused by *Peridermium cerebrum* (Peck) and *P. fusiforme* (A. and K.). These fungi are true rusts. Their alternate hosts are various oaks, particularly those growing on moist sites. The fungi attack planted pines from those 2 years old to those old enough to produce merchantable products, killing some and deforming others (fig. 21). The potentialities of these diseases are unknown. In one 8-year-old plantation of slash pine 3 percent of the trees were found to be infected, and loblolly pines in a 20-year-old natural stand have been observed to be infected at points 1 to 20 feet above the ground and deformed by galls 1½ to 2 feet in diameter. It is possible that the diseases are serious enough to furnish another argument for mixing longleaf pine with pines of the three other species.

Longleaf pine when first planted is subject to injury by silting, that is, by washing of sand and surface soil onto the almost stemless bud. This mishap, commonly resulting in death or in retardation of growth, can be avoided by using large, vigorous planting stock.

by planting directly in the rough or in well-settled hoed spots instead of in furrows, by avoiding burning of the planting site, and by "setting up" the seedlings as described on page 92.

Wind throw sometimes causes serious losses in young plantations of slash pine, apparently because of a combination of wet soil, shallow root habit, and doubling up of the roots in the slit in the process of planting. It is particularly likely to occur when the foliage is loaded with sleet, and may limit artificial extension of the range of slash pine northward.

Frost heaving causes little trouble in plantations in the southern part of the southern pine region, but is a serious problem in the piedmont plateau, the Ozark Mountains, and the Coastal Plain north of South Carolina. It can be avoided wholly or in part by planting in the spring instead of in the fall, by confining plantations to well-drained sites, and by using large stock. It is thought that using a planting bar instead of a mattock decreases frost heaving, but the point has not yet been demonstrated.

Injury done by competing vegetation has been discussed in connection with planting-site preparation. Where serious competition from other vegetation seems likely, it is particularly important to use high-grade planting stock. Southern pines other than longleaf, once established in the field, very soon outgrow the danger of injurious competition from vegetation that does not actually overtop them from the start.

SURVIVALS AND REPLACEMENTS

Failure of planted southern pine to survive well is usually explainable by one or more of the following: Poor planting stock, poor planting, adverse site, insect attack, fire, and drought. Of these factors drought alone is beyond man's power to modify, and even drought does its least harm to the best stock on the best sites.

With ordinarily good management any plantation of southern pine on good sites and in ordinary seasons should show a survival of 80 to 90 percent at the end of 1 to 5 years in the field. Except in the case of longleaf pine, the greatest loss usually takes place the first year. Between the second and the fifth to tenth years, mortality is likely to be higher in longleaf pine plantations than in plantations of the other species, sometimes because of the lingering death of seedlings injured by silting but more often because of brown spot or of competition from plants of other species. Survival of more than 95 percent at the end of the second or third year in the field has been recorded for several plantations of longleaf, slash, and loblolly pine.

Records of more than 300 separate southern pine plantations established by a great number of agencies in Florida before 1931–32 show survival either somewhat above 65 percent or very much below this percentage. From records kept by the Florida Forest Service on these plantations it is clear that survival well above 65 percent represents normal results with the species under reasonably favorable conditions, and that survival well below 65 percent represents, almost without exception, the effect of drought, fire, adverse site, or inept planting.

Large places in plantations where practically all seedlings failed should be replanted unless the soil is clearly unsuited for the planting of any of the species available. If failures are distributed rather evenly throughout the plantation and the resulting stand is not too open to produce material of merchantable quantity or quality, it may be unnecessary to replace the dead trees. Ordinarily any plantation spaced fairly evenly 8 by 8 feet or closer need not be filled in if the survival is more than 70 percent. It is sometimes advisable to replace with another species, either better adapted to the site or more resistant to the injurious factors at work in the plantation. Failures in longleaf pine plantations may sometimes be replaced with slash pine when the survivors of the original planting are 3 or 4 years old. In that case the longleaf pine has a practically even start with the slash pine, and ordinarily will not be badly overtopped by it unless the site is much better adapted to the latter species.

In a series of experiments at Bogalusa, La., in which replacements were made in plantations of longleaf and slash pine, the mortality of the replacements was much higher than that of the original plantation. It was found that the failure of many of the replacements had been due to competition from brush and to the presence of roots of old stumps, or of hollows left by the decay of roots, within the root zone of the seedlings. In making replacements it may be well to plant a foot or two to the side of the spot on which a seedling of the original planting was unable to survive.

GROWTH

Too few plantations of southern pine have passed the age of 10 years to permit computation of useful growth and yield tables for planted stands as distinct from stands arising through natural regeneration. The few figures available are given in table 21. Comparison of these figures, particularly those for height, with figures for fully stocked natural stands indicates that plantations are well able to hold their own in rate of growth.

TABLE 21.—*Examples of growth of planted southern pine*

Species	Locality	Spacing	Time in field when measured	Height		Diameter	
				Average	Maximum	Average	Maximum
		Feet	*Years*	*Feet*	*Feet*	*Inches*	*Inches*
Longleaf	De Ridder, La.		21	35			
Slash[1]	Kirbyville, Tex.		6	15.6	23.3	2.8	4.5
	Clemson College, S. C.		8	17.0	20.3	3.2	4.2
	Bogalusa, La.	5 by 5	10	21.0		3.4	
		6 by 6	10	19.7		3.5	
Loblolly		8 by 8	10	19.9		4.0	
	Prince Georges County, Md.		13	40		6	
	Burlington County, N. J.		20		40	7.3	11.0
Shortleaf	Griffin, Ga.		35	52	60	11.5	14

[1] Both plantations were beyond the natural range of slash pine.

Longleaf pine is conspicuous for good growth in planted stands as compared with natural stands. The most remarkable instance so far noted is that of a small plantation in St. Tammany Parish, La. (fig. 22), in which the trees reached an average height of 10

feet when 5 years old from seed. The largest tree in the plantation at that age was 16 feet high and 3 inches in breast-height diameter. This plantation received no soil fertilization or other special care except that around every tree, to a radius of about 1 to 2 feet, a heavy

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FIGURE 22.—Exceptionally well-developed planted longleaf pine 5 years from seed, in St. Tammany Parish, La. The top of the handkerchief in the row to the right is 4½ feet above the ground.

mulch of pine needles was applied each fall and allowed to rot in place.

Several hundred acres of almost equally promising longleaf pine plantations have been observed near Sumter, S. C., but measurements from these are not available. The height distribution in a

much larger and more representative plantation of longleaf pine is given in figure 9, which also gives the height distribution in a better-than-average stand arising from natural reproduction and shows that the planted pine compares very favorably with that reproduced naturally.

The relative promptness of planted longleaf pine in beginning height growth as compared with that reproduced naturally is attributable largely to the superior development of the seedlings during their growing season in the nursery. Ten-month-old longleaf pine nursery seedlings of high quality are as large as wild stock 3 to 5 years old growing under good conditions. A further reason for rapid height growth in longleaf plantations may lie in the fairly wide spacing, which presumably has a restraining effect on the spread of brown spot needle blight. Preparation of the planting site by hoeing spots may contribute to the vigor of some seedlings. No experimental evidence available supports the hypothesis that pruning of the roots at the time of lifting and planting has a stimulating effect on height growth.

The course of development of a representative successful plantation of slash pine is shown in figure 23.

Future experimental work in artificial reforestation with all four principal species of southern pine should include efforts to segregate strains characterized by rapid and well-sustained height growth. That such strains exist may be inferred from many items of information already gleaned from studies of the southern pines.

RECORDS

Intelligent conduct of a planting program depends in great part on the technical records kept for each plantation. The record of establishment should include the following: Location (preferably in terms of section, range, and township); size (in acres); species; dates between which planting was done; preparation of site; planting method (tool, and any striking variations in manner of using it); character of planting stock (wild or nursery; age, size, and quality); specific source of stock; and source of seed from which stock was grown (State and county in which collected or, if these are not known, dealer from whom obtained). Later records, the first of which should ordinarily be made when the trees have been in the field 1 year, should include survival percentage, average height, and principal injuries (causes and extent). The more complete the technical records, the more valuable they will be in connection with future operations.

Economical conduct of a large commercial operation requires accurate cost records, which should include the cost of stock, of site preparation, of planting, of protection (including fencing and any insect-control measures), and of any necessary cleanings or liberation cuttings made during the first few years after establishment.

Of utmost importance in the records of any plantation containing more than one species, or more than 5 or 10 acres of a single species, is a plantation map showing clearly species, methods of planting, and dates of planting. Replacements, with the same or with other species, should be indicated on this map with particular care. The map should be on a scale large enough to permit showing clearly

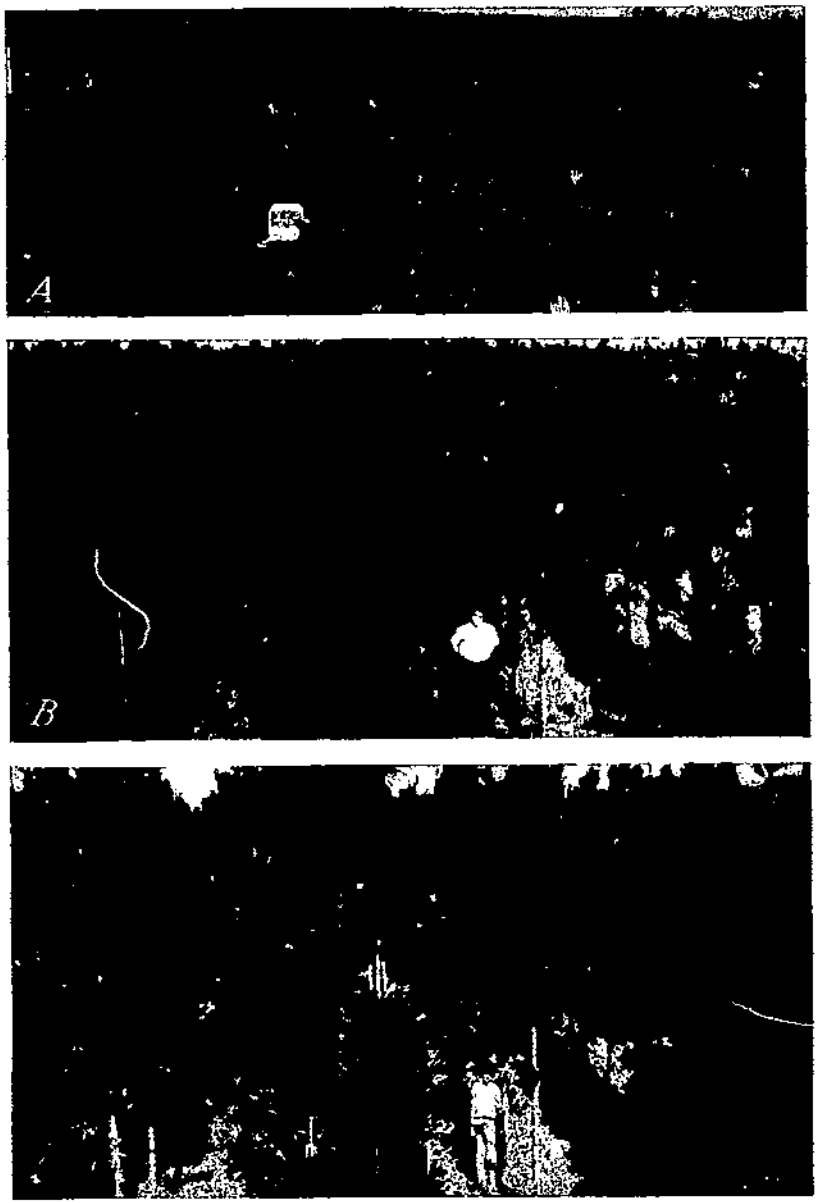

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FIGURE 23.—Representative good commercial plantation of slash pine in Washington Parish, La.: *A*, Four years after planting; *B*, 7 years; *C*, 8 years. (All views from the same platform, 12 feet above the ground.)

in detail the boundaries of areas occupied by individual species or species mixtures, in relation to natural features such as swamps and streams and cultural features such as roads. A scale of 4 inches to the mile is satisfactory for mapping large areas planted with one species at one time. If the pattern of plantations is complicated and full of detail, it is advisable to double this scale.

An extensive planting program is subject to weather variations from year to year, differences in site quality, fluctuations in planting-stock quality, and even changes in species used. To check the success of such a program requires something more than casual ocular observation. Perhaps the simplest way to check it is by means of staked plots in representative portions of each natural unit of plantation. Such plots can include one-fourth, one-half, or 1 acre each. They should be marked with stout permanent posts on which their numbers and, preferably, indications as to species, date, and method of planting are painted distinctly. The plots should be tied in by survey to some familiar section corner or some permanent feature of the landscape, and their location should be precisely indicated on the plantation map. Such plots afford a crude but frequently adequate index of survival and height growth in the entire plantation. They are preferable to line plots particularly for the reason that they form convenient units for computing volume of wood produced when the plantations approach merchantable size.

Under the Forest Service line-plot system for observing survival and early height growth of plantations, from 100 to 300 trees are staked out in each natural unit of plantation, or in each 50-acre homogeneous block if the area of the plantation approaches or exceeds 100 acres. These line plots run diagonally across the plantation, including, for example, the first tree in the first row, the second tree in the second row, and the third tree in the third row, so as to sample the work of as many different crews as possible. In order to identify the trees by number, on every tenth stake the number is marked.

Another means of keeping track of the development of a plantation consists in a series of photographs showing the same portion of the plantation, taken from the same station at 1-year intervals for the first 2 or 3 years and thereafter, ordinarily, at 5-year intervals. The position and direction of each view should be chosen with care when the plantation is first laid out, and if possible the same camera should be used for all successive pictures.

Unless plantation photographs are taken from a lookout tower or some other point from which the view cannot be cut off by growing trees, they should be taken from outside the plantation or looking down the aisle between two rows, not looking down over the top of a row or across rows, and the picture's center of interest should be not more than 50 feet from the camera. Preferably, the film or plate should be used in the vertical rather than in the horizontal position, lest later repeat pictures fail to show the tops of the trees.

The photograph stations should of course be marked with permanent posts, tied in to section corners or natural features, and indicated on the plantation map, with great precision.

It is an excellent plan to deposit duplicates of plantation-establishment records with public agencies interested in artificial reforestation

in the locality. As the plantations develop, especially if they are among the earliest in their particular locality, they will be of immense value to such agencies as guides and object lessons, and filing establishment records with the agencies will not only insure preservation of important data but also increase the plantations' experimental value to the lumber industry and the general public.

The Southern Forest Experiment Station, with headquarters at New Orleans, La., maintains a directory of forest plantations, which will guide it in selecting areas for studies on technical problems involved in improving the survival and growth of planted southern pine. The station will welcome establishment reports of any forest plantations in its territory or of any southern pine plantations elsewhere in the United States. Such records should include the information itemized in the first paragraph under the heading Records. A form suitable for transmitting this information will be furnished by the station on request.

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APPENDIX

FORMULAE FOR NURSERY BAITS AND TREATMENTS

POISONED BAIT FOR FIELD MICE

Mix 1 tablespoon of gloss starch in one-fourth teacup of cold water and stir into three-fourths pint of boiling water to make a thin, clear paste. Mix 1 ounce of powdered strychnine (alkaloid) with 1 ounce of baking soda, and stir into the starch to a smooth, creamy mixture free of lumps. Stir in one-fourth pint of heavy corn sirup and 1 tablespoon of glycerin or petrolatum. Apply to 12 pounds of wheat, or preferably steamed crushed whole oats, and mix thoroughly to coat each kernel. Barley or cracked corn may also be used.

Complete instructions for field-mouse control are given in Farmers' Bulletin 1397 (27).

POISONED BAIT FOR "SALAMANDERS", OR POCKET GOPHERS (GEOMYS)

Cut sweet potatoes in pieces 1 inch long and one-half inch square; wash and drain. Grind together in a mortar one-eighth ounce of powdered strychnine (alkaloid) and one-eightieth ounce of saccharin and sift the mixture slowly into 4 quarts of the dampened bait, stirring to distribute the poison evenly. Thrust an iron rod into the animal's runway, drop in a piece or two of the bait, and close the hole with earth.

Complete instructions for control of "salamanders" are given in Farmers' Bulletin 1709 (9).

CONTROL MEASURES FOR NEMATODES

Steam sterilization of soil infested with nematodes, where applicable, gives the best control and is recommended especially for seed and nursery beds. Chemical soil treatments have in no instance proved 100 percent successful, and give satisfactory results only in light sandy soils. The two most satisfactory chemicals known at present for soil treatment in the open are carbon disulphide and chloropicrin (often also called chlorpicrin). Both must be applied with caution—carbon disulphide is highly inflammable and chloropicrin is a war gas requiring the use of gas masks during handling. Both may have fertilizing qualities, so that larger returns will partly pay for the expense of treatment. Carbon disulphide should be applied 100 to 303 gallons per acre, buried in holes 6 to 9 inches deep, 18 inches apart each way, in staggered rows, two-thirds to 2 fluid ounces per hole. The holes should be covered after application; soil may be replanted 2 to 3 weeks later. Chloropicrin should be applied 253 to 380 pounds per acre, by burying one-sixth to one-fourth fluid ounce in holes 6 inches deep, 18 inches apart each way, arranged in staggered rows and covered. Planting should be delayed until odor has disappeared.

The most practical, least expensive, yet very satisfactory method of cleaning land infested with nematodes is to plant it for 3 successive years to an immune crop. Clean cultivation free from weeds is necessary for success, since weeds may be hosts of the nematode and carry it over the starvation period otherwise produced by the immune crop. *Crotalaria spectabilis*, especially, and *C. juncea* are recommended as immune crops for the control of the root-knot nematode. Various grasses such as timothy, perennial ryegrass, Para grass, fescue grass, redtop grass, rye, Florida and Mauritius varieties of the velvetbean, and Iron and Victor varieties of the cowpea may also be planted to starve out this nematode.

Careful digging and burning of all infested root material as soon as possible after harvest help greatly in cleaning infested land, and using clean tools and implements helps to prevent the spread of these pests.

POISONED BAIT FOR MOLE CRICKETS

Mix 1 pound of paris green, or 1 pound of calcium arsenate, with 20 pounds of cottonseed meal and moisten with cheap sirup. Scatter the bait about the nursery at nightfall, because mole crickets feed at night (5).

POISONED BAIT FOR CUTWORMS

Wheat bran	pounds	50
Paris green or crude arsenic	do	2
Blackstrap molasses[15]	quarts	2
Water	gallon	[16]1

Mix the dry ingredients very thoroughly. Mix the water and sirup (if sirup is used), and add slowly to the dry ingredients until the bait is just moist enough to fall, when scattered, in lumps about the size of wheat grains. The bait seems to work better if allowed to stand a few hours before being scattered. It is well to scatter the bait late in the evening, so that it will remain moist until the worms, which ordinarily feed at night, have had a chance to eat it. Use 10 to 15 pounds of bait per acre of nursery (*10, 36, 37, 38*).

BRAN BAIT FOR GRASSHOPPERS

The following formula is recommended by the Bureau of Entomology and Plant Quarantine:

Coarse bran	pounds	100
Crude arsenic	do	5
Cane molasses	gallons	1½
Water	do	10 to 12

Mix to a consistency permitting scattering in small flakes. Scatter early in the morning, preferably before sunrise, as grasshoppers do not feed at night.

Lead arsenate is not an effective substitute for paris green in grasshopper bait (*5*), nor are calcium arsenate and sodium arsenate.

LEAD ARSENATE FOR SAWFLY LARVAE AND COLASPIS BEETLES

Lead arsenate (powder)	pound	1
Fish-oil soap, casein, or laundry soap	do	1
Water	gallons	25

NICOTINE SULPHATE FOR APHIDS AND RED SPIDERS

Nicotine sulphate (40 percent)	ounces	8
Fish-oil soap (or common laundry soap)	pounds	4
Water:		
For aphids	gallons	50
For red spiders	do	32

Spray thoroughly and forcibly, and repeat after about 10 days (*30, pp. 407, 414*).

KEROSENE EMULSION (SOAP FORMULA)[17] FOR SCALE INSECTS

Kerosene	gallons	2
Whale-oil soap	pound	½
or soft soap	quart	1
Water	gallon	1

Divide soap finely; dissolve in water by boiling. *Remove from fire* and add, boiling hot, to the kerosene. Agitate violently by spraying back on itself with a force pump. After 3 to 5 minutes' pumping the mixture should be perfectly emulsified, from one-third to one-half greater in bulk, and the consistency of cream. Dilute 1 part of emulsion with 15 of water for summer use on plant lice or for use on red spider and other mites. For use on scale insects, 1 part of emulsion should be diluted with 7 to 10 of water.

BORDEAUX MIXTURE (5–5–50), MADE WITH PREPARED POWDER

Commercial prepared bordeaux powder	pound	1
Casein	ounces	3
Water	gallons	5

[15] Some authorities say sirup is unnecessary.
[16] Or more, as needed.
[17] An emergency substitute for the more easily handled miscible oils.

HOME-MADE BORDEAUX MIXTURE

Copper sulphate crystals	pounds	4
Hydrated lime	do	5
Water	gallons	50

To make a large quantity of bordeaux mixture, or to make small quantities repeatedly, it is desirable to prepare in advance separate stock solutions of copper sulphate and lime, each about 1 pound to the gallon. To prepare a stock solution of copper sulphate, a weighed quantity of the commercial crystals, bluestone, is placed in a sack and suspended in a barrel or other wooden vessel containing 1 gallon of water for each pound of copper sulphate. If the copper sulphate is placed in the bottom of the barrel, it dissolves slowly even with frequent stirring. When dissolution is complete, the solution should be made uniform by stirring.

The stock solution of lime is made by simply stirring the hydrated lime into the water; it is best to do this on the day preceding use.

The common method of making bordeaux mixture in the field has been to dilute the required quantities of copper sulphate and lime separately, each to half the final volume required, and to pour them together into a third container, usually the tank of the sprayer. Both solutions should be well stirred just before mixing. The colloidal suspension obtained by this method of mixing breaks down very slowly.

To 50 gallons of bordeaux mixture prepared by these directions, add 2 pounds of casein.

USE OF EXOTIC SPECIES

Early efforts at artificial reforestation with exotics in the southern pine region included various attempts to establish Scotch pine (*Pinus sylvestris* L.) and maritime pine (*P. pinaster* Ait.). The seed of these species used evidently was very unsuitable as to strain. One attempt to introduce the latter species was made by Clemson College at Summerville, S. C., in 1912, with the assistance and advice of the Forest Service. The Forest Service itself began in 1911 a series of direct seedings of maritime pine in the central peninsula and on the extreme west coast of Florida, and later planted in these same localities maritime pine nursery stock, part shipped from a northern nursery and part produced locally. In Florida, also, the Forest Service planted some cork oak (*Quercus suber* L.) and made a painstaking attempt to establish several species of eucalyptus. By 1930 nothing was left of several hundred acres of exotics planted by the Forest Service in Florida except a few eucalyptus sprouts arising from the stumps of trees killed back by frost and a few sickly maritime pines from 2 to 20 feet tall.

No noteworthy effort to establish forest plantations of exotic species in the South was made by the Forest Service in the period 1916–26. In 1927 efforts were renewed to find an exotic pine adapted to the soil of the Choctawhatchee National Forest, Fla., an extremely coarse sand very low in moisture-holding capacity. The Southern Forest Experiment Station made an exhaustive study of the climatic conditions under which pine species throughout the world reach optimum development, selected for study about 60 species growing in climates somewhat resembling that of western Florida, and systematically tested all these species on a small scale. Most of the trials failed totally. The species giving greatest promise of initial success were Italian stone pine (*Pinus pinea* L.), Chinese red pine (*P. massoniana* Lamb.), Japanese black pine (*P. thunbergii* Parl.), and strains of *P. pinaster* Ait. obtained from Corsica and central Portugal. It is entirely too soon to predict whether these pines will develop into merchantable stands on the soil of the Choctawhatchee Forest. Himalaya longleaf pine (*P. longifolia* Roxb.), a three-needled pine of the Himalayan foothills, from many standpoints a most desirable species, is unable to endure the winter cold of the Gulf Coast States.

Various species of *Eucalyptus*, including species growing at higher elevations in Australia and species successfully introduced in California, were killed by frost when tested on the northern half of the Florida Peninsula and in southeastern Louisiana.

Tests of exotic pines have been made in western Florida, central and western Louisiana, and east-central Texas by collaborators of the Institute of Forest Genetics, of Placerville, Calif. This institute, which is studying the

possibilities of breeding an extremely fast-growing pine, has tried in other parts of the South most of the species being tested by the Forest Service on the Choctawhatchee National Forest. With the exception of some of the species just listed as possibly successful, all the exotic pines it has tested so far have failed.

Many species of pine native to California and some exotic pines when grown or planted in the South have shown an extreme susceptibility to brown-spot needle blight.

NURSERY INSPECTION AGENCIES

The officials to be consulted for detailed information on nursery inspection, plant quarantines, and shipping regulations in the southern pine region are listed below. If seedlings are to be shipped from one State to another, officials of both the State of origin and the State of destination must be consulted.

State	Title of official or department	Address
Alabama	Division of Plant Industry	Montgomery.
Arkansas	Chief inspector, State Plant Board	Little Rock.
Delaware	State Board of Agriculture	Dover.
Florida	State Plant Board	Gainesville.
Georgia	State Board of Entomology	Atlanta.
Louisiana	State entomologist	Baton Rouge.
Maryland	do	College Park.
Mississippi	do	Agricultural College
North Carolina	Division of Entomology, Department of Agriculture	Raleigh.
Oklahoma	State nursery inspector	Oklahoma City.
South Carolina	State Crop Pest Commission	Clemson College.
Texas	Chief, Division of Horticultural Inspection and Quarantines	Austin.
Virginia	State entomologist	Richmond.

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