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LIFE HISTORY OF SHORTLEAF PINE.

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CONTENTS.

NAME AND IDENTIFICATION.

It is important to distinguish clearly the true shortleaf pine[1] (*Pinus echinata* Mill.)—variously known throughout portions of its range as "yellow," "old field," "rosemary," "two-leaf," "heart," and "spruce" pine—from other so-called shortleaf pines of the Southern States. Confusion occurs because of the custom, more or less generally prevailing throughout the South, of distinguishing only two kinds of pine, shortleaf and longleaf. Under this custom, the pine most commonly included with shortleaf is loblolly pine,[2] slash pine being classed in similar manner as longleaf pine. Shortleaf is most readily distinguished from loblolly pine by means of differences in leaf and cone, described on page 7. Other pines associated with shortleaf are the smaller, crooked-stemmed scrub pine and the northern pitch pine which seldom forms old-field stands and grows both in wetter and colder situations.

[1] Shortleaf pine was first described botanically by Miller in 1768. In 1803, the elder Michaux defined more fully the specific characteristics of the species under the name of *Pinus mitis*, widely circulated in his work on American forest trees and largely used in botanical literature. The name *Pinus echinata*, first given to the tree by Miller, was not taken up by any author of note until the publication of Sargent's Silva, Vol. XI, in 1897, and by the accepted rule of priority, this is the correct name of the species.

[2] *Pinus taeda*, know locally by various names, as "old field," "shortleaf," "swamp," "bull pine," etc.

NOTE.—This bulletin gives in detail the life history of shortleaf pine, known under various names throughout the South, where only it is found in commercial quantities.

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GEOGRAPHICAL AND ECONOMIC RANGE.

Shortleaf pine occurs in 24 of the States. Its geographical range includes all the States east of the Mississippi River, except Wisconsin, Michigan, and New England, and six States west of the Mississippi. It extends from the Hudson River Valley in New York[1] south through all the Atlantic and Gulf States to eastern Texas and from West Virginia and Ohio southwestward through the Ohio and Mississippi Valleys to Missouri, Kansas,[2] and Oklahoma. The tree is distributed over more than 440,000 square miles. This is much larger than the range in the United States of white pine, its nearest competitor among the pines.

TABLE 1.—*Comparative distribution of eight species of pines having the largest ranges within the United States.*[1]

Species.	Area of distribution.	States represented.
	Sq. miles.	
Shortleaf pine	440,000	24
White pine	381,000	23
Pitch pine	360,000	19
Western yellow pine	350,000	14
Scrub pine	317,000	14
Red pine	300,000	14
Loblolly pine	295,000	13
Longleaf pine	171,000	10

[1] Areas derived from Forest Service data on the geographic distribution of pines in the United States, including approximately the exterior boundary of the botanical range.

From sea level shortleaf pine ranges up to an altitude of about 3,000 feet in the southern Appalachians. At or near sea level it covers more than 11 degrees of latitude, or about 800 miles. In the North the species is confined nearly to sea level. It attains its best development at altitudes of 600 to 1,500 feet over the Piedmont and at 400 to 1,000 feet in Arkansas. In both these localities loblolly pine reaches only to altitudes of about 500 to 600 feet, above which shortleaf is the only important southern pine up to 3,000 feet and the only conifer except scattering juniper above about 700 feet in Arkansas, Missouri, and Oklahoma.

The commercial range of shortleaf pine comprises most of the botanical range except that portion lying in the States north of Virginia and in the Ohio River basin. It includes preeminently the broad Piedmont region lying between the Appalachians and the Atlantic coastal plain from Virginia to South Carolina; the northern half of Georgia, Alabama, Mississippi, and Louisiana; all of Arkansas; eastern Oklahoma; and eastern Texas. Shortleaf pine is the only commercial conifer on more than 100,000 square miles of upland

[1] Sargent. Herbarium notes, May, 1913.

[2] Britton and Brown. Flora of Northern United States and Canada. Illustrated.

region between Virginia and northern Alabama and Mississippi. The total area of its commercial range covers not less than 280,000 square miles. The production reaches its maximum over the gently rolling and hilly country of the Mississippi basin in northern Louisiana, most of eastern Arkansas, eastern Oklahoma, and eastern Texas. In common with practically all other commercial pines, the economic range of shortleaf has become greatly reduced, and over the extreme northern part it has been almost driven out by close utilization and

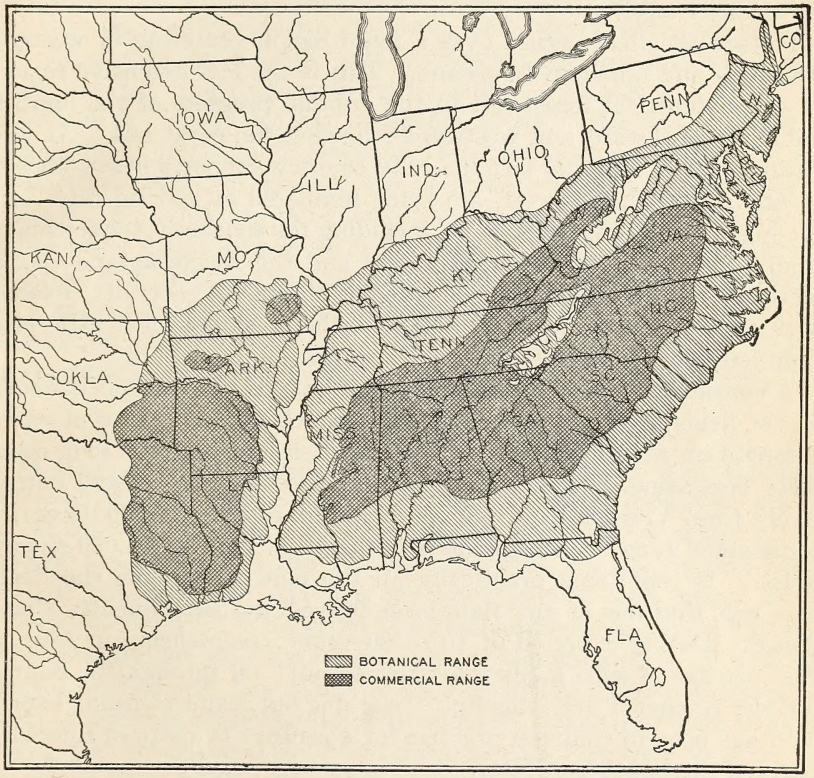

FIG. 1.—Botanical and commercial range of shortleaf pine.

the consequent encroachment of hardwoods. In the upper portions of the Atlantic coastal plain it is to a considerable extent being replaced by loblolly pine on abandoned fields. The early clearing for agriculture of the lighter and better-drained soils greatly decreased the shortleaf seed trees and correspondingly increased the relative proportion of loblolly seed trees, which were left growing along the watercourses and on low heavy soils, where they find a congenial home.

CHARACTER OF STANDS.

PURE STANDS.

Shortleaf is very well adapted for growth in pure stands, and it occurs extensively in this form of forest. The stands are not usually continuous over large areas, but are separated by mixed stands of pines and hardwoods. Stands of pure shortleaf pine once covered a much larger area than at present. It is doubtful whether shortleaf is now found in pure type on more than from 20 to 40 per cent of its former range.

Mature shortleaf occurs over a large region centering in western Arkansas and northern Louisiana. This is the last extensive region of virgin shortleaf forest left in the gradual progress of the lumber industry southward and westward following the coast line. At elevations of 400 to 1,200 feet the hilly country supports heavy stands of timber, which, however, are being lumbered at a rapid rate. In the higher mountainous regions, including the southern Appalachians from 1,000 to 2,000 feet in elevation and the Arkansas and Ozark National Forests, the warm south-facing slopes are generally covered with pine in pure stands, and the northerly slopes with little else than hardwoods, chiefly oaks and hickories.

A considerable proportion of the pure stands of shortleaf is found in old fields formerly under cultivation. Here the factor of early competition with hardwoods was eliminated and the pine took complete possession. This form of second-growth forest occurs extensively from Virginia southward and westward throughout its entire commercial range and aggregates probably more than 68,000 square miles.[1] It represents practically all the land within the shortleaf-pine belt that has at any time been cleared and subsequently abandoned. During a period of 10 to 20 years, commencing in 1861, a vast acreage of such lands was "turned out" all through the South; but the process of "clearing up," "working out," and "turning back" land has been in common practice for a century or more in the older parts of the Southern States.

MIXED STANDS.

CONIFERS.

In its geographical relation to the other eastern pines of commercial importance, shortleaf occupies a position characteristically intermediate between white and Norway pines on the north and loblolly and longleaf on the south. Between these two widely separated groups of important commercial pines, shortleaf occupies and dominates a broad strip of country.

[1] Based upon general forest studies in practically all of the States, and detailed examination of 21 counties in North Carolina.

Altogether 10 different species share in varying degree the range of shortleaf. Pond and slash pines and spruce pine merely overlap along the southern margin, but pitch and scrub pines share as much as one-third to one-half the botanical range. In parts of Virginia and North Carolina, scrub pine occurs in varying proportion in the mixed shortleaf conifer stands,[1] particularly in old fields, and it succeeds in getting a strong foothold in the poorer soils, dry pastures, and waste places. On the lower or warmer side, shortleaf throughout practically its entire range associates extensively with loblolly pine. In this association the two maintain, to a large degree, the relation of complementary species, loblolly holding the heavier, moist soils and shortleaf the drier and lighter soils. Valuable and extensive commercial forests of this character occur in Georgia, Alabama, Mississippi, Texas, and especially heavy stands in Arkansas and Louisiana. Both of these pines to some extent, and particularly loblolly, are replacing the slower-growing longleaf on all situations, except the driest and most sandy soils, throughout their region of contact.[2] In the longleaf region shortleaf occurs generally in groups or small stands on favorable situations, but in large areas west of the Mississippi the two occupy practically the same soil type, and in mixture they make up heavy stands of maximum development.

HARDWOODS.

A large number of broadleaf species are associated with shortleaf through its extended range. Oaks and hickories, however, are so constant in their association as to be characteristic in many of the mixed stands. Over the Northern Atlantic States chestnut oak, yellow oak, and red oak are the most typical associates. From Virginia southward throughout the Piedmont country, lying between the coastal plain and the lower slopes of the mountains up to 2,500 feet, shortleaf still maintains its position generally as the dominant tree in mixture with the upland oaks and hickories. The primary associated species are yellow and Spanish oaks, big-bud and bitternut hickories, and, on the thin ridges, post oak and black-jack oak. The amount of shortleaf in the mixture varies widely, but throughout the eastern range represents usually from 35 to 60 per cent of the stand. In the hilly and mountainous parts of Arkansas, the mixed shortleaf and loblolly type gives way at elevations above about 400 feet to heavy stands of nearly pure shortleaf up to about 1,000 feet, whence

[1] Following are botanical and common names of pines mentioned:

Loblolly pine (*Pinus taeda* Linn.).
Longleaf pine (*Pinus palustris* Mill.).
Pitch pine (*Pinus rigida* Mill.).
Pond pine (*Pinus serotina* Michx.).
Table Mountain pine (*Pinus pungens* Michx.).
Norway pine (*Pinus resinosa* Ait.).
Scrub pine (*Pinus virginiana* Mill.).
Slash pine (*Pinus caribaea* Morel.).
White pine (*Pinus strobus* Linn.).

[2] Ashe, W. W. Proceedings of the Society of American Foresters. Vol. V, No. 1, p. 84.

the shortleaf-hardwood mixed forest ascends the mountain slopes to about 2,000 feet. The prevailing associates west of the Mississippi River are oaks and hickories, particularly yellow oak, bitternut and pignut hickories; on the dry ridges post and black-jack oaks; and in the fresher soils white and red oaks, big-bud or mocker-nut hickory, and red gum.[1] The commercial importance of all the hardwoods typically associated with shortleaf is comparatively small, except white oak in the region of its better development. Several inferior species, including persimmon, sassafras, and dogwood, are nearly everywhere represented in the mixture.

TABLE 2.—*Forest composition of the Arkansas and Ozark National Forests.*[1]

Species.	Arkansas National Forest.[2]				Ozark National Forest.[3]	
	Total stand.	Per centage of total stand.	Diameter.		Total stand.	Per centage of total stand.
			Average.	Maximum.		
	Board feet.		*Inches.*	*Inches.*	*Board feet.*	
Shortleaf pine	1,500,000,000	75.00	18	34	108,890,000	10.15
White oak	300,000,000	15.00	17	36	605,925,000	56.51
Red and black oak	100,000,000	5.00	16	18	252,809,000	23.57
Hickory	350,000	.02	16	18	40,271,000	3.76
Red gum	3,348,000	1.67	16	22	63,248,000	5.90
Miscellaneous	96,302,000	3.31	.....	.....	1,174,000	.11
Total	2,000,000,000	100.00	.....	.....	1,032,317,000	100.00

[1] Figures for the Arkansas Forest secured during reconnaissance in 1913. Figures for Ozark Forest from Bulletin 106, Forest Service, "Wood-Using Industries and National Forests of Arkansas."
[2] Area of Forest, 750,000 acres.
[3] Area of Forest, 481,575 acres.

The percentage of shortleaf is relatively small in the Ozark, which is farther north, and increases outside of both Forests because of the lower elevations and warmer situations.

Under virgin conditions the progressive changes within this mixed type resemble in some respects those that occur with white pine. By the thinning or removal of the valuable shortleaf pine, opportunity has been afforded for the more rapid reproduction of tolerant hardwoods already on the ground. Thus, some territory formerly dominated by shortleaf in mixture is now held almost exclusively by hardwoods.

[1] Names of hardwoods mentioned:

Big-bud hickory (*Hicoria alba* Britt.).
Black gum (*Nyssa sylvatica* Marsh.).
Black-jack oak (*Quercus marilandica* Muenchh.).
Dogwood (*Cornus florida* Linn.).
Chestnut oak (*Quercus prinus* Linn.).
Persimmon (*Diospyros virginiana* Linn.).
Pignut hickory (*Hicoria glabra* Britt.).
Post oak (*Quercus minor* (Marsh.) Sarg.).
Red gum (*Liquidambar styraciflua* Linn.).
Red maple (*Acer rubrum* Linn.).
Red oak (*Quercus rubra* Linn.).
Sassafras (*Sassafras sassafras* (Linn.) Karst.).
Scarlet oak (*Quercus coccinea* Muenchh.).
Spanish oak (*Quercus digitata* (Marsh.) Sudw.).
White oak (*Quercus alba* Linn.).
Yellow oak (*Quercus velutina* Lam.).

SIZE, AGE, AND HABIT.

Over much of its range the average height attained by shortleaf is between 80 and 100 feet, and in regions of better development between 100 and 120 feet, with a maximum of about 130 feet. Mature diameters of from 2 to 3 feet are most common; those of 4 feet are rare except in trees grown in the open. The tree commonly reaches an age of between 200 and 300 years, a maximum of about 400 years being occasionally attained.

In size, shortleaf holds about middle ground between longleaf and loblolly pines. Loblolly grows to an equal height and a greater diameter, but is not so straight a tree. Longleaf averages a little higher, but has a somewhat smaller trunk at maturity.

FORM.

A long clear straight bole with small taper and short crown makes shortleaf pine almost an ideal tree for the saw. These characteristics are so much more pronounced in shortleaf than in several of its pine associates, for example, pitch, scrub, and loblolly pine, that they serve commonly as distinguishing marks. In early life the tree has a narrow pyramidal stem, which later becomes more cylindrical (Pls. I and II). Tables showing the form or taper of the stem, both outside and inside the bark, will be found in a forthcoming bulletin on the importance and management of shortleaf pine. These include tables for North Carolina and Arkansas, showing inside bark measurements at intervals of 8.15 feet above a 1.5 foot stump for trees from 40 to 120 feet in height and of corresponding diameter classes. The tables are adapted for use in calculations of cubic volume of saw timber from 8 and 16 foot logs, allowing 0.3 foot additional length for each 16-foot log. The butt taper at 1-foot intervals of trees of various diameters is also shown, and there is a table of tapers outside the bark at 10-foot intervals above the ground for trees from 40 to 90 feet in height.

CROWN AND BARK.

A short crown composed of numerous small branches, forming a narrow pyramidal head, permits of the close density which characterizes shortleaf-pine stands. This inherent narrow crown habit is well shown in trees grown in the open, where it is conspicuous even to an advanced age. Although changes take place in the relative demand of the crown for light after the period of maximum height growth (about 50 to 70 years), the change in the general shape of the crown is slight. While the crown of longleaf in early life has about the same outline as shortleaf, though less dense, in later life it broadens out far more. Loblolly maintains a much wider and heavier crown at all periods of life than either of the other important southern pines. This habit is more pronounced on the drier soils; hence in

the upper portions of its range, where associated with shortleaf, this difference in outline and internal branching of the crowns becomes striking and serves as a distinguishing characteristic.

In keeping with the small, close crown are the short, slender leaves of shortleaf pine. The leaf characteristics, together with the cone, afford the best means of identifying the species. (Fig. 2.) Special notice of this is essential, because confusion prevails generally in distinguishing the various pines. Shortleaf belongs distinctly to the two-leaf group of pines. On the more vigorous portions of the crown, however, three leaves in the bundle are not uncommon. The leaves are mostly 3 to 5 inches long, in some localities appearing en masse of a slightly bronzed or pale-green color, in contrast to the glaucous or blue-green color in other localities or regions. Short shoots and colonies of sessile leaf bundles are often scattered along the trunk and over the upper sides of the larger branches. These are found on the pitch pine of the North and the pond pine of the South; but since they occur in none of the important southern timber pines except shortleaf, they serve practically as a characteristic distinguishing shortleaf from both loblolly and longleaf pines. The size of the cones ("burrs") aids in recognizing shortleaf when otherwise it might be confounded with loblolly pine, its most common associate in the lower soils. The small cones of shortleaf (from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in length) when open on the tree appear to be about the size of pigeon eggs; those of loblolly (from 3 to 5 inches in length) about the size of duck eggs. The individual scales composing the cone in shortleaf are armed with slender, needle-pointed prickles, broken off more easily than the stouter persistent prickles of loblolly cones. The seed of shortleaf (described on p. 19) is likewise much smaller than that of loblolly pine.

A difference in the bark of shortleaf and loblolly is readily perceptible up to the beginning of old age. The bark of loblolly is on the average thicker, more deeply furrowed and ridged, and somewhat darker in color than that of shortleaf. After maturity these differences in bark become less marked, or disappear.

RELATION OF CLEAR LENGTH TO CROWN.

Measurements taken in shortleaf stands of average density show much regularity in the relation of the length of the living crown to the total height of the tree. In stands about 10 feet in height the depth of the canopy averages 5 feet, or one-half the height of the stand. Above this height the canopy gradually becomes proportionately shorter, until at 80 feet clear lengths of 45 to 55 feet are reached. This is from about 60 to 70 per cent of the total height, varying with different qualities of site. The crown is relatively longer, in proportion to the total height of the tree, on the poorer situations, and, conversely, the clear length of the stem is shorter.

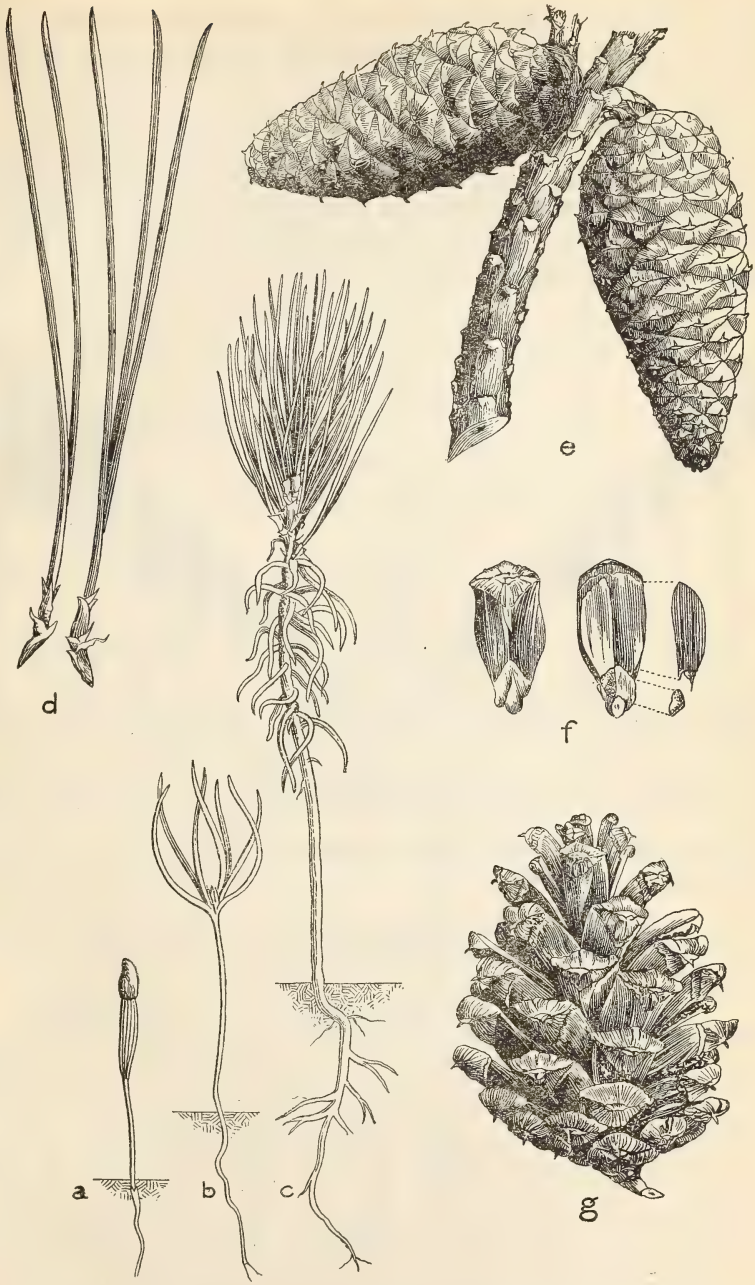

FIG. 2.—Shortleaf pine leaves, seed, cone (burr), and seedling: a, Young seedling; b, same one month later; c, seedling at end of first season showing early bundles of true leaves; d, two-leaf and three-leaf clusters; e, branch with mature closed cones (burrs); f, cone scale and seed with wing detached; g, mature cone opened. (Drawn to scale from actual specimens.)

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Figure 3, based on measurements of 34 well-stocked shortleaf pine stands in Arkansas, represents graphically the proportion of clear length to crown length for trees of various heights on the better and poorer quality of situations.

The lengths of the crown and clear stem and their proportion of the total height of the tree are given in Table 3. In New Jersey 70-year-old stands 65 feet high had practically the same actual depth of canopy as vigorous stands 50 years old and 80 feet in height in Arkansas. The proportion of clear length to total height in New

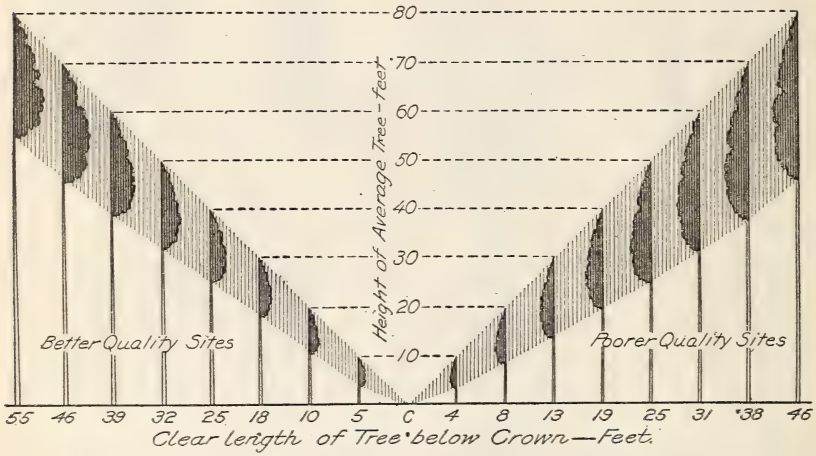


FIG. 3.—Relative proportions of clear length and crown depth for shortleaf pine of various heights on better and poorer qualities of site in Arkansas.

Jersey was about 48 per cent, as compared with 70 per cent for the better stands in Arkansas.

TABLE 3.—*Clear length and crown length of dominant trees in well-stocked stands of shortleaf pine in Arkansas.*

Total height of tree (feet).	Better quality site.				Poorer quality site.			
	Clear length.		Crown length.		Clear length.		Crown length.	
	Feet.	*Per ct.*	*Feet.*	*Per ct.*	*Feet.*	*Per ct.*	*Feet.*	*Per ct.*
10	5	50	5	50	4	40	6	60
20	10	50	10	50	8	40	12	60
30	18	60	12	40	13	43	17	57
40	25	63	15	37	19	47	21	53
50	32	64	18	36	25	50	25	50
60	39	65	21	35	31	52	29	48
70	46	67	24	33	38	54	32	46
80	55	69	25	31	46	57	34	43
90	63	70	27	30	53	60	37	40

CROWN SPREAD AND TREE DIAMETER.

In well-stocked stands of shortleaf pine a very close relationship has been found to exist between the diameter of the tree at breast height and the diameter of the crown. This relationship is striking in its

constancy and, so far as is known,[1] has never before been found to exist in any North American tree species. It was found to hold true for all crown classes within a range of ages from 20 to 80 years, representing average diameters up to about 16 inches. Indications point to this relation holding true beyond 80 years, although no measurements in pure shortleaf pine have been made. Later measurements by Prof. H. H. Chapman, of Yale Forest School, indicate a

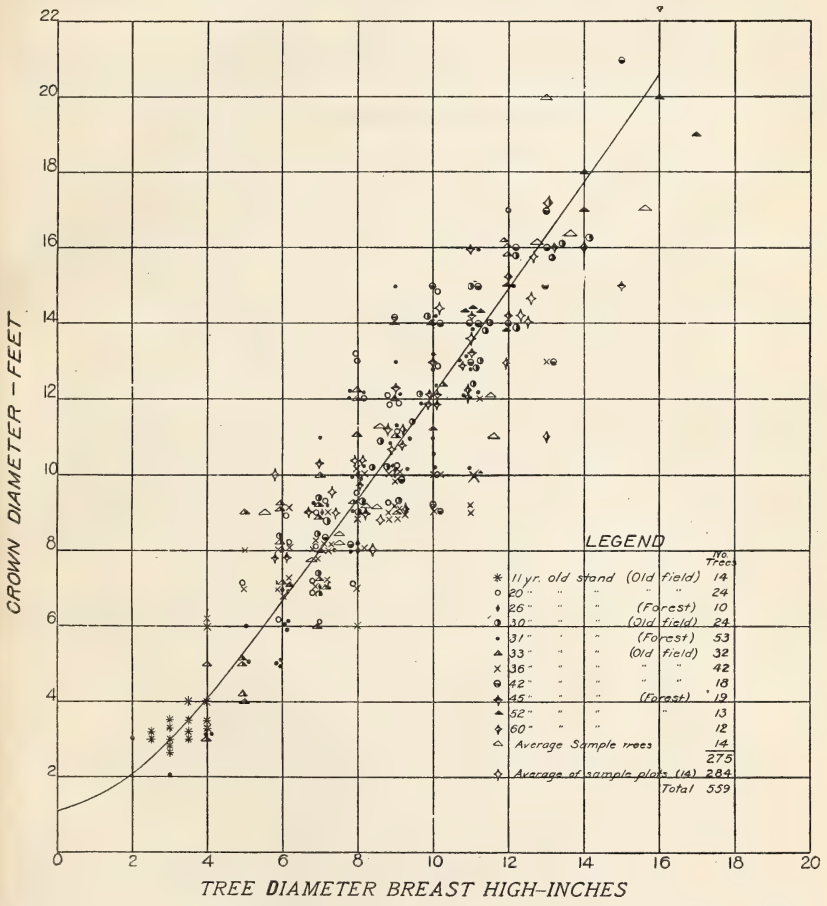


FIG. 4.—Relation of crown width to diameter of tree. (Shortleaf pine, 11 to 60 years old, in Arkansas.)

constant relation between the diameter and crown in mixed shortleaf and loblolly pine stands from 80 up to 200 years; also recent deductions from yield and growth data of red spruce show a definite relation existing between basal area and growing space in even-aged stands between 20 and 100 years.[2]

The evidence from which the conclusion is drawn is shown in figure 4, based on 545 trees on 25 sample plots, representing 16 different ages,

[1] Determined in January, 1913, from measurements taken in November and December, 1912.
[2] By L. S. Murphy, Forest Service.

and the average tree on each of 14 other sample areas, or a total of 559 trees. All the trees of the three crown classes in the stand and on the different qualities of site are represented. Under the influence of all these different factors, which are considered variables in matters of tree growth and volume increment, the size of both diameter and crown spread have been found to vary uniformly and in the same direction. This intimate relationship between tree diameter and crown spread is apparently an expression primarily of tolerance or relative demand of the species for light.

Table 4 gives the average crown spread in feet of each breast-high diameter class from 5 to 16 inches. It shows a perfect regularity between the size of the tree and the space occupied by its crown, irrespective of age and vigor.

The table shows that for each increase of 1 inch in tree diameter the crown spread increases 1.4 feet in Arkansas and 1.75 feet in New Jersey. This difference in rate is probably due to the effect of different climatic conditions upon the tolerance of the species. During earlier life up to about 15 years the relation appears to be in the ratio of 1 foot of crown spread to each inch in tree diameter.

This law of growth finds practical application in determining for any specified diameter class the total number of trees that can most profitably be grown per acre in a well-stocked stand. Since diameter is a direct function of age in any given quality of situation, the tree density on the ground at any desired age can likewise be ascertained. Knowledge of this sort is fundamental in working out problems of thinning, cutting, and final yields of timber.

TABLE 4.—*Relation of tree diameter and crown diameter for shortleaf pine trees in fully stocked stands for all ages from 20 to 80 years—Contrast of regional difference for Arkansas and New Jersey.*

Tree diameter breast high (inches).	Crown diameter.					
	Favorable region (Arkansas).			Unfavorable region (New Jersey).		
	Crown diameter.	Amount of increase.	Difference in crown diameter and tree diameter.	Crown diameter.	Amount of increase.	Difference in crown diameter and tree diameter.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
5	5.2	.....	4.8	3.25	.....	2.85
6	6.6	1.4	6.1	5	1.75	4.5
7	8	1.4	7.4	6.75	1.75	6.15
8	9.4	1.4	8.7	8.50	1.75	7.8
9	10.8	1.4	10.05	10.25	1.75	9.5
10	12.2	1.4	11.4	12	1.75	11.21
11	13.6	1.4	12.7	13.75	1.75	12.85
12	15	1.4	14	15.50	1.75	14.5
13	16.4	1.4	15.3	.....	.....	.....
14	17.8	1.4	16.6	.....	.....	.....
15	19.2	1.4	17.95	.....	.....	.....
16	20.6	1.4	19.3	.....	.....	.....

ROOT SYSTEM.

Having strongly developed taproot and laterals, the tree is seldom thrown by wind except in the case of tornadoes. This root system also enables the tree to thrive in relatively dry situations. Taproots 14 feet deep have been found on 8-year-old saplings, which shows the ability of the tree to search for moisture. (Pl. I.) This root habit may account, in part at least, for the wide geographical distribution of shortleaf pine, and, within much of its range, its supremacy over all other conifers, except red juniper, in successfully occupying the driest upland soils and exposed ridges. It is significant that shortleaf pine, which maintains throughout life a higher tree density in pure stands than any other eastern or southern commercial pine, possesses inherently both a narrow crown and deep root system. The distribution of loblolly pine over the tideland districts and along watercourses and the absence there of shortleaf pine is undoubtedly due to an ecological effect of root development and inherent adaptation.

DEMANDS UPON SOIL AND CLIMATE.

SOIL.

Shortleaf occurs on a wide variation of soil types, ranging from the gravels and sands to stiff clays. In respect to soil moisture, however, its requirements in one particular are more exacting; namely, under all conditions, shortleaf avoids very poorly drained or wet situations. Its home is essentially on the better-drained soils. In New Jersey it grows on the low ridges of gravelly loam, associated with chestnut oak. Over the extreme lower portion of the Atlantic coastal plain, from North Carolina through southern Georgia, Alabama, and Mississippi, its occurrence is always on the well-drained ridges and hummocks. The physiography and soil types of the Piedmont region, from the upper coastal plain well into the lower slopes of the mountains, are favorable to its vigorous growth. The deep, well-drained, gravelly or clayey loam soils of this region favor shortleaf but discourage loblolly, which is much inferior in ability to withstand drought. In the lower shortleaf range toward the southern coasts the lighter grades of sandy soils are occupied by longleaf, which possesses remarkable tolerance for deep and very dry soil conditions.

CLIMATE

The broadness of the climatic conditions favorable to shortleaf pine is clearly indicated by the tree's wide geographical range The range of temperature is from the mean annual temperature of 48° F. in northern New Jersey, through 60° in central Arkansas, to 70° in southeast Texas. Of greater significance is the difference be-

tween the midwinter (January) mean of 26° in northern New Jersey and the midsummer (July) mean of 84° in southeast Texas. Within its geographical range occurs a total temperature range of 134° F., from a minimum of −22° in New Jersey to a maximum of 112° in northern Louisiana. The length of the growing season is indicated approximately by the period during which killing frosts do not occur. In New Jersey this period averages only five months, from May 1 to October 1; in northern Louisiana it is a little less than eight months, from March 16 to November 8. There is a variation in snowfall from an average of 40 inches at the north to none whatever over the southern range of the species.

In the northeast, the 45-inch line of annual precipitation closely parallels the northern limit of shortleaf's range, and the line marking an average of 40 inches of precipitation about coincides with its southwestern boundary in Kansas, Oklahoma, and Texas. Shortleaf advances farther into this region of low relative humidity than any other pine, and in its advance into Texas falls behind only cypress and eastern red cedar. The belt of maximum development of shortleaf—northern Louisiana and Arkansas and the southern Piedmont—coincides strikingly with the rainfall zone of 45 to 55 inches, or an average of 50 inches.

In general, shortleaf pine reaches its best development under (1) a mean annual temperature of about 55° F., from a 35° average for the coldest months of the year to a 75° average for the warmest; (2) an annual precipitation of 45 to 55 inches, distributed through at least nine months of the year; and (3) in deep, porous or well-drained, clayey, or gravelly loam. In less favorable conditions, the species shows considerable vigor of growth over regions of wide variation in temperature, atmospheric moisture, soil composition, and, excepting in the heavier, poorly drained soils, soil moisture. In demands upon both moisture and heat, shortleaf is clearly the least exacting of the important southern pines, which may be put in the following order: Slash, longleaf, loblolly, shortleaf.

LIGHT REQUIREMENTS.

Shortleaf pine requires an abundance of direct overhead light for development, yet at the same time it possesses to a remarkable degree both the power to withstand suppression for many years and the capacity of rapid recovery following suppression. The intimate relation between light supply and growth in early life is graphically shown in figure 5, drawn to scale from an 11-year-old crowded shortleaf-pine stand. The adjacent stands cut off all side light and slightly reduce the overhead supply. The height growth increases at an accelerated rate as the distance from the adjacent stand increases, reaching its normal level of 22 feet at a distance approxi-

mately the same as the height of the marginal trees. Incidentally this close response in growth to varying degrees of light makes shortleaf a good recorder of unusual climatic or other events which strikingly alter existing light relations. Typical examples of this are given on page 32, under the discussion of recovery after suppression.

Because of its inherently narrow crown and medium light requirements, the density of shortleaf stands remains high to a relatively advanced age. So many factors enter into the problem that it is impossible to determine the absolute position of shortleaf in the scale of light requirements without a much greater number of exact measurements. To compare it, however, with other southern pines, under similar conditions of soil, heat, moisture, and age, shortleaf throughout life requires less light for development than longleaf, does not in early life tolerate shade so well as loblolly, but retains longer the

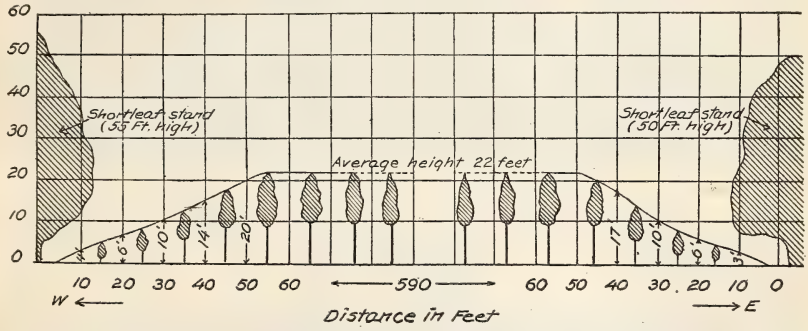


FIG. 5.—Effect of light supply upon height growth, shown by a vertical section through a 2-year-old shortleaf stand. Fully stocked, even-aged shortleaf stand, 11 years old and 22 feet high. (Drawn from actual stand.)

power of growth under limited light supply, showing this retention of power by a relatively later and slower decrease in tree density.

NATURAL THINNING AND STAND DENSITY.

The dependence of shortleaf on a full supply of light in early life is seen in the rapid reduction of very high tree density in natural unthinned stands. A square rod of 8-year-old saplings, encroaching upon a cotton field in Nevada County, Ark., contained a stand of about 58,000 per acre. At 10 years, as many as 25,000 to 40,000 trees per acre over limited areas are not uncommon. At 20 years the normal stand contains from 900 to 1,200 trees.

In fully stocked stands natural thinning progresses very rapidly during the first decade and at an increasingly slower rate during the following 20 to 30 years. After this period the loss of trees is very noticeably gradual for the remainder of life. Natural thinning is most rapid and culminates earliest in the best quality of situations both from a regional and local standpoint. In the central Mississippi

Valley region the first general period ends somewhere between the ages of 40 and 50 years, depending upon the local situation; in the central Atlantic coast belt apparently between 55 and 70 years. Figure 6, showing progressive stages of natural thinning and crown, classed according to age, represents actual numbers of trees and outlines of crowns as they existed in four fully stocked stands in Arkansas measured for growth and yield. The 20-year-old stand contained 800 trees per acre; the 33-year-old stand, 580 trees; the 42-year-old stand, 400 trees; and the 52-year-old stand, 320 trees per acre.

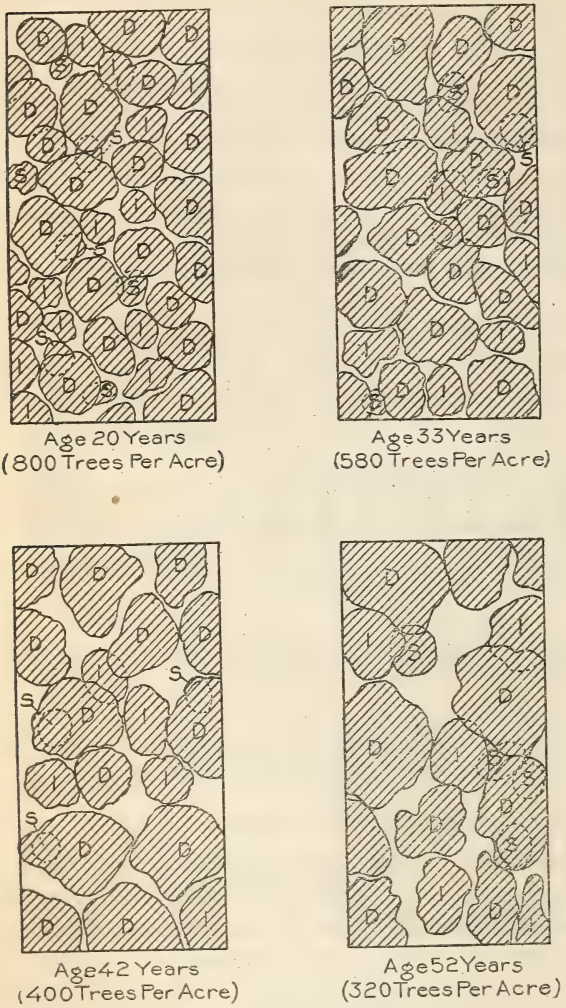


FIG. 6.—Progressive change in tree density by natural thinning in pure even-aged stands of shortleaf in Arkansas: D, Dominant classes; I, intermediate; S, suppressed classes. Areas, 33 by 66 feet. (Drawn from actual stands.)

Shortleaf pine shows progressive changes in the character of the forest canopy other than the mere reduction in number of trees. These changes are well illustrated in figure 6 for stands from 20 to 50 years old. In early life the tree crowns are approximately circular in outline and closely approach each other, leaving very little unoccupied space. At the age of 50 years, however, the tree has become less tolerant, the crowns are quite irregular in outline, and crown isolation leaves relatively large light spaces in the canopy. The slow rate of natural thinning after about 50 years undoubtedly is accompanied by relatively small changes in the tolerance of the tree. The climax of lateral growth or spread of the branches characteristic of the species seems to be closely ap-

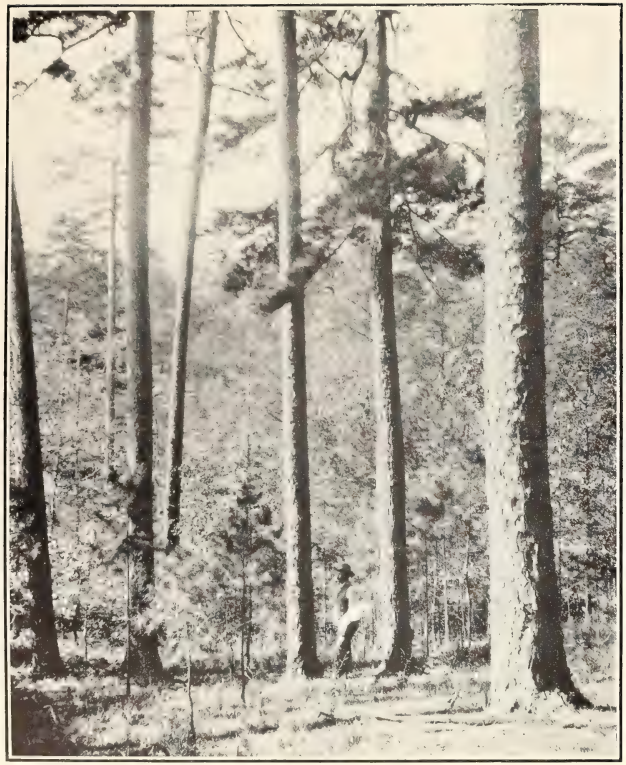


Fig. 1.—Mature Shortleaf Pine, Age about 170 Years.

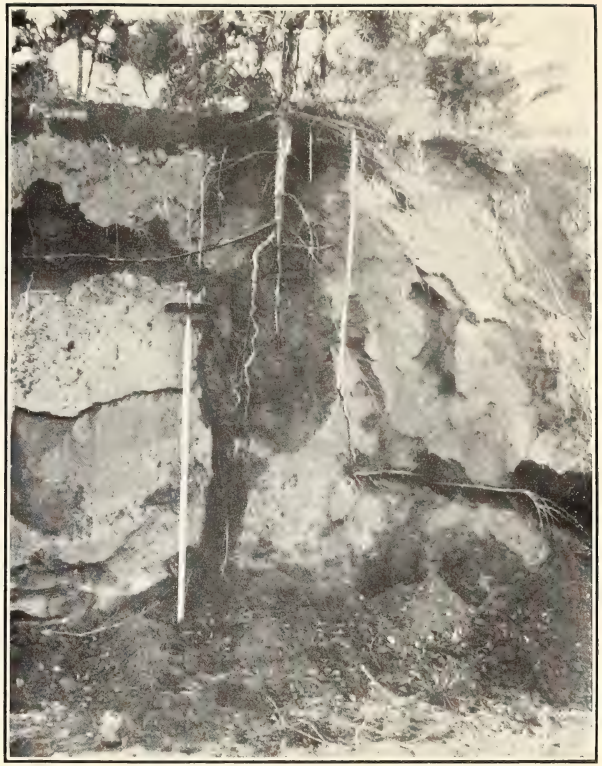


Fig. 2.—Root System of Sapling, 7 Feet in Subsoil.

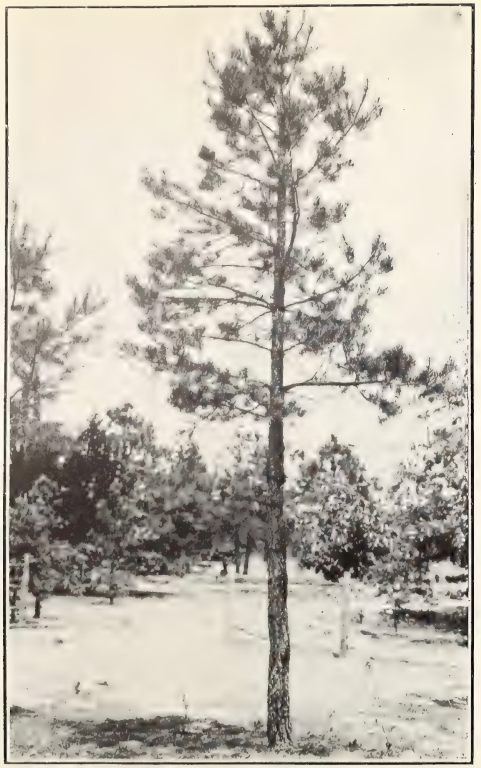


Fig. 1.—Narrow Crown when Grown in the Open.

Fig. 2.—Sixty-Year-Old Stand of about 300 Per Acre.

STRAIGHT, CLEAN TRUNK AND NARROW CROWN OF SHORTLEAF PINE.

FIG. 1.—VIGOROUS 3-YEAR-OLD SHORTLEAF PINE OF SECOND GENERATION OF FIRE SPROUTS.

FIG. 2.— *a*, SPROUT OF SHORTLEAF PINE SHOWING CHARACTERISTIC DOUBLE CROOK IN TAPROOT, AND STUB OF PARENT STEM; *b*, RARE CASE OF ROOT SUCKERS OF SHORTLEAF PINE FOLLOWING INJURY TO EXPOSED ROOT BY GROUND FIRE.

FIG. 1.—SHORTLEAF PINE FIRE COPPICE 4 YEARS OLD IN FOREGROUND FROM 6-YEAR-OLD SPROUT PARENT STOCK. A FEW TREES OF THE FORMER STAND, NOW 10 YEARS OLD, ARE SEEN IN CENTER.

FIG. 2.—THRIFTY STAND OF SHORTLEAF PINE REPRODUCTION, 3-YEAR-OLD FIRE COPPICE, FROM 3-YEAR-OLD SEEDLINGS PARENT STOCK. ARKANSAS NATIONAL FOREST.

proached at about the age of 50 or 60 years on the best sites and 70 to 90 years on the poorer sites. In respect to the number of trees per acre at these ages, shortleaf somewhat exceeds longleaf and notably surpasses loblolly on similar qualities of site. At ages, ranging mostly from 175 to 225 years, natural thinning of stands, due to old age and overmaturity, goes on at a more rapid rate. This is closely associated with the incoming of the new generation and the sudden and rapid increase in numbers per acre.

The number of trees per acre in well-stocked stands decreases as the quality of the site improves. At 20 years, well-stocked stands in the Arkansas region have usually from 1,000 to 1,300 trees per acre; in North Carolina, 1,400 to 1,800; and in central New Jersey, 1,800 to 2,400. In general, this regional difference holds good for several decades; so that at 50 years well-stocked unthinned stands have approximately 300, 355, and 500 trees per acre, respectively, in the above three regions. The relation of the density to the quality of situation, both in one locality and in widely separated regions, appears to be constant and regular. The difference in densities in normal or well stocked stands in North Carolina and Arkansas is well shown by the contrast between Table 5 and Table 6.

TABLE 5.—*Number of shortleaf trees per acre in stands of different densities in Arkansas.*[1]

Age (years).	Under-stocked.	Well stocked.	Over-stocked.	Age (years).	Under-stocked.	Well stocked.	Over-stocked.
20	840	1,130	1,540	120	75	115	155
30	475	600	1,000	130	70	110	150
40	290	400	550	140	65	105	145
50	210	300	400	150	65	102	140
60	170	250	325	160	60	100	140
70	140	215	280	170	60	100	140
80	100	185	250	180	60	100	140
90	80	145	185	190	55	98	140
100	80	128	175	200	55	95	135
110	75	118	160				

[1] Based on measurements in 38 even-aged stands. The number of trees per acre vary quite widely in each case in accordance with the quality of the situation, and the numbers should be considered approximate rather than exact.

TABLE 6.—*Number of trees per acre for well-stocked shortleaf stands in North Carolina.*[1]

Age (years).	Quality I.	Quality II.	Quality III.	Age (years).	Quality I.	Quality II.	Quality III.
20	1,000	1,635	2,450	55	200	310	475
25	675	1,095	1,880	60	165	270	420
30	510	765	1,405	65	140	230	370
35	410	600	1,045	70	120	205	330
40	340	500	795	75	100	180	295
45	280	420	655	80	90	155	270
50	235	355	550				

[1] Based on measurements of 80 sample plots; area, 21.6 acres.

As a result of repeated burnings the density of natural stands is usually very variable. Occasionally second-growth stands have been protected by surrounding cultivated fields and the watchfulness and care of their owners. Such stands show striking regularity of tree density and much quicker wood production than unprotected stands, which is due to the influence of a protective mulch consisting of leaves ("pine straw"), twigs, and bark.

REPRODUCTION.

Few of the valuable pines in the United States reproduce as vigorously as shortleaf. The regeneration is accomplished by seed and by complete sprouting during the period of early life when the tree is most susceptible to severe injury. Reproduction by means of natural seeding is successful and heavy, because of the frequent and full seed crops, the lightness and short germinating period of the seed, and the high resistance of the seedling to unfavorable conditions of temporary shade and drought.

Abandoned fields and openings made by lumbering, windfall (in the tornado belt west of the Mississippi), and fires are quickly occupied by shortleaf pine. Ten representative counties in western North Carolina contain 393,670 acres of old-field stands of mostly pure shortleaf pine. This is 14 per cent of the total area, or 27 per cent of the forested area, of the counties. Such old-field stands characterize the forest lands of the upland regions from Virginia southward and westward throughout the range of the species. The extensive pineries near Lakewood, N. J., are mostly pure stands of shortleaf ("two-leaf") pine of similar origin. (Pl. II.) In mixture with the inferior pitch pine in New Jersey and loblolly pine in the lower or outer portions of the shortleaf range, it has not successfully held its former place of importance. The cause lies chiefly in the much closer utilization of the shortleaf and the resulting relatively greater abundance of seed trees of the associated species. In the southern mixed hardwood forest there has been a notable extension of the importance and commercial range of shortleaf. This has been due to the successive clearing, working, and "turning out" of fields and to the extensive ranging of hogs. The hogs consume practically all of the oak and hickory seed and at the same time prepare excellent seed beds for shortleaf pine by uprooting soil and humus in the fall of the year. Some seedlings, of course, are later destroyed by the same process. The results of these two agencies, operative for periods of 75 to 200 years, have been cumulative and have produced marked changes in the composition and density of the forest in various parts of the South.

On the National Forests of Arkansas natural reproduction is heavy except on the cool northern exposures, and the encroachment of

shortleaf pine into the oak and hickory type is particularly noticeable. Fresh openings become fully stocked usually during the first four years; and, normally, in the mixed pine-and-hardwood type, groups of pure young pine of a few prevailing age classes are numerous.

SEED.

The seed of shortleaf is very small, varying usually from 50,000 to 70,000 to the pound. The cones which produce them are among the smallest for all pines—from 1½ to 2½ inches in length. They persist on the trees for periods of about four years on vigorous shoots to seven or eight years on suppressed portions of the crown. Ripening in early autumn, the seeds fall by the middle of November and lie dormant during the winter. Germination usually takes place during March or April. In ordinary seed years the seed averages 50 to 60 per cent germination, varying quite widely below this standard in unfavorable seasons and with unhealthy or old-aged trees. One tree 280 years old had a full crop of cones bearing apparently good seed. The germinative power of shortleaf pine is retained to a large degree for several years. Seed of the 1911 seed crop, kept at ordinary living temperatures, gave 56.8 per cent germination in the spring of 1914. The seedlings, however, were apparently somewhat lower in vigor than those grown from fresh seed.

The seed of the shortleaf has some advantages over seeds of other species. A marked ability to germinate successfully in grass and leaf litter, as compared with other southern pines, has been observed.[1] This is in line with the inherent capacity of the species to thrive on the lighter upland soils deficient in soil moisture. The very small size of the seed gives it an advantage over larger seed in quickly reaching mineral soil. By means of a relatively large wing the seed is readily borne by the wind. A breeze will carry seed a distance of from 2 to 5 times the height of the tree; and strong winds will carry it from one-eighth to one-fourth of a mile.

Seed is produced both abundantly and regularly. Full crops occur at an average interval of about three years, with intermediate or partial crops almost every season. In a typical region of the Arkansas National Forest, during a period of 13 years commencing in 1901, shortleaf pine bore four full seed crops, seven partial crops, and failed entirely during two seasons.[2] The years of abundant seed were 1902, 1907, 1910, and 1913; 1903 and 1909 were blank years, and the others intermediate. Thrifty trees with good light supply begin to produce seed at about 20 years. Exceptional trees have been noted with cones at 16 years. In open or mixed forest

[1] Proceedings of the Society of American Foresters, Vol. V, No. 1, "Loblolly and Shortleaf Pines," by W. W. Ashe.

[2] Record of seed crops determined by study of crowns in a large logging area, Womble, Ark.

stands seed is produced at intervals throughout life after about the thirtieth year. In crowded stands seed production is confined to the larger dominant trees and is deferred until about 40 years.

SPROUT OR COPPICE REPRODUCTION.

Shortleaf pine sprouts vigorously, and thus reproduces itself if killed back during the period of early life. This period fortunately is the time of greatest susceptibility to injury both by fire and various mechanical agencies. Its range over the drier uplands is coincident with a region of frequent forest fires, yet it is saved by notably abundant reproduction practically everywhere. Of the important commercial pines in the United States shortleaf alone possesses this capacity of complete reproduction.[1] A field investigation in 1912–13 showed clearly that comparatively very few seedlings reach ages of 3 to 6 years without being burned back, and that most forest stands have passed through this experience on repeated occasions.

It has been found possible, although somewhat difficult, to trace the history of most stands and determine definitely their origin, whether of direct seedling or coppice growth. Thus, the majority of all standing shortleaf timber examined in various portions of Arkansas was found to be of coppice origin. In abandoned fields fire less frequently sweeps over young stands because of the fire protection afforded by the naked soil. In spite of this, many old-field stands have suffered from at least one fire. Observation in Georgia, South Carolina, Virginia, and New Jersey showed that similar conditions exist throughout the geographical range of the species. The property of sprouting accounts for the remarkable aggressiveness of shortleaf pine over the region in the South most endangered by fire. Second-growth forests of the Piedmont and Appalachian regions have been subject to frequent fires during more than a century. As a general law, it may be stated that, in any specified locality, the proportion of shortleaf pine of seedling origin varies inversely as the frequence and general prevalence of fires. Stands of direct seedling origin are on the whole of insignificant area, because there are few localities protected against fire by natural barriers or by man. In one locality of optimum shortleaf development in Pike County, Ark., the only stands of direct seedling origin found were located in low, moist situations where burnings have been infrequent. Obviously the perfection of vigorous reproduction by coppice, though limited to early years, is of high importance in the profitable management of a forest species. Since the occurrence of a commercial coniferous forest largely of coppice origin is very unusual in any other species, a discussion of the function of coppicing, the sprouting capacity of the tree, and the way in which the sprouts are produced is of interest.

[1] Other pines which to a greater or less degree sprout when young are pitch pine (*P. rigida*), pond pine (*P. serotina*), and *Pinus chihuahuana* along the Mexican border.

EXTENT AND NATURAL LIMITATIONS.

In open-grown, vigorous stands, shortleaf successfully coppices up to about the eighth year, and in slow-growing, crowded, or shaded stands, to the tenth or twelfth years. The upper limit of size at which coppicing may take place ranges from diameters near the ground of 3 to 4 inches for vigorous individuals down to 2 to 3 inches for trees of slow growth. Thus the chief limitation seems to be age, modified by the general vigor and size of the individual stem.

Within these limits shortleaf is known to coppice repeatedly. Regions of frequent fires afford opportunities to observe the effects of repeated burning to the ground upon younger-aged stands. Figure 7 shows diagrammatically a fully stocked stand in Arkansas, composed

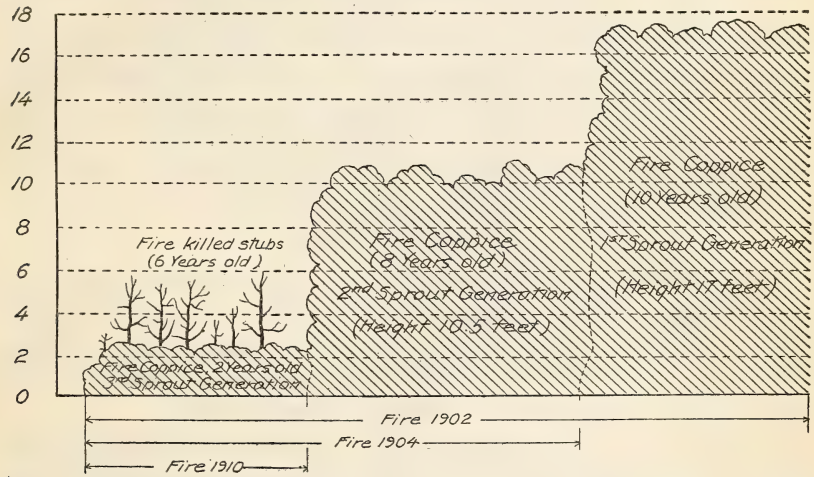


FIG. 7.—Vertical section through three successive generations of shortleaf pine fire coppice. Pike County, Ark. (Drawn from actual stand.)

of three successive generations of coppice resulting from fires in 1902, 1904, and 1910. Each age class was regular and normally stocked. The heights averaged 17 feet for the 10-year-old, 11.5 for the 8-year-old, and 2.5 feet for the 2-year-old stand. Similar successive generations of coppice are commonly met throughout all the shortleaf region. Around the margin of a young stand, surface fires burn freely, fed by the better growth of grass and light dry materials deposited by the wind; while farther within the stand there is less ground litter, and the shaded surface is often too moist to burn in the cool season when fires prevail.

The number of successive generations of sprouts that can be produced from an original parent seedling is not known. Young coppice of the second generation of sprouts is readily identified under close observation. It occurs abundantly except in old-field stands. Three

successive generations of coppice have been definitely identified; but beyond this, evidences of the past history of the tree become greatly obscured. In the third generation of sprouts the rate of height growth appears to be undiminished. Practically all of the root system is utilized by the new generation. As an effect of the root energy and stored-up food, the rate of early height growth is remarkably rapid and, within limits, increases with the age of the parent tree when cut or burned back. As a rule, during the first two to four years, depending upon the age of the parent, the sprouts make up completely for the previous loss of time in growth. The most rapid height growth observed was in a 4-year-old fire sprout stand, many trees being from 5 to 8 feet in height and the tallest 9.6 feet. The growth in height of thrifty stands of fire coppice, based on measurements of both trees and whole stands up to 18 years old, is shown in Table 6. The age at which trees of sprout origin grow at approximately the same rate as seedling trees is not precisely known. Under average conditions this point is perhaps between the fifth and ninth years. In general, the great acceleration in growth in fire sprouts takes place at approximately the same rate in diameter and volume as in height.

CAUSE AND METHOD.

Fire and cutting are the chief external causes for the sprouting of shortleaf pine. The physiological cause lies in the capacity of shortleaf pine to develop on the upper portion of the root and lower portion of the stem special reproductive buds, at least one of which has the same function as the central terminal bud on the stem.

The double crook, at the upper end of the taproot of shortleaf pine, characteristic of and always present in young trees, seems to be intimately associated with its power of reproduction by sprouts. By means of this double crook a horizontal section from 1 to 3 inches in length, varying with the age, is formed at the upper end of the taproot. This form persists during the first 8 to 12 years, after which its identity becomes lost through the increasing thickness of the annual accretions. It is significant that the capacity for sprouting is coincident with the period during which the root maintains this characteristic form. During this period adventitious stem buds are present and may readily be seen along the horizontal section of the root. The corky bark here is unusually thick, affording a high degree of protection against ordinary fires.

The killing of the stem is followed by the development of a colony of sprouts at the base of the stem and top of the taproot, usually from 6 to 12, as shown in figure 8, and not infrequently 16 to 20. Normally one stem (occasionally two) assumes the function of leader, the others being more or less procumbent in habit and serving as laterals or

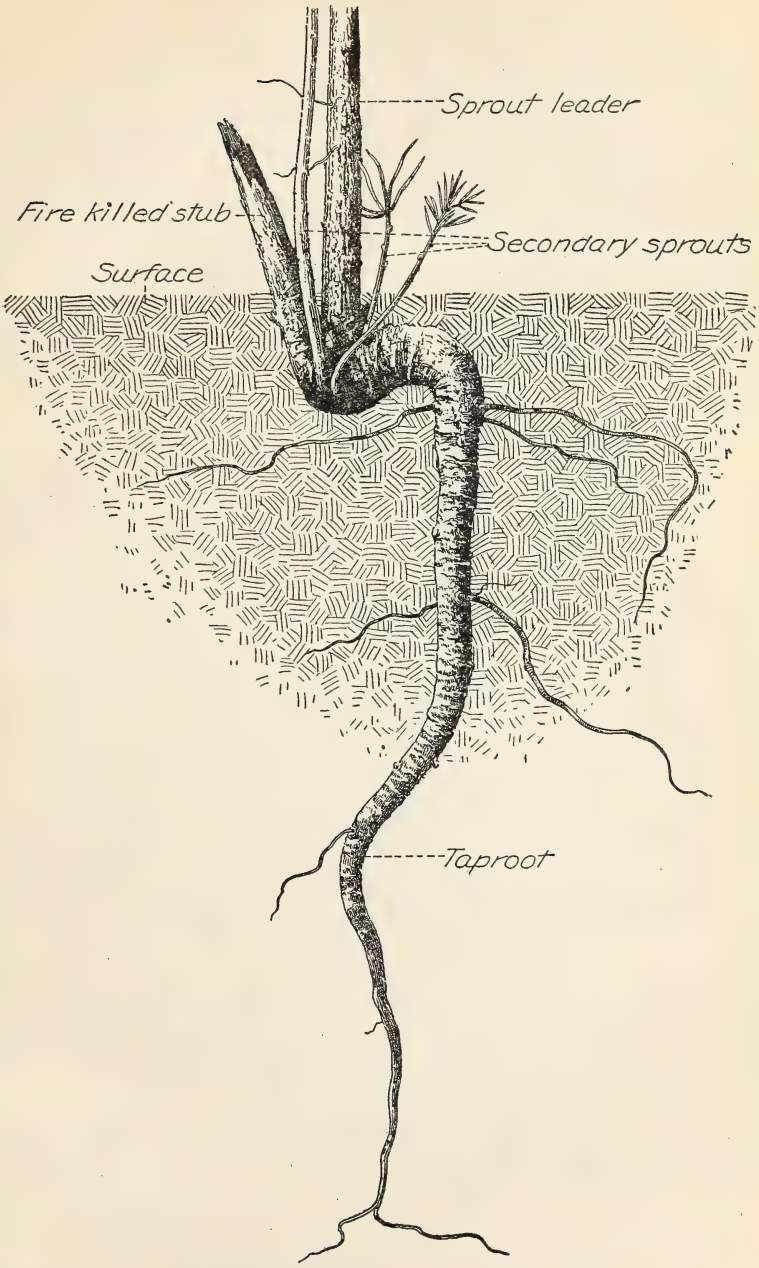


FIG. 8.—Sprout shortleaf pine following fire, showing new upright stem, secondary sprouts, or "laterals," and characteristic crook of the taproot. Three-year-old coppice from 7-year-old seedling parent. (Drawn from actual specimen.)

feeders. In the organization of the sprout colony, the correlation of the two classes of vegetative buds of the tree is thus carried out. In producing normally a single new upright stem, shortleaf resembles the hickories, in contrast to the oaks and chestnut, which commonly mature several main stems. In open situations and understocked stands a tendency to develop twin stems is sometimes seen in vigorous stands of shortleaf. A tendency to increase the number of stems above two appears to be caused directly by unfavorable factors of age, weakness of the parent, poor light supply, or climatic conditions. For example, as many as 42 coordinate upright stems have been counted on a stump 4 inches in diameter, cut in midsummer. In coppice stands up to 50 years old, a few twin trees will usually be found. The oldest tree of undoubted sprout origin observed was 226 years.[1]

TABLE 7.—*Height growth of dominant shortleaf pine in pure, well-stocked stands of fire coppice origin.*[1]

Age (years).	Height (feet).	Age (years).	Height (feet).
1	1.3	10	18.3
2	2.7	11	20.6
3	4.2	12	23.3
4	5.8	13	26.0
5	7.5	14	28.8
6	9.5	15	31.7
7	11.6	16	34.7
8	13.9	17	37.9
9	16.1	18	41.0

[1] Based on 100 individual trees and the average trees for 8 sample plots 9 to 18 years.

An 18-year-old coppice stand, near Glenville, Nevada County, Ark., averaged 248 trees per acre. Of these, 71 trees had two stems each, 7 had three stems, and 1 had four stems, or a total of 336 stems per acre. Thus 33 per cent of the trees had more than one stem. The sprout origin of the stand was completely identified, but there is no record whether the cause was fire or chopping to clear a pasture. The stand was vigorous and averaged 44 feet high. The average diameters of all stems was 6.3 inches, while that of the trees proper, or each tree colony taken as a unit, was 7.4 inches. Three colonies of twin trees and some single stems are shown in Plate V.

[1] A large twin-stemmed tree with single root system exposed by erosion on a stream bank. There were others of nearly the same size and form in the same stand.

TABLE 8.—*Number of trees per acre and number of tree stems per acre in 18-year-old coppice shortleaf stand, Nevada County, Ark.*

Diameter breast high (inches).	Trees per acre.[1]					Total stems per acre.
	Stems per tree colony.				Total.	
	1	2	3	4		
2	6				6	6
3	28	1			29	30
4	24	8	3	1	36	53
5	9	27	3		39	72
6	28	18	1		47	67
7	27	10			37	47
8	34	5			39	44
9	6	2			8	10
10	6				6	6
11	1				1	1
Total	169	71	7	1	248	336

[1] Individual trees with one or more stems, as the case may be.

As a result of the tree's vigorous coppicing during early life, shortleaf occurs characteristically in even-aged stands. A fire after 6 to 8 years reduces to a single age class all the several ages of young growth that may have come in during the period. This has been found to be the case in all of the regions studied. It is significant in this connection that in one region of abundance and good development of shortleaf,[1] two age classes strongly predominated throughout the whole stand. One group consisted of pure stands from 160 to 180 years old and the other of similarly pure stands from 60 to 70 years. The average between the two groups is 105 years. This may be looked upon as indicating the occurrence of periods of either tornadoes or unusually destructive crown fires. The 60-year-old age class is especially abundant over the region. Old local records may possibly confirm this supposition of some unusual occurrence of the sort indicated between the years 1848 and 1852.

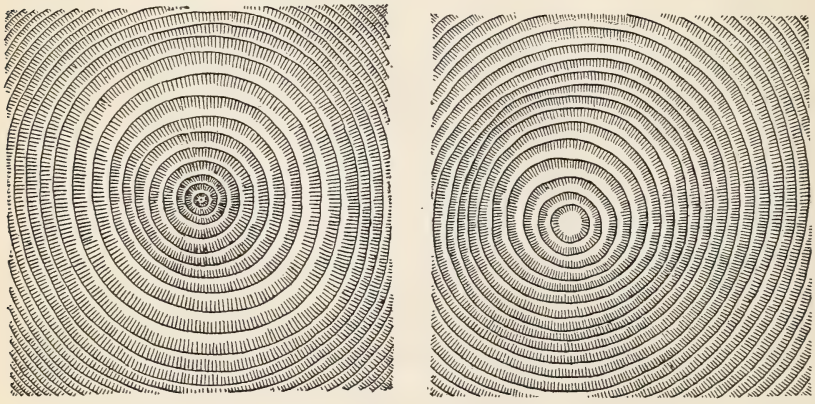
SEASON OF YEAR.

In common with the broadleaf species, the sprouting takes place least actively following midsummer cutting. Pastures and rights of way are thus commonly treated. In one instance a pasture contained a good stand of vigorous shortleaf-pine sprout saplings, 4 years old and from 6 to 10 feet high, representing the third generation of coppice from winter or early spring cutting. Along railroad rights of way in the Arkansas region, it is common to see dense sprout thickets of shortleaf pine due to repeated mowing. The forest-fire season occurs during the fall and late winter. This is during the period of vegetative inactivity, and such burnings generally result in vigorous sprout growth the following spring.

[1] Montgomery and Pike Counties in western central Arkansas.

METHOD OF DETERMINING SPROUT ORIGIN.

Determination of the sprout origin of shortleaf pines during early life is possible by means of external characteristics. The presence of a colony of two or more living stems, also the presence of dead stems or stubs of the parent tree (charred in the case of fire), and the large size of the sapling or pole in relation to its age are clear evidence of coppice origin. A clean, smooth base without scars or adjacent stubs indicates seedling origin. This evidence is sufficient and dependable up to about the eighth year. Dead stems from 2 to 5 feet high, when killed by fire, will ordinarily be found standing at the end of the third year. In very early life sprout stands may be found to contain a considerable number of twin and triple colonies, but the number decreases rapidly with advance in age. In the latter stands,



A *B*

FIG. 9.—Determination of origin of shortleaf pine by basal sections at the ground: *A*, Tree of seedling origin; *B*, coppice tree 64 years old. Diameter of core, or first year's growth, is 3 times and cross-section area 8.9 times that of tree (*A*) of seedling origin. (From photographs.)

trees are frequently seen with dead or dying stems, forked at an acute angle or emerging from their sides, at distances a few feet above the ground. Following the first 6 to 10 years no external characteristics are usually apparent except occasionally multiple living stems.

The first year's stem growth of trees of seedling origin is about as thick as a darning needle and 2 to 4 inches high, while the corresponding growth of young coppice sprouts is commonly as large as an ordinary lead pencil in diameter and about double its length. (Fig. 9.) The following few years' growth in each case is on a proportional scale. Thus the character of early growth, particularly that of the first year, recorded in the base of the tree and visible when the tree is cut level with the ground, affords a dependable record of the origin of the tree. Coppice trees, furthermore, usually have some of the dead stubs of

the former generation embedded at their bases. (Fig. 10.) In most cases fire has been the cause of the sprouting, and since both the inclusion of charred stubs and the size of the core can readily be ascer-

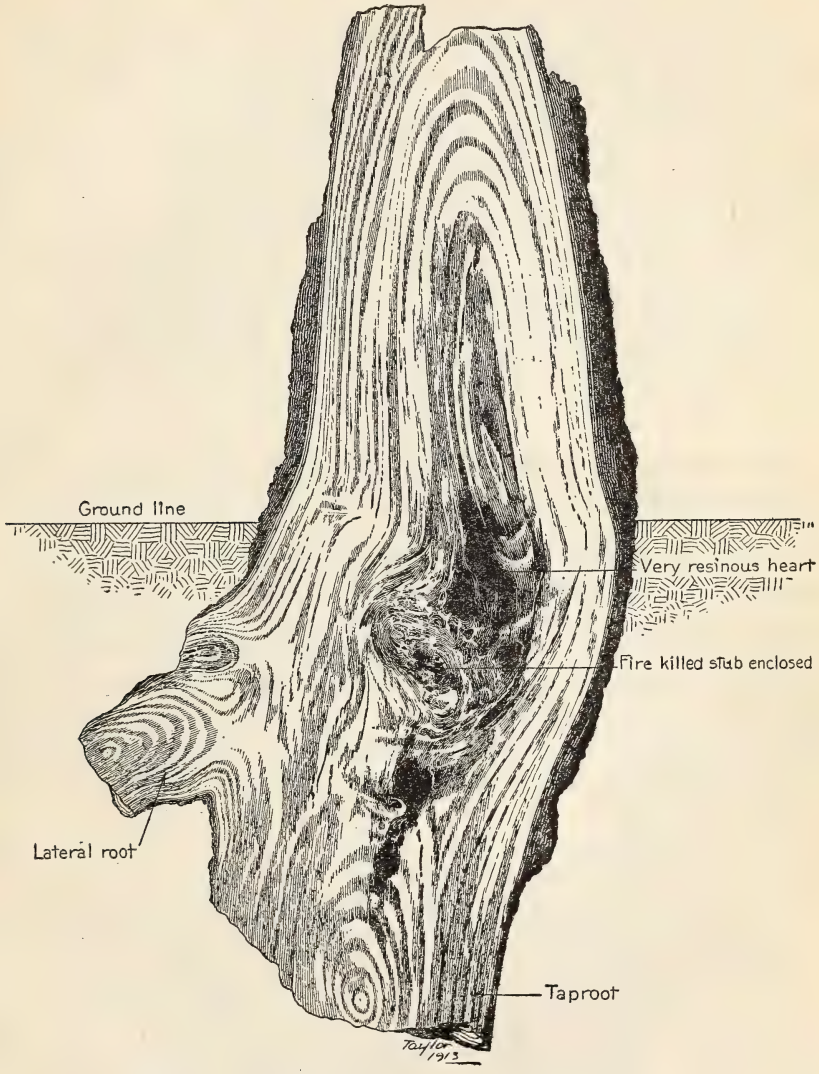


FIG. 10.—Vertical section through base of 18-year-old, thrifty shortleaf pine of coppice origin, inclosing stub of parent stem. (From photograph.)

tained, if present, by an examination of the extreme base of the tree, these marks embedded similarly in a number of trees selected at random will serve to confirm the coppice origin of the whole stand. An indication of origin may be seen in low-cut stumps [1] in logging

[1] In Arkansas 6 to 9 inches high for small trees and 1 foot for the larger ones are customary heights.

areas, the core of coppice being composed of large conspicuous rings in contrast to the small rings of seedling trees.

ECONOMIC VALUE.

Fire as a menace to young pine in great measure prevents capital from going into what otherwise appears to be a paying investment. White pine in New England is a well-known example. The case is somewhat different with shortleaf, in which practically the only fire loss is from exceptionally hot fires which destroy large saplings or pole stands too large to sprout. Repeated burning in the dormant seasons of the year, when almost all fires occur, seems to offer no appreciable setback for at least three sprout generations. Therefore the element of fire risk in the production of all important eastern coniferous species is reduced to the minimum in shortleaf pine by its vigorous sprouting habit. This feature highly recommends the species for profitable managment throughout its range.

GROWTH.

HEIGHT.

The long growing season throughout most of its range and its inherent vigor make shortleaf pine a tree of rapid height growth. In situations of equal favorableness it is more rapid than longleaf pine and only slightly less so than loblolly pine. On average upland soils typical of most of its range it excels its most common associates among the oaks and hickories. In Arkansas and adjacent States, on the better sites bigbud and bitternut hickories are distinctly below it, yellow and Spanish oaks nearly equal it, and sweet gum slightly exceeds it in height growth. In the Piedmont and Arkansas regions height growth is not widely different on similar qualities of site. Table 9 shows the rate of growth and relation of heights to age for the two regions.[1]

TABLE 9.—*Height growth of shortleaf pine, based on age, in Arkansas and North Carolina.*[2]

WESTERN ARKANSAS.

Age (years).	Height.			Age (years).	Height.		
	Maximum.	Average.	Minimum.		Maximum.	Average.	Minimum.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
20	51	45	37	90	79	73	67
25	56	50	43	95	80	74	68
30	59	54	48	100	81	74	68
35	62	57	52	110	83	76	69
40	64	60	54	120	85	77	70
45	66	62	57	130	87	78	71
50	68	64	59	140	88	79	71
55	69	65	60	150	89	80	71
60	71	66	62	160	90	81	72
65	72	67	63	170	91	81	72
70	74	69	64	180	92	82	72
75	75	70	65	190	93	82	72
80	76	71	65	200	93	83	73
85	78	72	66				

[1] Table 7 shows the height growth of shortleaf known to be of coppice origin.

[2] The Arkansas table is based on age-height measurements of 285 trees and diameter-height of 3,214 trees; the North Carolina table is based on age-height measurements of 332 trees and diameter-height of 384 trees.

TABLE 9.—*Height growth of shortleaf pine, based on age, in Arkansas and North Carolina*—Continued.

PIEDMONT REGION, NORTH CAROLINA.

Age (years).	Height.			Age (years).	Height.		
	Maximum.	Average.	Minimum.		Maximum.	Average.	Minimum.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
5	22	13	.....	45	75	67	40
10	48	29	10	50	76	68	43
15	63	42	15	55	76	69	45
20	69	50	20	60	77	69	48
25	71	57	25	65	77	70	49
30	73	61	29	70	77	70	51
35	74	63	33	75	78	70	53
40	75	65	36	80	78	71	55

During early life the terminal leader of shortleaf pine commonly forms from two to four secondary or false terminal nodes during the growing season. These are accompanied by false rings of growth in the wood, usually plainly marked and apt to be mistaken for true rings.

The influence of side light upon height growth is well illustrated in figure 5, showing a 10-year-old stand of shortleaf with the east and west side light cut off by an adjacent stand. The heights increase from 2 feet near the margin to 22 feet under full light. This illustrates very well the need of light for development, and, at the same time, the power of endurance of shortleaf under limited light supply. A 9-year-old stand with 3,800 trees per acre averaged 19 feet high as compared with only 16 feet for a near-by stand of the same age and on similar soil with 12,200 trees per acre. Two adjacent young stands, similar in all points except tree density, averaged 9 feet high for 4,100 trees per acre and 5 feet high for 32,000 trees per acre.

DIAMETER.

The rate of diameter growth of shortleaf pine is intermediate between that of loblolly and that of longleaf pine, the slowest of the important southern pines. Besides the well-defined annual rings of wood which clearly record diameter growth, from two to four terminal nodes in the stem of the tree, accompanied by slight resting periods in the tree's activity, usually occur during the period of vigorous growth in earlier life. These growth periods are recorded by fine lines of denser wood within the true annual rings. Periods of injury, caused by insect attack, fire, or severe drought during which growth is temporarily checked, usually have the same effect. Such lines, forming false rings, are frequent in shortleaf pine, and must be distinguished in examining a cross section for age. Prominent bands of wood stained brown in color are particularly apt to be found in

young shortleaf and erroneously mistaken for true annual rings of growth.

Diameters throughout this bulletin, unless otherwise stated, are measured at breast height (4½ feet above the ground). Table 10 shows the diameter growth based on age for the Piedmont region of North Carolina and for western Arkansas. The tables may be considered as broadly applicable to large areas within the two specified regions, since differences in growth over large areas are not important except as caused by local variation in quality of situation.

TABLE 10.—*Diameter growth of shortleaf pine, on the basis of age, in Arkansas and North Carolina.*[1]

WESTERN ARKANSAS.

Age (years).	Diameter breast high.			Age (years).	Diameter breast high.		
	Maximum.	Average.	Minimum.		Maximum.	Average.	Minimum.
	Inches.	*Inches.*	*Inches.*		*Inches.*	*Inches.*	*Inches.*
20	7.2	5.7	4.3	90	18.5	15.9	13.3
25	8.6	7.0	5.4	95	19.0	16.3	13.6
30	9.9	8.1	6.4	100	19.4	16.6	13.8
35	11.0	9.1	7.4	110	20.3	17.3	14.2
40	12.0	10.1	8.2	120	21.1	17.8	14.6
45	12.8	10.9	9.0	130	21.7	18.3	14.9
50	13.6	11.7	9.7	140	22.3	18.7	15.1
55	14.4	12.3	10.3	150	22.8	19.0	15.3
60	15.1	12.9	10.8	160	23.2	19.3	15.4
65	15.7	13.5	11.3	170	23.6	19.6	15.5
70	16.3	14.0	11.8	180	23.9	19.7	15.6
75	16.9	14.5	12.2	190	24.1	19.9	15.7
80	17.5	15.0	12.6	200	24.3	20.1	15.8
85	18.0	15.5	12.9				

PIEDMONT REGION, NORTH CAROLINA.

5	2.0	0.9	.....	45	17.1	10.5	4.5
10	5.9	3.0	0.6	50	17.6	11.0	5.0
15	9.2	4.9	1.2	55	18.0	11.4	5.4
20	11.6	6.3	1.8	60	18.4	11.7	5.8
25	13.3	7.5	2.4	65	18.7	12.1	6.1
30	14.5	8.4	3.0	70	19.0	12.4	6.4
35	15.6	9.2	3.5	75	19.2	12.7	6.8
40	16.5	9.9	4.0	80	19.4	13.0	7.1

[1] The table for Arkansas is based on breast-high diameter measurements of 285 trees and 34 trees representing the average of even-aged plots; the North Carolina table is based on decade measurements on 332 stumps, 26 to 89 years old.

The close relation between tree density and growth in diameter is illustrated in Table 11, compiled from measurements on unit areas of different density of trees of a 30-year-old fully stocked shortleaf stand. In seven consecutive sample areas of one-tenth acre each, the size of the diameter class prevailing on each plot increased regularly with a corresponding regular decrease in the number of trees per acre. So far as is known this close relation holds true for all pure stands of shortleaf pine.

TABLE 11.—*Relation of tree density and diameter growth in 30-year-old pure stands of shortleaf of varying densities, Arkansas National Forest.*[1]

Prevailing diameter class (inches).[2]	Tree density (trees per acre).	Decrease (trees per acre).	Prevailing diameter class (inches).[2]	Tree density (trees per acre).	Decrease (trees per acre).
4	800		8	475	85
5	720	80	9	390	85
6	640	80	10	300	90
7	560	80	11	210	90

[1] Based on seven plots in the same stand of varying density, but having uniform soil conditions.
[2] The diameter class having the largest number of trees in the individual stand.

VOLUME GROWTH.

The merchantable contents of a tree obviously depends upon total height and diameter taken at successive points along the stem. The rise in percentage of the rate of increase in the volume of shortleaf pine in common with most trees culminates at a comparatively early age, considerably prior to the year of maximum production of wood for the individual tree. Furthermore, the highest annual production of wood is reached somewhat earlier than the production of saw timber. In stands of relatively equal density those on the poorer sites and near the margin of natural distribution reach the maximum rate of volume production at a later age than similar stands on more favorable sites and more centrally situated within the region of distribution. For example, the individual trees in stands in Missouri, West Virginia, and New Jersey apparently show the greatest annual wood increment at about 70 years, but in North Carolina the culmination is reached at about 50 years, and in Arkansas at about 35 to 40 years.[1] The contents in board feet and cubic feet of trees of different ages, up to 80 years, for two qualities of site, are shown in Table 12.

TABLE 12.—*Volume of shortleaf pine in North Carolina, based on age for two site classes.*

[Based on diameter growth of 332 trees, and volume table. Stump height, 1 foot for trees 6 to 16 inches; 1.5 feet for trees 17 inches and over.]

Age (years).	Saw timber.				Solid contents.[2]	
	Scribner rule.		Doyle rule.			
	Quality I.	Quality II.	Quality I.	Quality II.	Quality I.	Quality II.
	Board feet.	*Board feet.*	*Board feet.*	*Board feet.*	*Cubic feet.*	*Cubic feet.*
15	51		17		13.5	
20	100	6	50	3	24	2.6
25	147	23	87	7	34	6.7
30	186	38	125	11	43	10.3
35	221	51	160	17	50	13.8
40	251	63	191	24	56	16.7
45	275	75	216	32	61	19.3
50	296	86	237	39	65	22.0
55	315	96	255	46	69	24.0
60	331	105	271	53	72	26.0
65	345	113	284	60	75	28.0
70	357	121	295	66	78	29.0
75	369	129	306	73	80	31.0
80	381	135	316	79	82	32.0

[1] For volume tables of shortleaf pine based upon height and logs per tree, see a forthcoming bulletin on the Importance and management of shortleaf pine.
[2] Total volume of stem, including bark, between stump and top diameter, outside bark, of 5.5 inches.

RECOVERY AFTER SUPPRESSION.

Shortleaf pine possesses to a high degree the ability to recover after suppression. This feature is well exhibited in a rapid increase in diameter growth following an increase in the supply of light. Events of any sort which produce changes in stand densities are recorded in quite a remarkable manner by shortleaf pine.

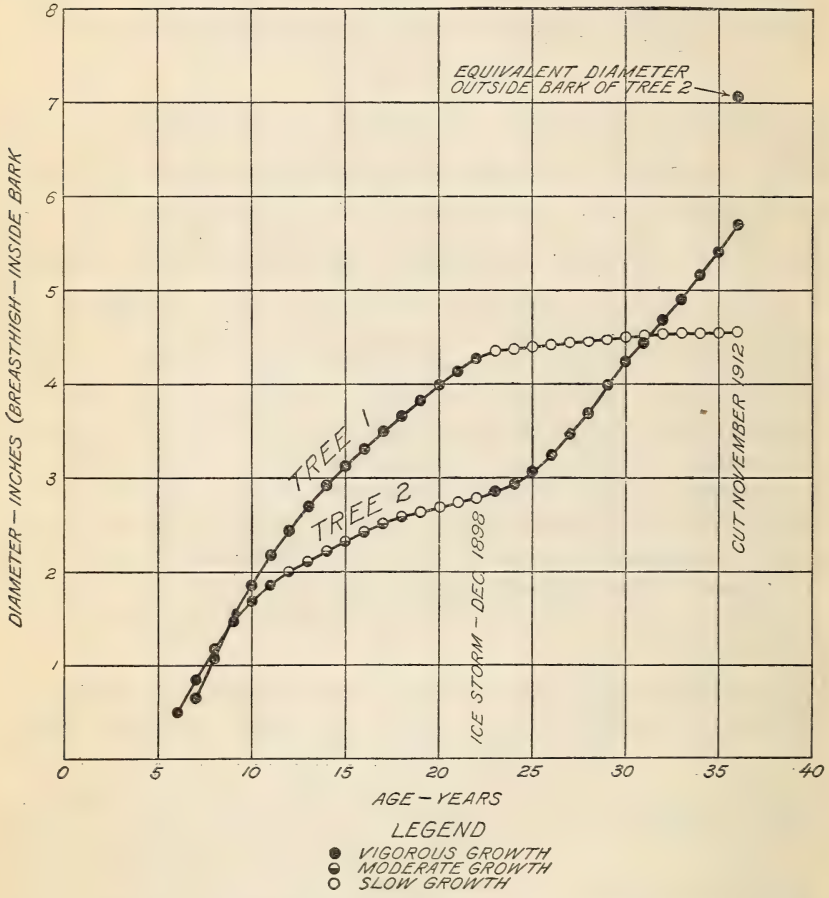


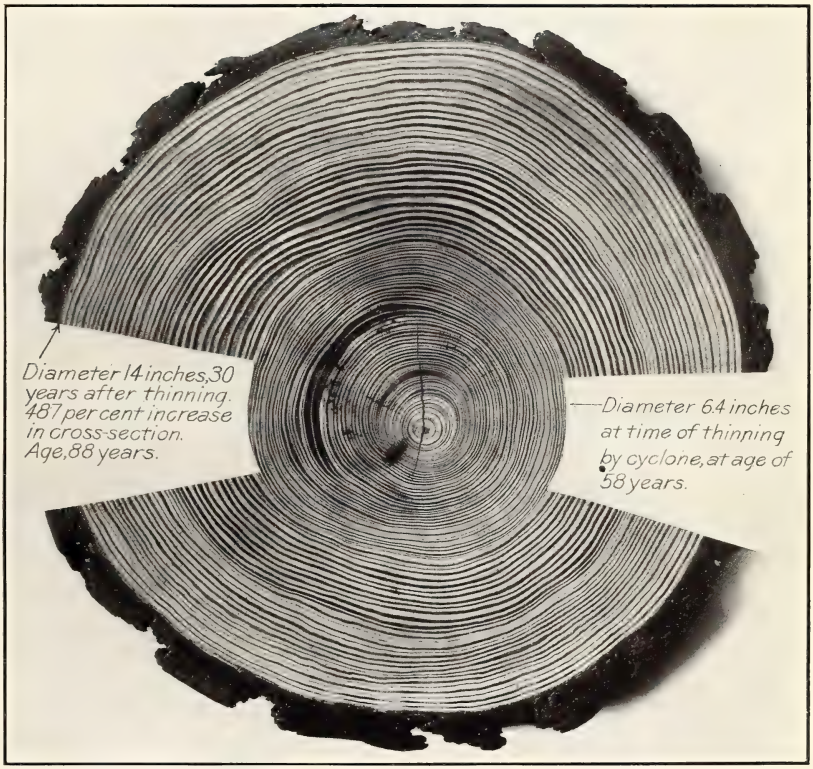
FIG. 11.—Effect of an ice storm upon subsequent diameter growth in a 22-year-old crowded shortleaf stand. Tree 1, formerly dominant, permanently bent over by ice and suppressed for a period of 14 years; tree 2, formerly partially suppressed, given more light by the storm, vigorous and dominant for the past 14 years.

The effect of a heavy ice storm upon a thrifty 22-year-old fully stocked stand in Nevada County, Ark., as recorded by the diameter growth, is seen in figure 11 and Plate VIII. The storm occurred in December, 1898, and the stand in 1912 was 36 years old. The heavy ice bent over many of the larger-crowned, dominant trees, thereby opening up many smaller-crowned, middle and lower class trees.

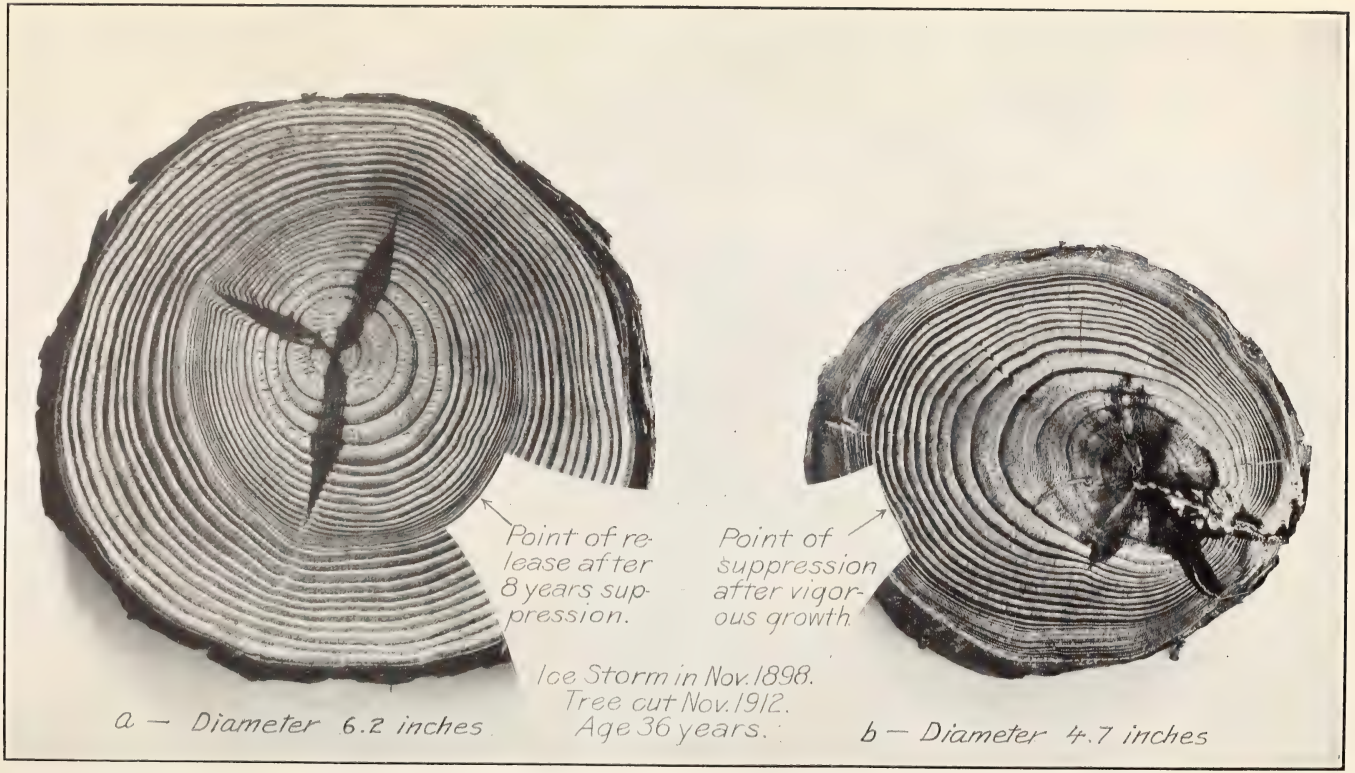
COPPICE STAND OF SHORTLEAF PINE 18 YEARS OLD.

Thirty-three per cent of the trees have more than one stem. Dominant trees are 6 to 11 inches breast-high diameter.
Nevada County, Ark.

SECTION THROUGH BASE OF 65-YEAR-OLD TWIN SHORTLEAF PINE OF SPROUT ORIGIN.



RAPID RECOVERY OF SHORTLEAF PINE AFTER SUPPRESSION. EFFECT OF NATURAL THINNING BY TORNADO, 31 YEARS AGO, UPON TREE 58 YEARS OLD. ARKANSAS NATIONAL FOREST.



EFFECT OF NATURAL THINNING BY ICE STORM. SECTIONS OF ADJACENT TREES.

a, Tree formerly suppressed now vigorous and dominant; *b*, tree bent over and permanently suppressed by ice storm.

FIG. 1.—EFFECT OF NANTUCKET TIP MOTH (LEFT) ON 8-YEAR-OLD COPPICE SHORTLEAF. TREES SAME AGE AND HEIGHT AT OPENING OF SEASON.

FIG. 2.—EFFECT OF ICE STORM AFTER A LAPSE OF 14 YEARS.

INJURY BY INSECTS AND HEAVY STORMS.

FIG. 1.—BADLY DISEASED SHORTLEAF IN NEW JERSEY.

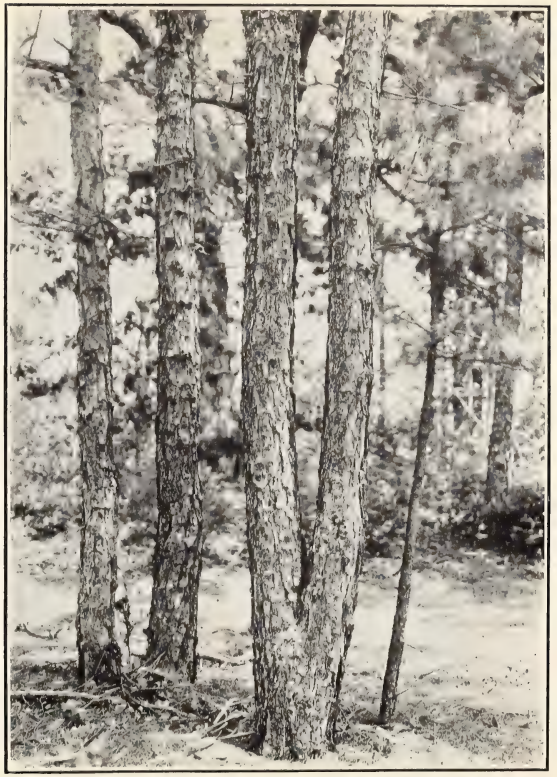


FIG. 2.—EFFECT OF FIRE IN CAUSING FORKED STEMS. NEW JERSEY.

INJURY FROM FUNGI AND FIRE.

The storm lasted for nearly a week and many of the bent trees which were given a permanent "set" were alive after 14 years of suppression. The record of interchange of crown classification and resultant growth is well illustrated in the breast-high sections of two representative trees shown in the illustration. In the 10-year period following the storm, the tree suppressed by the ice changed from 97 per cent to 13 per cent rate of diameter growth, while an adjacent and formerly partly suppressed tree showed, as a result of the opening up, an increase of growth from 65 to 122 per cent.

An immediate response in diameter growth at the age of 58 years is exhibited in Plate VII, showing a representative tree opened up 31 years prior by a tornado in Montgomery County, Ark. As a result of this natural thinning the growth averaged 8 rings to the inch for the 30 years following as compared with 16 rings per inch for the 30 years preceding the natural thinning. The increase in basal area

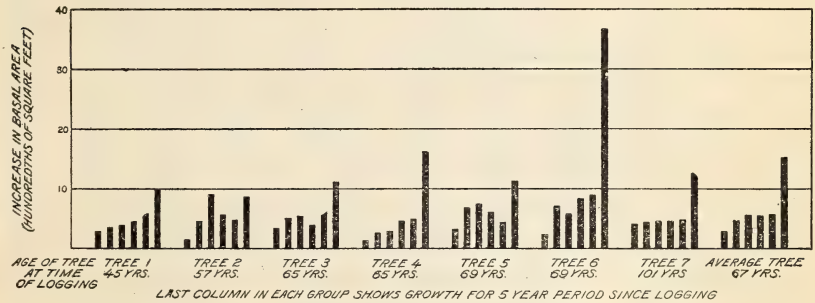


FIG. 12.—Increased rate of growth of 7 representative shortleaf pine trees on a typical cut-over tract, cut 5 years ago. Growth in basal area at breast height, for successive 5-year periods, during the past 30 years.

was 487 per cent during the latter period. The immediate recovery is shown by the increase during the first season. The tornado made a clean sweep along the center, about one-half mile in width, and a thinning of decreasing degree toward the margin of its path, which was about 14 miles in length.

The ability of a species to recover from suppression can be ascertained by a study of cut-over areas following logging operations. The stimulation in growth of shortleaf pine on a typical cut-over tract, logged to an approximate minimum stump diameter of 14 inches[1] 5 years prior to the examination, is shown graphically in figure 12, based on Table 13. The increase in basal area during the five years following logging is contrasted with the increases for the five preceding five-year periods. Practically all trees observed showed stimulated growth due to thinning and increased light supply. Trees formerly suppressed, however, grew relatively much faster after the logging. The least gain

[1] Hellbig, Ark., near the Arkansas National Forest, logged in 1907 and examined in 1912.

in basal area at breast height was 75.4 per cent, the largest 311 per cent, and the average for 7 representative trees was 171.4 per cent over their former rates of growth. The trees ranged from 45 to 101 years old at the time of the logging, but most of them were between 60 and 70 years. Since height growth was mainly complete at this age, it is perfectly safe to say that the volume increment of the trees took place at approximately the same or possibly at a somewhat greater rate, because of the greater increase in the size of the upper part of the stem at this age.

TABLE 13.—*Comparative growth of shortleaf in five-year periods before and after logging.*[1]

Tree No.	Age at time of logging.	Increase in basal area (breast height).						
		Five-year periods prior to logging.					Five-year period after logging, 1908–1912.	Rate of increase since logging over previous five-year periods.
		1883–1887	1888–1892	1893–1897	1898–1902	1903–1907		
		Sq. in.	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Sq. in.*	*Per cent.*
1	45	4.2	4.9	5.6	6.5	8.2	14.4	75.4
2	57	2.0	6.2	13.0	8.1	6.8	12.4	83.0
3	65	4.6	7.2	7.8	5.6	8.8	15.8	80.3
4	65	1.7	3.6	3.9	6.3	6.9	24.0	247.9
5	69	4.5	9.5	10.5	8.6	6.0	16.1	166.6
6	69	3.2	10.1	8.2	11.8	12.8	52.7	311.2
7	101	5.8	6.0	6.3	6.5	6.8	18.0	165.9
Average	67	3.7	6.8	7.9	7.6	8.0	21.9	171.4

[1] Typical shortleaf stand cut 5 years ago to an approximate diameter limit of 14 inches in average quality site in western Arkansas.

CAUSES OF INJURY.

FIRE.

The damage to forest growth caused by fire far exceeds the combined effect of all other injurious agencies. At the same time, this cause of injury is the most susceptible to control of man. The annual burning of the forest floor, extensively practiced in the past throughout the shortleaf region, has been done with little realization of the damage to the forest. Shortleaf which has passed the earlier stages suffers much permanent injury from fire. Abundant seeding, low resin content of the wood, and early rapid height growth, in addition to sprouting, afford shortleaf perhaps the best chance of any of the important southern pines to survive under adverse conditions caused by fire, but in spite of these favorable characteristics much loss and injury occur.

Completely stocked stands of shortleaf over 20 years in age are rarely found in tracts of considerable size, except in old fields and in other situations where fire has been practically excluded. As a rule, the stand is irregular in density, with many small openings, for which

fire is chiefly responsible. The heaviest direct injury to the stand occurs just after the ages of 8 to 12 years, because prior to this time the young forest is quickly restored by its power of coppicing. Repeated burnings, however, cause a setback which the tree is able to make up only in part. In older trees the effect of frequent fires is cumulative in weakening the tree at its base, resulting in its overthrow during high wind. Although not so complete in the case of shortleaf as in that of the more resinous longleaf, the sort of decimation of stands is continuous and rapid where fire occurs frequently. External injury and loss in vitality, due to excessive heat, open up avenues of ready attack by insects and fungi.

Ordinary surface fires usually develop sufficient heat to kill back trees up to 6 or 8 feet in height, and to injure trees from about 7 to 12 feet in height. Basal fire scars heal rapidly, and during intervals between fires thrifty pole and standard trees usually succeed in completely covering them. Such cases are quite frequently noted in examining the tops of stumps. The damage and loss due to fire is mainly in the form of defective lumber and reduced yield per acre from the stand, which may be ascertained by measuring the yields from well-stocked groups selected within a stand and comparing them with its total yield. The wide difference between the two is perhaps the most impressive measure of the beneficial effect of protection, since fire can safely be considered one of the most active causes of the poorly stocked condition of our forest stands.

INSECTS[1] AND MAMMALS.

Of all insects, the southern pine beetle (*Dendroctonus frontalis* Zimm.) is undoubtedly the most injurious to shortleaf pine. It is active throughout the warmer portions of the year, passing through the bark to the cambium, or living layer, and there eating out long, winding furrows or egg galleries, which partially girdle and weaken the tree. The eggs hatch into grubs, which feed on this tissue, completing the girdling and destroying the tree. Serious invasions of this insect occurred in 1890, 1893, and 1910. The last outbreak led to a special study by the Bureau of Entomology, whose report,[2] describing fully its life history and giving recommendations for controlling the insect pest, may be obtained upon application to the Division of Publications, Department of Agriculture, Washington, D. C. It has been demonstrated that using trees that die in the fall and early winter for fuel or other purposes during the winter serves both to control the beetle and to prevent its outbreak. This is an important point to bear in mind in handling shortleaf stands.

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[1] For further information in regard to causes of injury by insects, apply to the Office of Insect Investigations, Bureau of Entomology, U. S. Department of Agriculture.

[2] Farmers' Bulletin 476, "The Dying of Pine in the Southern States: Cause, Extent, and Remedy," U. S. Department of Agriculture. Also, Bureau of Entomology Bulletin 83, Part I, "Bark Beetles of the Genus Dendroctonus," by Dr. A. D. Hopkins, p. 56.

The Nantucket pine-tip moth (*Retinia frustrana* Scud.) attacks and deforms the rapid-growing tips of branches. The attack of this insect is locally the most perceptible injury, but the insect is not a serious menace. The presence of dead tips and pitch exudations are the characteristic external signs of the attack, usually equally present on other pines, for the insect is widely distributed and attacks without apparent discrimination practically all pines. As a rule, the insect is not abundant for more than one or possibly two years. By virtue of its high vigor and its capacity for forming new shoots, shortleaf pine recovers rapidly after an attack, suffering mainly the loss of time during the period of arrested growth.

Trees cut or thrown during the summer months soon become infested with larvæ of the southern pine sawyer, or borer, known commonly as a "flathead." [1] The larvæ of this genus, *Monohammus*,[2] hatched from eggs laid under the bark, feed on the rich sapwood, but seldom penetrate to the heartwood. They never attack living trees in the South. Rapid drying of the logs is the surest prevention; so that trees cut in the summer months should be removed from stands to dry situations exposed to sun and wind, or barked and opened up fully. Immersion in water where possible is the simplest remedy.

Mice, chipmunks, squirrels, and birds are very destructive of seed, and, to some degree, of seedlings. The abundant production of seed, however, accounts for the plentiful regeneration of shortleaf in spite of these enemies. On account of the small size of the seed, hogs destroy little or none directly, and they cover many in the process of rooting, so that the hog is to be looked upon rather as a benefit than a menace to the shortleaf forest. In mixed pine and nut-bearing forests, the presence of the hog is decidedly favorable to the regeneration of pine through the destruction of the hardwood seeds. In artificial forestation, mammals and birds are always one of the chief sources of injury, because they destroy large quantities of seed.

FUNGI.

The southern timber pines as a group are not badly infested with timber-destroying fungi until advanced in age or well past maturity. Up to 100 years of age, shortleaf pine is remarkably low in susceptibility to fungus attack; above this age, and especially after the age of about 150 years, in regions subject to frequent fires, fungi are more prolific and more easily gain a foothold in the tree.

Three species of fungi are more or less common in shortleaf pine and cause nearly all of the wood rot commonly known as "redheart." [3] Two species of fungi, *Polyporus schweinitzii* and *Polyporus sulphureus*, enter the tree through wounds on the butt or on the stool of

[1] The insect is really a roundheaded borer, and not a member of the flat-headed group.

[2] Chiefly, *Monohammus titilator* Fab. See Bureau of Entomology Bulletin 58, "Some Insects Injurious to Forests," p. 41.

[3] Long, W. H., Office of Forest Pathology, U. S. Department of Agriculture.

the tree just below the surface of the ground, causing butt rot; and one enters through branch stubs, knot holes, or other openings through the living sapwood in the upper portion of the tree, producing the true redheart. This disease is probably the most usual and is caused by *Trametes pini*. It travels downward and sometimes reaches to the base of the tree, leaving the wood firm rather than powdery, of a rich or dark reddish color, and permeated by oval or lens-shaped pockets of a light-gray color. The well-known dark-colored "punks," or fruiting bodies, are almost invariably from this species, since the other two common fungi have annual fruiting bodies.

The *Polyporus schweinitzii* leaves the wood in characteristic brown-colored cubical blocks. The fruiting bodies are hairy on top, brown inside, and weather brown. They are short-lived and are seldom seen. The sporophore or "punk" of *Polyporus sulphureus* is yellow on the outside changing to white, and its contents is white. Its work may be known by characteristic white bands of mycelium, which radiate outward from the center of the tree, filling the cracks in the rotted wood with felt-like masses of fungous tissue.

In cutting stands up to 70 years old heart rot is found infrequently. The liability to infection increases with the declining vitality of the tree. In one representative even-aged forest stand, 60 to 65, years in central Arkansas, only 2.2 per cent of the logs showed injury by fungi. In four large even-aged groups of shortleaf pine, 170 years old, the diseased logs ranged from 20 to 27 per cent of the total number of logs utilized, or 17.4 per cent of all logs, including sound logs left in the tops, which are merchantable or will be soon. A record of the infected logs in virgin timber at a large sawmill in Pike County, Ark., for March, April, and May, 1912, showed 25,689 sound logs and 4,430, or 14.7 per cent of the total logs, unsound. The log scale was slightly more than 3⅓ million board feet. The average run of infected timber for central Arkansas is further indicated in Table 14.

TABLE 14.—*Amount of "redheart" infection in average forest run shortleaf pine, mostly 60 to 180 years old.*[1]

Date.	Total cut for month.	Redheart defect.	Percentage sound.	Percentage infected with redheart.
1912.	*Board feet.*	*Board feet.*		
June	1,907,461	232,685	88	12
July	1,741,235	203,769	88	12
August	1,597,014	259,639	84	16
September	1,862,025	155,513	92	08
October	1,185,132	143,307	88	12
November	1,087,018	119,339	89	11
December	1,008,959	87,027	91	09
1913.				
January	1,147,115	128,436	89	11
February	754,610	85,723	89	11
March	1,048,638	118,692	89	11
April	994,102	100,662	90	10
May	1,178,236	110,996	91	09
Total	15,511,545	1,745,789	89	11

[1] Includes both butt rot and true redheart. Tally for a large representative mill in Clark County, Ark.

In a year's forest cut of shortleaf timber the average loss by redheart was 11 per cent of the total cut. The trees were mostly between 60 and 180 years old, some being 200 years old.

The wounds through which the spores enter the tree are caused partly by wind and sleet storms breaking the branches, but more largely by fires, which kill a portion of the sapwood, thus exposing the heartwood to infection. Thrifty young trees are to a considerable extent protected from infection by the resinous exudations which quickly form over wounds. The "punk," or fruiting bodies, of the fungus frequently occur near the place of attack, and, for butt-rotting fungi, are usually located on the lower half of the trunk. The damage can be very largely controlled by eliminating the chief cause—fire. In the more intensive management of small tracts of timber, so far as possible the diseased trees should be felled. The removal from the tree of the sporophores, or "punks," is of slight temporary benefit only, since it stimulates the formation of new fruiting bodies at other places on the tree.

Sap stain, or "bluing" of the sapwood, generally agreed among investigators to be the direct result of a fungus, is the most perceptible and the most controllable form of fungous injury. The reduction in value of stained lumber results in enormous annual loss. Since moisture and heat are favorable to the development and spread of the organism, the South suffers badly, but the presence of resin in the pines aids in checking the attack. In addition to the usual method of rapid drying of the wood, experiments have been conducted in chemically treating the wood of shortleaf pine with a view of preventing attack from sap-stained fungi.

WIND AND LIGHTNING.

Over the greater part of its range, shortleaf is only slightly susceptible to wind damage. This is due to its deep root system and its situation chiefly on the lighter, better-drained soils. Other aids to protection against wind are its short leaves, slender branches, and narrow crown. On the other hand, shortleaf is the only pine that extends well into the tornado[1] region of the Middle Western States. Here considerable damage is done every year, particularly in the Ozark uplands of Missouri, Arkansas, and Oklahoma. Strips of wind-thrown forest are present in all stages of recovery. After the decay of the thrown timber these are easily recognized by the even-aged stand, usually of pure pine, in the central area, with the two-storied and high-forest condition in increasing degree toward the margin of the cyclone strip. On account of its quick response to light and the small size and abundance of its seed, the occurrence of tornadoes has extensively aided the formation of pure, even-aged

[1] Known commonly as "cyclone."

stands of pine. Near Womble, on the Arkansas National Forest, is such a fully stocked, even-aged stand on a strip averaging approximately one-half mile in width by 14 miles in length. The tornado occurred on May 8, 1882, and a large amount of the young stand dates from the same spring, showing the coincidence of a heavy seed crop the previous fall and favorable conditions for germination.

Damage from ice storms is increased by the effect of wind upon the heavily laden trees. Ice or sleet storms cause serious injury at varying intervals of 6 to 12 years. An ice storm in December, 1898, in southwestern Arkansas uprooted and broke down so many trees that it completely blocked road traffic over all of the timbered roads for nearly one week. The damage from snow press is relatively small.

Lightning kills trees occasionally and injures very many. The secondary injury from winds and lightning is possibly even greater than the direct effect, since injurious insects and fungi find their chief avenue of attack in freshly opened wounds in the bark and cambium, or living layer, of the tree.

YIELD.

FACTORS INFLUENCING YIELD.

The growth of a stand as a whole determines its productiveness or yield. First, regions favorable to the greatest volume production in the individual tree likewise produce the largest crops or highest yields per acre of timber. The yield of well-stocked stands of 65-year-old shortleaf in central North Carolina is much greater than that of stands of similar age and density in New Jersey, and in the Arkansas-Louisiana region not less than 20 per cent greater than in North Carolina.[1] Second, the number of trees per acre affects directly the size and volume production of the individual tree and of the stand, and therefore the quality of the yield. Overstocked as well as understocked stands decline rapidly in saw-timber production as the number of trees departs in either direction from the normal or best condition of stocking. The decline in total cubic volume is not so great, especially in fully stocked stands. What the conditions are in any region can be accurately determined by measuring stands similar in all points except the degree of stocking. One nearly always finds wide differences occurring in respect to the number of trees per acre and the corresponding yields, both within adjacent stands and in portions of the same stand. Third, the yield varies with the age of the stand. The yield of a stand rises with age to a point of maximum production, after which there is a decline due to the progress of natural thinning by the loss of trees through declining vigor and

[1] This difference is undoubtedly due to regional differences in the supply of atmospheric and soil moisture, temperature, and the physical texture and composition of the soil.

attacks of natural enemies of various sorts. In good situations in Arkansas, for instance, well-stocked 160-year-old stands of shortleaf have average yields of about 45,000 board feet, or approximately the same as 58-year-old stands on similar situations. The point of highest average annual production of natural unthinned stands is probably between 90 and 100 years in Arkansas and some 10 years earlier in the central Piedmont region bordering the Atlantic coastal plain.

TABLE 15.—*Relation between tree density and yield per acre for 30-year-old shortleaf pine.*

[Yield from trees 8 inches and over in diameter. Based on 7 sample areas in Arkansas in stands of similar soil, protected against fires, and ranging from 210 to 780 trees per acre in quality I site.]

Trees per acre.		Yield (saw timber).		Average diameter.
Total.	8 inches and over in diameter.	Scribner rule.	Doyle rule.	
		Feet b. m.	*Feet b. m.*	*Inches.*
150	130	11,250	6,600	11.5
200	175	13,500	8,450	10.9
250	215	16,000	9,700	10.4
300	260	18,100	10,600	9.8
350	290	19,400	10,800	9.4
400	290	19,100	10,200	8.9
450	260	17,500	9,000	8.5
500	255	15,350	7,900	8.1
550	235	13,200	6,800	7.7
600	215	11,250	5,800	7.3
650	195	9,250	4,450	7.0
700	180	7,500	3,200	6.6
750	160	5,900	2,000	6.3
800	140	4,250	800	6.0

YIELD IN PURE STANDS.

Old growth or virgin stands in regions of good development show yields averaging 10 to 30 thousand board feet per acre over considerable areas. Most of such tracts are at the present time found only in the more inaccessible regions in the upper portions of the middle Atlantic coastal States and in the Louisiana-Arkansas district. Much larger amounts occur in mixed stands with hardwoods.

Fully stocked tracts of shortleaf pine in natural stands are scattered and rarely occur in areas of considerable size. Irregular stocking at the outset, fire, and other causes produce many open spaces where trees are needed to complete the stand. In other places the stand has from the start maintained too many trees per acre to give the best results in quality or quantity of product. The average yields of natural stands, therefore, vary widely and have little significance in considering the habits and possibilities of the tree when growing in full stands. The best basis for considering the yield of forest trees like shortleaf which occur in pure stands is the yield of fully stocked stands or portions of stands growing under known conditions of situation. Such information, when classified by age and site quality for normally stocked stands, is known as a normal yield

table. Tables 16, 17, and 18 have been thus prepared by measuring portions of well-stocked second-growth or old-field stands of known age and quality of natural environment, particularly character of soil and moisture supply. For example, the average yield of 50-year-old stands on the best class of sites in North Carolina (Table 16) is about 23,700 board feet, on medium or average sites 17,000, and on the poorest sites about 10,300 board feet. Table 18 shows yields in the Arkansas region at 50 years of 37,200, 23,750, and 12,200 board feet, respectively, on the three qualities of site. The original figures for North Carolina were secured from 80 selected sample tracts with an area of 21.6 acres, which may be considered fairly representative. The data for Table 18 are insufficient in amount, hence the table is tentative and has been included for the purpose of comparison and correction when more measurements become available.

TABLE 16.— *Yield of well-stocked second-growth shortleaf pine in North Carolina.*[1]

[Based on 80 sample plots in well-stocked stands; total area, 21.6 acres. Saw timber scaled to 6 inches in top diameter; stump height, 1 to 1.5 feet. Volume of stem is from 1-foot stump to 6-inch top diameter, including bark. All trees 6 inches and over diameter breast high were scaled.]

QUALITY I.

Age (years).	Trees per acre.	Average diameter breast high.	Average height.	Total basal area.	Yield per acre.		
					Saw timber.		Solid contents.
					Scribner rule.	Doyle rule.	
		Inches.	*Feet.*	*Sq. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*
10	2,940	2.8	22	104	400	.....	1,050
15	1,760	4.4	32	135	3,000	300	1,560
20	1,000	5.8	40	158	5,700	2,000	2,120
25	675	6.9	46	175	8,400	3,600	2,730
30	510	7.9	51	188	11,200	5,300	3,350
35	410	8.8	55	198	14,000	7,100	3,950
40	340	9.6	59	205	17,100	8,900	4,570
45	280	10.4	63	211	20,300	10,900	5,200
50	235	11.2	66	215	23,700	12,800	5,840
55	200	11.9	69	218	27,000	14,500	6,450
60	165	12.7	72	220	30,100	16,200	7,020
65	140	13.4	74	222	33,200	17,700	7,570
70	120	14.1	77	224	36,100	19,300	8,100
75	100	14.7	79	226	38,800	20,800	8,600
80	90	15.3	81	227	41,500	22,400	9,110

QUALITY II.

10	3,725	2.2	18	82	.....	.....	660
15	2,450	3.4	26	108	1,100	.....	1,000
20	1,635	4.6	33	129	3,200	300	1,380
25	1,095	5.6	38	145	5,200	1,700	1,840
30	765	6.5	43	156	7,300	3,200	2,330
35	600	7.3	47	165	9,400	4,700	2,820
40	500	8.0	50	172	11,700	6,300	3,320
45	420	8.7	54	176	14,300	7,900	3,830
50	355	9.4	57	179	17,000	9,500	4,360
55	310	10.0	59	182	19,700	11,000	4,880
60	270	10.6	62	183	22,400	12,500	5,360
65	230	11.3	64	185	25,200	13,900	5,830
70	205	11.8	66	186	27,800	15,300	6,280
75	180	12.4	69	187	30,400	16,700	6,730
80	155	13.0	71	188	32,900	18,100	7,160

[1] Counties in North Carolina are: Alexander, Burke, Cabarrus, Catawba, Cleveland, Davie, Gaston, Lincoln, McDowell, Rowan, Rutherford, Surry, Wilkes, and Yadkin.

TABLE 16.— *Yield of well-stocked second-growth shortleaf pine in North Carolina.*—Con.

QUALITY III.

Age (years).	Trees per acre.	Average diameter breast high.	Average height.	Total basal area.	Yield per acre.		
					Saw timber.		Solid contents.
					Scribner rule.	Doyle rule.	
		Inches.	*Feet.*	*Sq. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*
10	.....	1.6	14	60	.....	.....	290
15	3,270	2.5	21	82	.....	.....	450
20	2,450	3.4	26	100	700	.....	650
25	1,880	4.2	31	114	2,100	.....	830
30	1,405	5.0	35	125	3,400	1,100	1,290
35	1,045	5.7	39	133	4,800	2,300	1,670
40	795	6.4	42	138	6,500	3,600	2,070
45	655	7.0	45	142	8,300	4,900	2,470
50	550	7.6	47	144	10,300	6,200	2,880
55	475	8.2	50	145	12,400	7,500	3,300
60	420	8.7	52	146	14,700	8,800	3,700
65	370	9.2	54	147	17,100	10,100	4,100
70	330	9.7	56	148	19,600	11,400	4,490
75	295	10.2	58	149	22,000	12,600	4,860
80	270	10.6	60	149	24,200	13,900	5,230

TABLE 17.— *Yearly increment of second-growth shortleaf pine in North Carolina.*[1]

[Based on 80 sample plots in well-stocked stands; total area, 21.6 acres. Saw timber scaled to 6 inches in top diameter. Stump height, 1 to 1.5 feet. Volume of stem is from 1-foot stump to 6-inch top diameter, including bark. All trees 6 inches and over diameter breast high were scaled.]

PERIODIC ANNUAL INCREMENT.

Age (years).	Scribner rule.			Doyle rule.			Solid contents.		
	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
	Bd. ft.	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
20	500	370	.....	300	.....	.....	112	82	50
25	530	400	240	320	280	.....	117	88	59
30	560	430	275	340	295	.....	121	93	66
35	590	460	310	360	310	240	124	98	72
40	620	485	340	380	315	250	126	101	76
45	650	505	370	**400**	**320**	255	127	104	80
50	**680**	525	400	380	315	255	**128**	**106**	82
55	655	540	425	365	310	260	123	104	**84**
60	625	550	455	350	300	**260**	117	101	83
65	605	**560**	475	330	290	260	112	97	81
70	580	545	**500**	315	280	260	106	92	78
75	560	520	475	300	275	255	100	87	75
80	540	490	445	285	265	250	94	82	71

MEAN ANNUAL INCREMENT.

20	285	175	50	100	15	.....	107	69	32
25	335	205	80	140	65	.....	109	74	38
30	370	240	110	175	105	35	111	78	43
35	405	270	135	205	135	65	113	81	48
40	430	295	160	225	160	90	115	83	52
45	450	320	185	245	175	110	116	85	55
50	470	340	205	255	190	125	117	87	58
55	490	360	225	265	200	135	117	88	60
60	500	375	245	270	210	145	117	89	62
65	510	385	260	275	215	155	116	90	63
70	515	395	275	275	220	165	116	90	64
75	520	405	295	280	225	170	115	90	65
80	520	410	310	280	225	175	114	90	65

[1] Counties in North Carolina are: Alexander, Burke, Cabarrus, Catawba, Cleveland, Davie, Gaston, Lincoln, McDowell, Rowan, Rutherford, Surry, Wilkes, and Yadkin.

TABLE 18.— *Yield of second-growth shortleaf pine in Arkansas.*

[Based on 38 fully stocked sample plots; area, 5.8 acres. All trees 6 inches and over in diameter breast high were scaled. Top diameter, 5.5 inches; stump height, 1 foot; number of trees per acre, see page 17.]

QUALITY I.

Age (years).	Average height of tree.	Average diameter 6 inches and over.	Total basal area (breast high) per acre.	Yield per acre.		
				Saw timber.		Total volume.
				Scribner rule.	Doyle rule.	
	Feet.	*Inches.*	*Sq. ft.*	*Bd. ft.*	*Bd. ft.*	*Cu. ft.*
20	43	7.5	166	8,000	.....	2,500
25	50	8.6	182	12,700	4,200	3,630
30	55	9.6	195	17,500	6,600	4,900
35	60	10.6	205	22,400	9,700	6,060
40	65	11.4	213	27,500	13,400	7,010
45	69	12.2	219	32,500	17,600	7,730
50	73	13.0	225	37,400	21,800	8,320
55	76	13.6	230	42,200	25,600	8,850
60	79	14.2	234	46,850	29,000	9,320
65	81	14.8	237	51,350	32,100	9,760
70	84	15.3	240	55,750	35,000	10,160
75	86	15.8	242	.....	37,800	10,520
80	88	16.2	243	.....	40,500	10,850

QUALITY II.

20	35	6.6	125	4,350	.....	1,740
25	41	7.5	139	7,450	2,700	2,520
30	46	8.3	150	10,600	4,500	3,390
35	51	9.1	159	13,800	6,800	4,220
40	55	9.9	167	17,000	9,500	4,930
45	58	10.7	173	20,200	12,400	5,520
50	61	11.3	178	23,450	15,400	6,050
55	64	12.0	183	26,850	18,200	6,520
60	67	12.5	186	30,600	20,600	6,980
65	69	13.1	189	34,050	23,000	7,410
70	72	13.6	191	37,500	25,200	7,800
75	74	14.1	193	40,850	27,400	8,160
80	76	14.5	194	44,000	29,500	8,500

QUALITY III.

20	.....	.....	.....	.....	.....	.....
25	33	6.3	95	2,600	1,200	1,390
30	37	7.0	105	4,300	2,500	1,870
35	41	7.7	113	6,000	3,900	2,360
40	44	8.4	120	7,900	5,500	2,850
45	47	9.1	126	10,000	7,200	3,310
50	50	9.7	131	12,200	9,000	3,760
55	53	10.3	135	14,600	10,600	4,210
60	55	10.8	138	17,100	12,300	4,650
65	57	11.4	140	19,600	13,900	5,070
70	59	11.9	142	22,000	15,400	5,450
75	61	12.4	143	24,600	16,900	5,810
80	63	12.9	143	27,100	18,400	6,150

SCOTCH AND SHORTLEAF PINES.

In a number of silvical features Scotch pine (*Pinus sylvestris*) and shortleaf pine appear to be quite similar.

Both trees belong to the two-leaved group of pines [1] and form close stands made up of tall stems, free from branches for two-thirds of their length and terminating in short compact crowns. Both are vigorous and hardy growers and not subject to any markedly serious parasitic fungous disease. While both species are adapted to the drier type of soil occurring on the uplands, they differ in belonging characteristically to different zones of climate. Scotch pine does not require nearly so much heat during the summer and will endure much lower temperatures than shortleaf in winter. The seeds of both appear practically the same in size and general vigor, and both species are readily grown in the nursery. Shortleaf, however, regenerates itself by sprouting from the stump, inherently possesses a much straighter stem, has smaller-sized branches, and cleans itself more quickly in stands. Fully stocked stands of Scotch pine at any specified age contain a greater number of trees, although of smaller size than shortleaf pine indicating a somewhat greater degree of tolerance.

All measurements of yield show considerably larger returns from shortleaf than from Scotch pine. The maximum average annual growth per acre of shortleaf pine on the best quality sites in North Carolina is 117 cubic feet at the age of 55 years; that of Scotch pine in Germany, about 90 cubic feet at 55 years. These maximum yields range downward on the poorest quality sites to 65 cubic feet at 80 years for shortleaf pine and about 40 cubic feet for Scotch pine at 65 years. Weise's table for Scotch pine is based upon 351 sample tracts located in 5 German States, while the shortleaf-pine table shows the results of only 80 sample tracts located in 14 counties in North Carolina. Table 19 shows several points of likeness and unlikeness in these two pines. The shortleaf data are not so representative of the species as that for Scotch pine. The German plots were all normal stands, last thinned just prior to the measurement, while the North Carolina shortleaf plots were average well-stocked natural untreated stands in old fields, thinned somewhat by the action of fires. Under these unlike conditions the results can not be fairly comparable, but may be taken as an indication of the character and possibilities of the two pines.

In respect to height, shortleaf pine leads under all conditions of age and situation, but the difference is most marked during about the first 30 to 40 years, and on the poorer sites at all ages up to 80 years.

[1] Shortleaf varies to three leaves in the bundle on the vigorous growing parts of the crown.

TABLE 19.— *Yield of shortleaf pine in North Carolina, compared with yield of Scotch pine in Germany.*[1]

Characters compared.	Scotch pine.			Shortleaf pine.		
	Quality I.	Quality II.	Quality III.	Quality I.	Quality II.	Quality III.
Trees per acre:						
Trees 30 years old	1,543	2,536	.....	510	765	1,405
Trees 50 years old	590	758	1,200	235	355	550
Trees 80 years old	206	317	585	90	155	270
Diameter, breast high (inches):						
Trees 30 years old	4.0	2.8	.....	7.9	6.5	5.0
Trees 50 years old	7.3	5.8	4.2	11.2	9.4	7.6
Trees 80 years old	11.5	9.4	6.7	15.3	13.0	10.6
Basal area, breast high, total per acre (square feet):						
Trees 30 years old	130	104	67	188	156	125
Trees 50 years old	167	135	108	215	179	144
Trees 80 years old	184	151	132	227	188	149
Height, average (feet):						
Trees 30 years old	34	26	21	51	43	35
Trees 50 years old	68	43	34	66	57	47
Trees 80 years old	79	63	48	81	71	60
Yield, total per acre (cubic feet):[2]						
Trees 30 years old	1,690	830	400	3,350	2,350	1,300
Trees 50 years old	4,500	2,700	1,730	5,850	4,350	2,900
Trees 80 years old	6,570	4,260	2,930	9,100	7,150	5,250
Periodic annual increment (cubic feet):						
Trees 30 years old	92	98	49	121	93	66
Trees 50 years old	103	68	61	128	106	82
Trees 80 years old	53	44	24	94	82	71
Mean annual increment (cubic feet):						
Trees 30 years old	57	28	14	111	78	43
Trees 50 years old	90	54	35	117	87	58
Trees 80 years old	82	53	37	114	90	65

[1] Figures from Weise's yield tables for Scotch pine, Quality I and II averaged to make I; III taken as II; and IV and V averaged to make Quality III.

[2] Yield of Scotch pine taken for all wood down to 3 inches in diameter; of shortleaf pine taken only for trees up to 6 inches diameter breast high, and to 6 inches in tops.

The superiority of shortleaf over Scotch pine in size of trees and total yield is striking. Scotch-pine stands contain from two to three times as many trees per acre as the shortleaf stands, and the trees have correspondingly smaller average diameters. A comparison of the total yield of the two species is interesting. At the age of 30 years shortleaf shows about two or three times the yield of the Scotch pine for the better and poorer sites, respectively. At 50 years on first quality situations, the two species approach the closest in yield, yet the yield of shortleaf is just 30 per cent greater than that of Scotch pine. The shortleaf yield is again about 56 per cent greater at the age of 80 years. Similar yield tables for Scotch pine by Dr. Schwappach show usually from 15 to 20 per cent less yield than Weise's tables.

YIELD IN MIXED STANDS.

In mixed pine and hardwood stands the yield of shortleaf varies widely. In the lower mountains of northern Georgia recent timber estimates made by the Appalachian surveys show an average yield of 1,000 to 3,000 board feet per acre; but on the warmer slopes in the same region, pure virgin pine stands of mixed ages covering

several hundred acres yield from 12,000 to 20,000 board feet per acre.

Hundreds of square miles of the better shortleaf forests mixed with oak and hickory over central and western Arkansas and adjacent parts of Oklahoma and Louisiana will cut an average of about 5,000 board feet of shortleaf. The character of the forests in the more mountainous parts of Arkansas, where shortleaf is confined chiefly to the flats and warm south slopes, is seen in Table 2, showing the composition of the forest cover in the Arkansas and Ozark National Forests. In the higher hilly region of the Arkansas National Forest, cutting to an approximate diameter limit of 14 inches breast high, or about 15 inches on a 1-foot stump, the pine in the mixed type commonly yields about 2,000 board feet [1] of merchantable timber per acre, leaving about 1,000 feet for seed trees and second cut.

The average run in private cutting, down to a 12-inch stump diameter limit, is 10 logs per thousand board feet. In a representative sale on the Arkansas National Forest, cutting to a 14-inch diameter limit at breast height, the logs averaged 135 feet each, or 8 logs per thousand. The bulk of the timber cut ranged from 60 to 180 years old. The oldest good-sized groups or small stands observed over a wide district in central Arkansas were 170 to 180 years, and a large number of them were found throughout the whole region. The yields of these groups or small-sized stands ranged mostly between 25,000 and 35,000 board feet per acre, and the maximum acre measured was 62,000 board feet. In Montgomery County, Ark., a company recently cut 2,500 feet per acre (Doyle log scale), or an actual mill cut of nearly 4,000 feet of lumber per acre, from a private tract of 4,000 acres in the high hilly country within the Arkansas National Forest. The best cut of this company was 910,560 (Doyle scale) on 160 acres, or an actual mill cut of somewhat better than 1,500,000 feet, an average of approximately 9,500 feet per acre.

[1] Based upon growth and reproduction plots on the Arkansas National Forest in average cut-over tracts, 1912.

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