DE-IA-76SR00056
Final Technical Report 1958

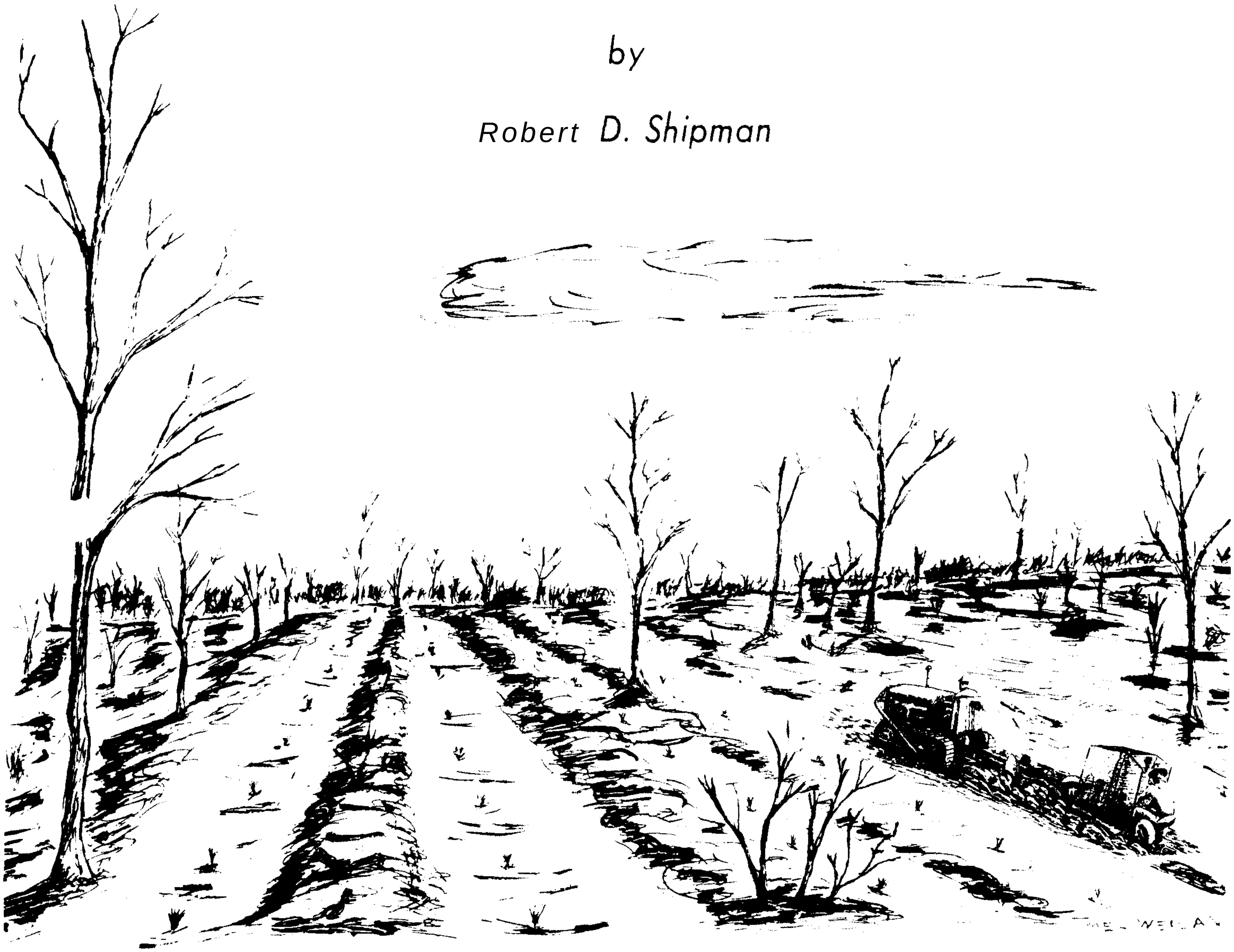
58-1-P

Station Paper No. 96 September 1958

Planting Pine in the Carolina Sandhills

by

Robert D. Shipman



U. S. DEPARTMENT OF AGRICULTURE · FOREST SERVICE

Southeastern Forest Experiment Station

Asheville. N. C.

Joseph F. Pechanec,
Director

ACKNOWLEDGMENTS

This publication represents the combined research efforts of the Southeastern Forest Experiment Station, the South Carolina State Commission of Forestry, the Savannah River Project of the Atomic Energy Commission, the School of Forestry of North Carolina State College, the North Carolina State Department of Conservation and Development, and the Westvaco Experimental Forest of the West Virginia Pulp and Paper Company.

CONTENTS

PLANTING PINE IN THE CAROLINA SANDHILLS

by

Robert D. Shipman
Southeastern Forest Experiment Station
Charleston, S. C.

INTRODUCTION

The man who is going to plant pine in the Sandhills will inevitably ask himself, "When shall I plant? What species will I choose? How do I plant them? What are the chances for survival?"

These have been some of the knotty questions asked by foresters and landowners for many years in the adverse Sandhill sites. Now, after 4 years of intensive regeneration research, we have some answers, many of them partial, but with helpful leads. Most of our research has been with longleaf pine, the species most difficult to establish on dry, Sandhill areas. Successful planting methods developed for this species will, in our opinion, apply in general to the more easily established species. The most urgent problem in the Sandhills is survival--how to bring the area into production of forest crops at reasonable cost.

The Sandhills of North and South Carolina and Georgia once supported good stands of longleaf pine with some hardwoods and loblolly pine on the stream terraces. The original pine forest vanished and no one much cared--until recently. Now it is hard to replace because decades of fire and leaching have kept soil fertility low, and a dense understory of small scrub oaks and wiregrass compete with pine seedlings. Insufficient seed trees remain to restock the area adequately by natural means.

The earliest effort at rehabilitating these seemingly worthless lands was begun in 1936 by the South Carolina State Commission of Forestry. The first plantings were-on old fields, which are the better sites, and by 1946 the Commission turned its attention to clearing scrub oak lands for planting. Slash and loblolly plantations were reasonably successful, but longleaf failed. In July 1948, a series of eight plots was established on the Sand Hills Forest by the Santee Research Center of the Southeastern Forest Experiment Station. On these plots, chemical methods of controlling scrub oak were tested. In 1949, Keith W. Dorman, of the Southeastern Station, prepared a "Problem Analysis of Forest Regeneration in the Sandhills of the Carolinas and Georgia." This analysis was an important step in defining regeneration problems in the Sandhills and largely formed the basis of the later and more intense research program. Then in 1952, with the expanded emphasis on forest regeneration, the Santee Research Center enlarged its Sandhills research efforts. In the same year, the Atomic Energy Commission, began an extensive large-scale regeneration program in South Carolina. The AEC annually plants over 9 million seedlings on abandoned fields within the Sandhill region.

This paper gives 4 years' results of studies attempting to find ways of establishing longleaf more successfully. We know quite a lot about planting slash pine in the Sandhills, since many existing slash pine plantations are now more than 20 years old. With longleaf the situation is quite different; extensive plantations did not exist, mainly because we did not know how to plant this species so that it would survive the critical early years. The studies reported here show that longleaf can be planted successfully if the site is properly prepared and only high-quality nursery stock is used. New information on other species also has been developed which will be useful in future planting programs.

BASIC FACTS ON THE SANDHILLS

Size and Location

The Sandhill region of the Carolinas and Georgia is a nearly continuous, irregular, narrow strip 10 to 40 miles in width and 420 miles long. The total acreage is nearly 8 million acres, of which more than 3 million are coarse deep sands suitable only for the production of forest crops. Of these deep sands, approximately 1,500,000 acres are in South Carolina, 820,000 acres in Georgia, and 680,000 acres in North Carolina. Following the edge of the Piedmont, the Sandhills form the upper part of the Coastal Plain, extending southwestward from Sanford, North Carolina, to Columbus, Georgia. The area is divided into five parts on the basis of underlying geologic formations (2). These subdivisions closely parallel the severity of site conditions. The Congaree Sandhills and similar areas of the Georgia Fall-line Hills are the most northern and southern areas respectively. Extremely deep sands, long gentle slopes and rounded summits, make these the most difficult areas. The Richland Red Hills and High Hills of Santee, located in central South Carolina, rank as the best sites; the Aiken Plateau area may be classified as intermediate between the most difficult and the best sites (fig. 1).

Soils and Soil Moisture

Soil and its relation to precipitation play major roles in limiting first-year seedling survival in the Sandhills. The principal soils are the Norfolk, Ruston, and Orangeburg series, which differ mainly in the color and nature of the subsoil. There are also small areas of Marlboro, Bradley, Hoffman, and other series. All are exceptionally well-drained,[1] both in the surface and subsoil. The materials for these series were deposited by the ocean during several periods of inundation. They are characterized by light-gray or grayish-yellow sand or loamy sand surface soils, and predominantly yellow, friable sandy clay or sand subsoils (17). Elevations throughout the Sandhills generally range from 100 to 600 feet above sea level. Drainage is rapid and the soils occur on broad flat ridges as interstream areas, or on land which

---

1/ Dorman, K. W. Problem Analysis of Forest Regeneration in the Sandhills of the Carolinas and Georgia. Office report, U. S. Forest Serv. Southeast. Forest Expt. Sta. 1949. Revised 1956 by R. D. Shipman.

is steeply sloping or hilly. As a result of this drainage pattern, leaching of plant nutrients is rapid, the soils are strongly acid in reaction, and organic matter is inherently low (19). These conditions have a direct bearing on soil fertility, soil texture, and the all-important soil moisture relationships (8).

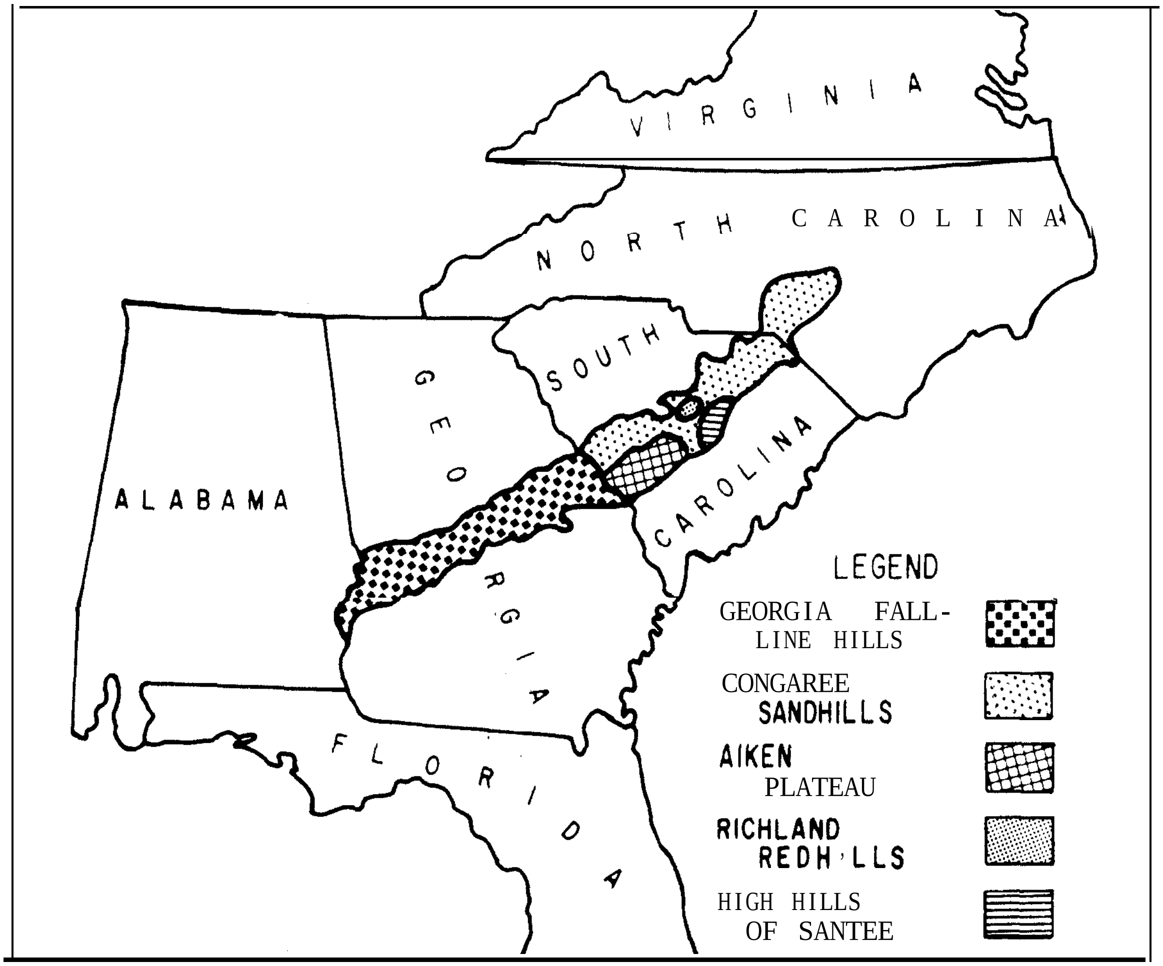


Figure 1. --Subdivisions of the Sandhills.

Drought is the principal cause of seedling mortality in the Sandhills. Despite the fact that rainfall averages over 45 inches a year, the sandy soils do not retain this moisture. For this reason, the Sandhills have been aptly called "deserts in the rain"--a land of coarse, deep sands subject to extremes in growing season temperature and moisture availability. Frequently rain does not occur for a 3- to 4-week interval during the critical growing season; moreover, within 3 days after a summer rain, drought conditions may prevail. Desert-like plants such as cactus, lichens, and wiregrass (Aristida stricta) indicate the extremely dry conditions. Exceedingly high surface soil temperatures intensify the already rapid soil-moisture evaporation. As an example of desert conditions, the leaves of turkey oak (Quercus laevis) are oriented edgewise, and the cotyledons of longleaf seedlings stand upright to avoid reflected heat.

Present Cover Condition

After the original timber was cut, uncontrolled fire and cultivation reduced the forest area to its present state--scattered longleaf with an understory of scrub oak, largely turkey oak The abundance of turkey oak is closely related to absence of fire, hut even with fire turkey oak holds on in a repressed condition through its well-known habit of sprouting. It is present over vast areas and will increase in size and dominance with protection from fire (fig. 2). Dense stands of turkey oak may exceed 3,400 or more stems per acre ranging from $\frac{1}{2}$ to 6 inches in diameter (11). On the better or more moist sites, turkey oak gives way to bluejack oak (Quercus brevifolia) and blackjack oak (Quercus marilandica). The best sites support such species as sand post oak (Quercus stellata var. margaretta), post oak (Quercus stellata), hickories (Carya spp.) and white oak (Quercus alba). The lesser vegetation on Sandhill lands consists primarily of wiregrass and broomsedge (Andropogon scoparius), which also compete with planted seedlings for soil moisture and nutrients. The Sandhills include large acreages of old fields with varying amounts of grass and weed cover. For planting purposes these are classed as the better sites.

Figure 2. --A typical scrub oak planting site in the South Carolina Sandhills.

CHOOSING THE RIGHT SPECIES

One of the first problems facing the prospective Sandhill planter is the choice of species. For the past 25 years the major planting has been restricted to three southern pines. The pines most easily established on these sites are slash pine (Pinus elliottii) and loblolly pine (Pinus taeda). Longleaf pine (Pinus palustris), despite the fact that it formed the original forest, has been difficult to re-establish until recently.

Whether the objective is production of pulpwood-size trees or saw-timber, it is important to select the species best adapted to the local soil and climatic pattern. Susceptibility to such factors as drought, fire, disease, insects, wind, and animal damage play a vital role (18). Admittedly there are schools of thought on species choice; but the writer's experience leads him to accept longleaf pine as one of the best species to plant in the Sandhills because its superiority in withstanding these adverse conditions over the long haul may be of greater significance for timber production than early-growth superiority of certain other species.

Species Adaptability and Early Growth

For information on establishment and past performance of the most commonly planted species, we must look to the earliest plantings *on* State lands, which date from the 1930's. Slash pine did not occur in the original forest, and loblolly pine was generally confined to the moist sites along stream courses and first bottoms. On level hilltops, where the sand was deep, longleaf pine was found in rather open stands with trees up to 18 inches in diameter. On lower slopes, or where roots could make contact with water-retaining clay or red sand layers, the trunks were about 3 feet in diameter (1).

Due to its characteristic delay in emerging from the grass, longleaf pine may be 2 to 3 feet shorter than other species at early ages. Such a delay can be partly offset by removal of grass and weed competition at the time of planting. A comparison of early height and diameter growth between longleaf and slash pine planted on sites of similar quality shows an early height difference in favor of slash pine (fig. 3). On the other hand, its relative freedom from infection by southern fusiform rust (Cronartium fusiforme), and its remarkable resistance to fire definitely favor longleaf. There has been some localized damage from brown spot needle disease, caused by Scirrhia acicola, and a question remains whether this infection originated from the nursery. All things considered, longleaf is one of the preferred species to plant in the Sandhills (fig, 4).

However, although it is generally assumed that deep sands are longleaf sites, most landowners plant slash pine because it survives better. In spite of the fact that most of the Sandhills area is outside of the slash pine range, plantations dating from the 1930's have grown faster than plantations of the native longleaf *on* the better sites (fig. 5).

Figure 3. --Comparison of early height and diameter growth of longleaf and slash pines after 5 growing seasons. Both species were planted in old fields of similar soil type and spacing, Savannah River Project, S. C. Above, longleaf, average height 7.7 feet, average diameter 2.75 inches. Below, slash, average height 9.7 feet, average diameter 3.10 inches.

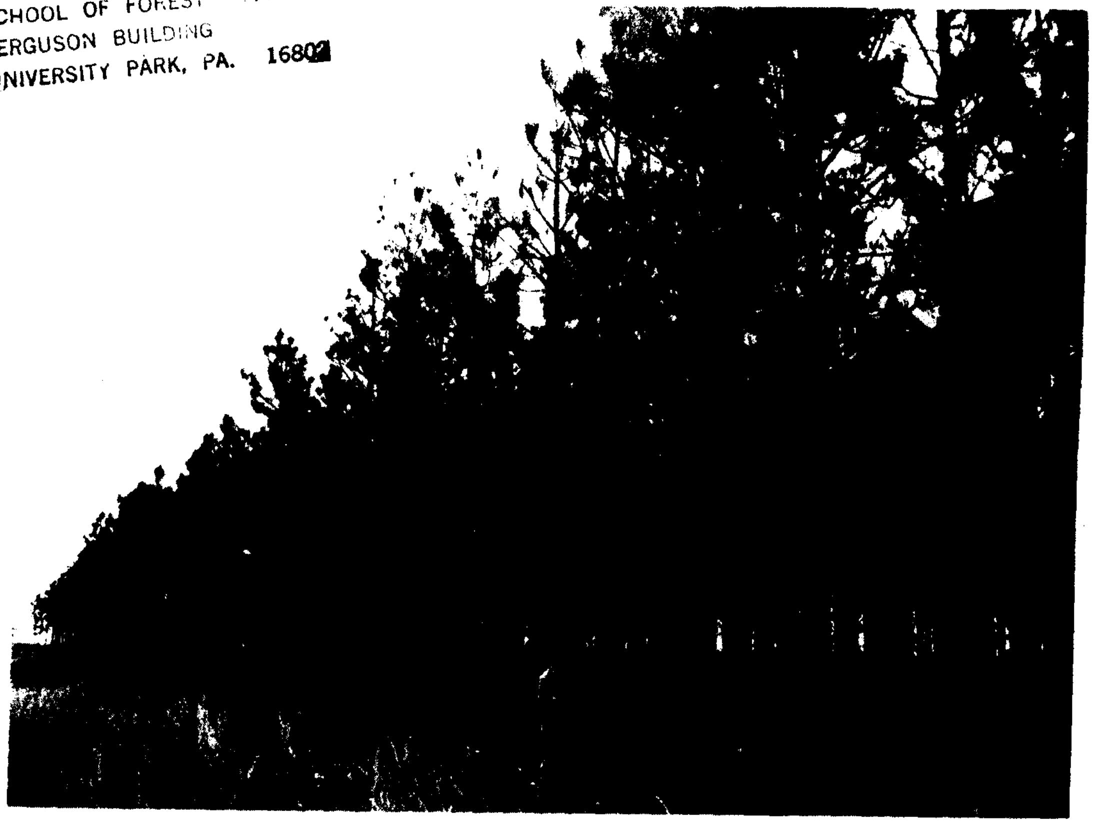


Figure 4. -- A 19-year-old longleaf pine plantation on an old-field site, Sand Hills State Forest, S. C.

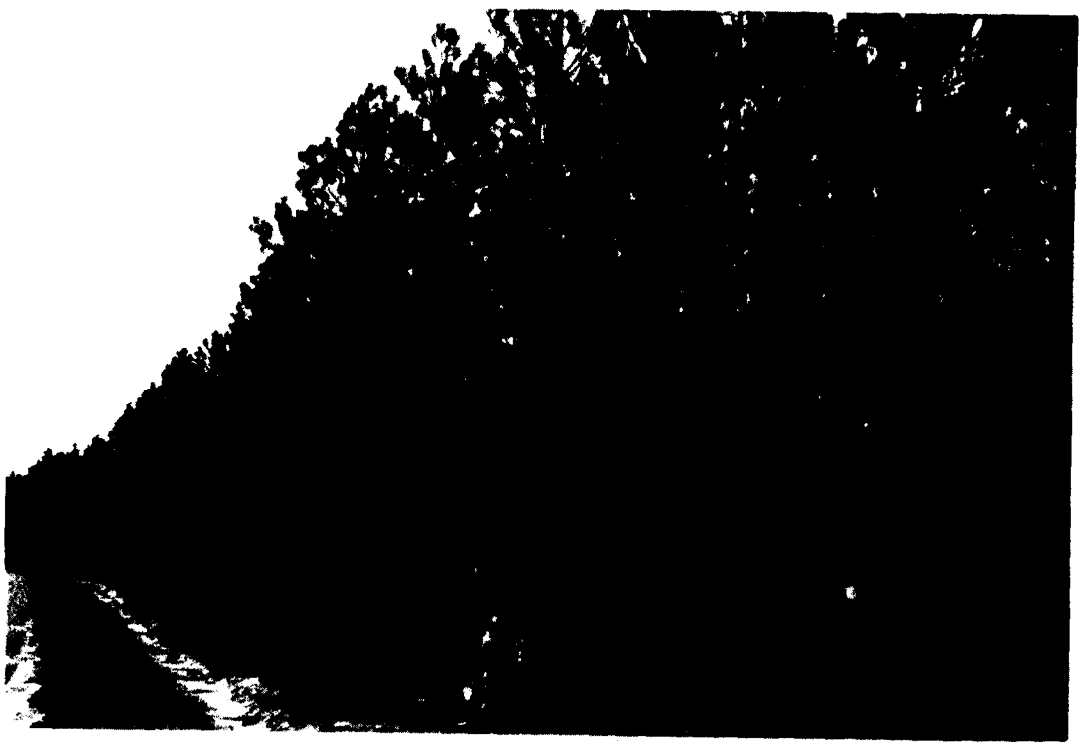


Figure 5. --Pulpwood marking on a 17-year old slash pine plantation, Sand Hills State Forest, S. C.

It should be pointed out that many of these slash pine plantations are infected with southern fusiform rust, but generally not so severely as in many localities outside the Sandhills where a great deal of slash pine has been planted. Some stands are infected by the root rot fungus (Fomes annosus), especially on the heavier soils.

Loblolly pine is particularly susceptible to attack from tip moth (Rhyacionia frustrana) in young plantations. Such infestation generally declines as the stands mature, but often results in delayed growth and poor form. There is some evidence that loblolly pine may be "off-site" on the majority of Sandhill areas. On the better old-field sites, many stands of loblolly are heavily infected with southern fusiform cankers, especially on the branches.

Since information was still insufficient to make firm recommendations regarding the best species to plant, a test was begun in 1955 to determine the early survival and adaptability of ten different coniferous species planted on cleared shrub oak areas of the Manchester State Forest, S. C. (table 1).

Table 1. --Survival of coniferous species planted on cleared Sandhill sites

Species	Seed source	1955 planting	1956 planting	Average
		- - Percent survival - -		
Redcedar (Juniperus virginiana)	N. Carolina	99	87	93
Virginia pine (Pinus virginiana)	Tennessee	96	87	91
Loblolly pine (Pinus taeda)	S. Carolina	94	87	90
Shortleaf pine (Pinus echinata)	N. Carolina	89	87	88
Slash pine (Pinus elliottii)	S. Carolina	95	77	86
Jack pine 1/ (Pinus banksiana)	Michigan	--	80	--
Longleaf pine (Pinus palustris)	S. Carolina	81	65	73
Pond pine (Pinus serotina)	N. Carolina	77	68	72
Spruce pine (Pinus glabra)	S. Carolina	71	--	--
Lodgepole pine (Pinus contorta)	Oregon	--	47	--

1/ 2-0 planting stock.

Although it is too soon to make valid comparisons of early growth, survival and vigor were satisfactory with all species except lodgepole pine. Excessive crookedness and side branching were particularly marked among the pond, Virginia, shortleaf, loblolly, spruce, jack, and lodgepole pines. Best early form was exhibited by slash pine and redcedar.

Pond pine, characteristically a wet-site species, showed a good early response to a dry site despite its poor form. The survival of lodgepole and jack pines is of special interest, since these species are considerably beyond their natural range. The high survival and vigor of redcedar points to a possibility of Christmas-tree production.

The future survival and growth of these seedlings will further test their adaptability to Sandhill soils. This initial test suggests that redcedar, slash, longleaf, shortleaf, and possibly Virginia pine, have most promise for future planting, with loblolly restricted to the better sites on stream terraces (16). More extensive use of longleaf planting stock is anticipated, in view of the recent improvements in planting methods. Other species, including hybrids, should be tested.

The soil and site relationships of the important Sandhill species will be investigated more fully in the future. A plantation yield study started in 1957 will provide needed information on the adaptability of various species to different sites (see footnote 1).

NURSERY TREATMENTS AND THEIR EFFECT UPON LONGLEAF SURVIVAL

The production of high quality and drought-hardy planting stock is of prime importance to successful plantation establishment on dry sites. Newly planted seedlings must be able to withstand the rigorous drought and sudden freezes of the area. Good planting practices begin in the nursery with the production of the best morphological and physiological grades of planting stock. Santee Research Center studies during the past 4 years have given high priority to testing the effect of various nursery treatments upon early survival of longleaf pine. 2/

Seed Source

As part of the regeneration program, a small test on the effect of geographic seed source on survival was made. Seed was collected from three different seed sources: (1) upper Coastal Plain, N. C., Bladen County; (2) upper Coastal Plain, S. C., Aiken, Chesterfield, Richland, and Sumter Counties; (3) lower Coastal Plain, S. C., Berkeley, Horry and Jasper Counties. Eight hundred longleaf pine seedlings were raised from seed of each source. After the first year, survival in Group 1 was 91 percent, Group 2 was 83 percent and Group 3 was 78 percent. Seedlings from the more northerly seed source had a higher percentage of survival, but many years must elapse before the full effect of seed source becomes apparent.

2/ Most trials were conducted in cooperation with Dr. T. E. Maki, School of Forestry, North Carolina State College. Seedlings were outplanted on lands of the South Carolina State Commission of Forestry and the Savannah River Project of the Atomic Energy Commission, South Carolina.

Season of Sowing

In the South Carolina Sandhills, slash, loblolly, and longleaf pine seed is most often sown in the nursery during late February and March. The principal reason for spring sowing is to reduce the risk of late winter freezes and losses of seed to migratory birds. These factors have caused appreciable losses in nurseries in this locality. Occasionally, longleaf and other species are sown in the fall (October and November). Larger stock results from fall sowing than from spring sowing in Sandhill nurseries (fig. 6).

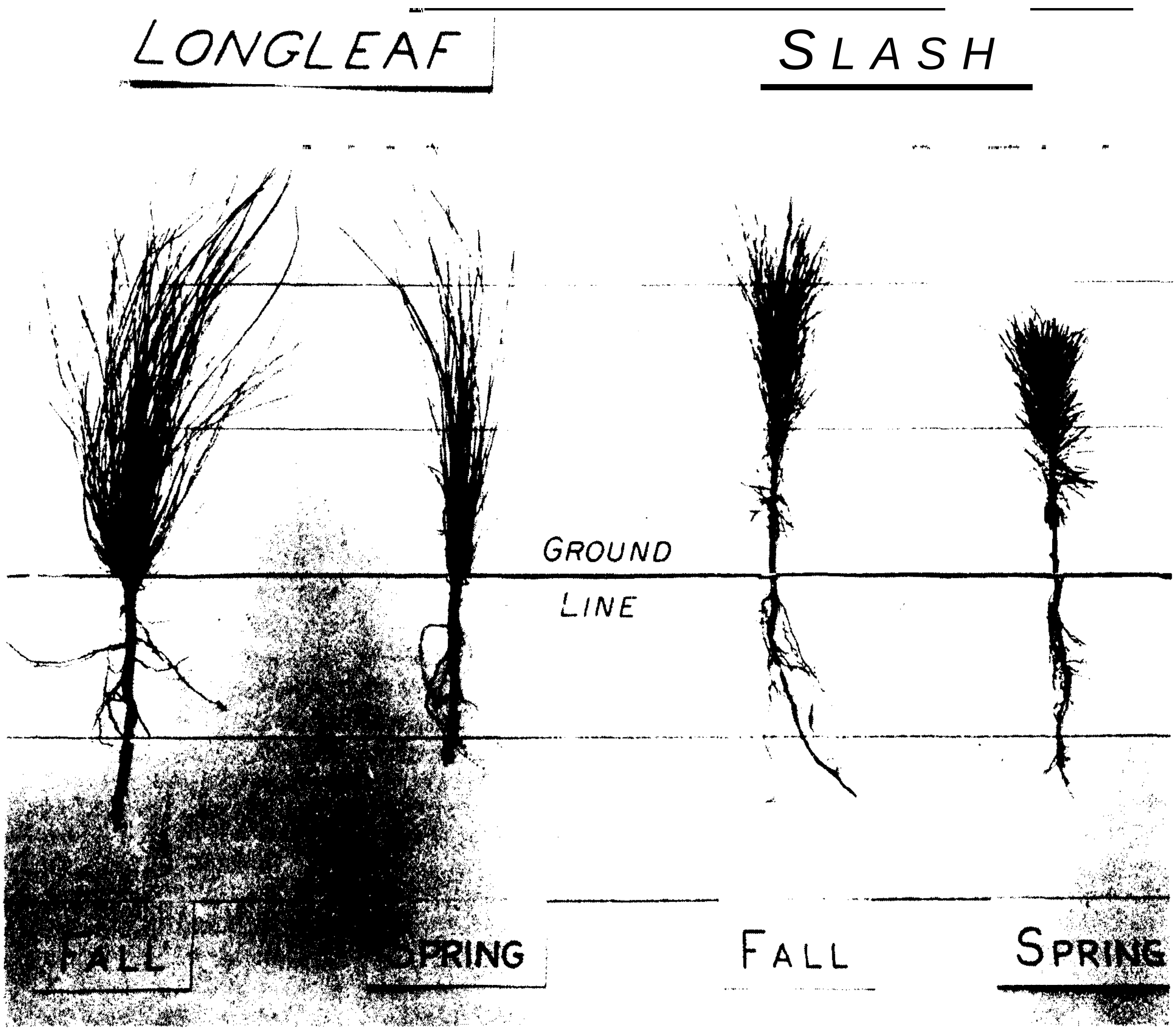


Figure 6. --Longleaf and slash pine seedling size as affected by season of sowing in the nursery. Fall-sown (October) and spring-sown (March). Horizontal lines are 4 inches apart. Horace Tilghman Nursery, S. C.

Our tests showed that under all site conditions fall-sown longleaf nursery stock survives better than spring-sown (table 2). Maximum survival, 96 percent, was obtained with fall-sown stock planted on old-field, furrowed sites. The poorest survival, 55 percent, occurred on old fields with spring-sown stock.

Table 2. --Effect of season of sowing in nursery upon first-year longleaf survival on various planting sites.

Planting site	Fall-sown (November)	Spring-sown (March)
	- Percent survival -	
Scrub oak, furrowed	84	79
Scrub oak, furrowed poisoned	71	50
Scrub oak, cleared furrowed	78	76
Scrub oak, cleared	81	77
Old field, furrowed	96	87
Old field	62	55
Mean for all sites	79	72

Seedbed Density

The objective of regulating density of seedling stands in nursery beds is to produce the maximum number of top quality, plantable seedlings at lifting time. Sowing too much seed per bed (high density) merely intensifies competition among the seedlings; sowing too little seed per bed may produce seedlings too large to plant and may not fully utilize the soil capacity. The number of seedlings to be grown per square foot should be closely related to the true basis of good nursery economics - -high field survival.

Two separate investigations to determine the relation of seedbed density to longleaf survival were established in 1952 and 1953 (6). All seedlings were grown at the Clayton Nursery, N. C., in cooperation with the Division of Forestry, N. C. State Department of Conservation and Development and the North Carolina State College, School of Forestry. The nursery beds were thinned in mid-June to 10, 20, and 40 seedlings per square foot and half were root-pruned in July. The lower bed densities and half of the high density seedlings were given periodic dosages of nitrogen, phosphorus, and potassium during the growing season.

Three planting trials of seedlings were made in: (1) old, abandoned fields with a 7-8 year "rough"; (2) deep (10-inch) furrowed scrub oak; and (3) scrub oak poisoned in advance of planting. During both investigations the summer months were some of the hottest on record and rainfall was deficient at all locations by October. Under all site conditions, seedlings grown at the lower bed densities showed significantly better survival and vigor than those grown at the highest density (table 3 and fig. 7).

Table 3. - -First-year longleaf pine survival as affected by nursery seedbed density when field planted under three different site conditions

(In percent survival)

Treatment	Number of seedlings per square foot		
	10 (low)	20 (medium)	40 (high)
Old field	19.3	23.1	12.3
Deep (10-inch furrows)	31.8	45.8	37.7
Poisoned scrub oak	36.7	37.1	20.8

Figure 7. - - Longleaf seedlings taken from nursery beds of different densities and planted on deeply furrowed scrub oak areas. Savannah River Project, S. C. Above, large and vigorous seedlings from medium density beds (20 per square foot). Below, smaller less vigorous seedlings taken from high bed densities of 40 per square foot.

Root pruning

Normally, seedlings in large nurseries are lifted by tractor-drawn lifters which undercut the seedling beds, thus pruning the roots to a length of 7 or 8 inches. This same equipment is often used to root prune during the growing season. The aim of additional root pruning during the active growing season is to create a more fibrous system, or to encourage the development of a large number of small lateral rootlets. In our tests root pruning in mid-season (July) of the first year in the nursery beds definitely improved longleaf seedling survival (6). The greatest response to pruning occurred with seedlings grown at high bed densities. Even at low densities, however, pruned seedlings survived better and were more vigorous than unpruned seedlings (table 4). These differences occurred despite the fact that all seedlings were outplanted under the best site preparation treatment (deep furrows).

Fertilization

Fertilization of southern pine seedlings in the nursery has varied effects upon the size and physiological quality of planting stock. The effects of inorganic fertilizers are

Table 4. --First-year survival of pruned and unpruned longleaf seedlings outplanted from three seedbed densities
(In percent survival)

Treatment	Number of seedlings per square foot 1/		
	10 (low)	20 (medium)	40 (high)
Pruned	98.3	96.2	88.6
Unpruned	93.7	92.7	79.1

1/ All fertilized, spring-sown stock.

closely associated with watering practice and soil characteristics. Some chemical elements are harmful; others are decidedly favorable to production of quality seedlings. As with bed densities, the object of fertilization is to produce seedlings with internal and external characteristics that will enable them to withstand the rigors of climate after planting.

Although our nursery fertilization tests have not been intensive, they serve to indicate the importance of various controlled fertilizer applications. The addition of fertilizer during the growing season at the rate of 200 pounds ammonium nitrate (35 percent N), 200 pounds potassium chloride (48-60 percent K_2O), and 600 pounds superphospate (16-47 percent P_2O_5) per acre had a highly significant favorable effect on survival of longleaf seedlings (6).

The effect of supplementa! fertilization of longleaf seedlings was most marked on seedlings grown at high bed densities of 40 per square foot. In a test which included 300 seedlings for each treatment, first-year survival of fertilized longleaf seedlings was 4.4 percent, better than that of unfertilized seedlings :

Seedlings per square foot of seedbed	First-year survival	
	Fertilized	Not fertilized
(Number)	(Percent)	(Percent)
40 (high)	23.6	19.2

Effect of Soil Texture on Seedling Roots

Two exploratory studies indicated that the successful planting of longleaf pine may be related in part to the amount and position of lateral roots of seedlings. It is apparent that the most fibrous portion of the root system should be developed at a depth where maximum soil moisture is available. On sandy areas, this is probably the bottom half of the planting hole. One of the most promising methods of developing a more fibrous root system for longleaf pine is to select areas of proper soil textures for nursery sites. This possibility of modifying the root system was explored in a cooperative investigation with the West Virginia Pulp and Paper Company 3/ in South Carolina.

3/ At the Westvaco Experimental Forest, Georgetown, S. C.

In cur initial test, longleaf pine seedlings of 1-O stock Were planted in each of several lo-inch soil profiles varying in texture from sand to sandy clay. One-year results indicate that both the number and position of lateral roots are strongly influenced by soil profiles. For example, seedlings in a sandy soil had an average of 13.6 lateral roots at a 7-inch depth, while those in a sandy clay had an average of only 3.6 lateral roots at the same depth. In soils of intermediate textures the average number of lateral roots was between those two extremes (15).

Following these early leads, a second experiment was designed to compare early survival of outplanted seedlings grown on various nursery soil profiles. Soils of four different profiles were located at a small nursery on the Westvaco Experimental Forest, South Carolina. A mechanical analysis of each soil was made, with duplicate samples taken at 3 and 10 inch depths. On each of these soils, seed from a Sandhill source was sown in drills 3 inches apart in March 1955. By means of a sharpened spade, half of each bed was root pruned to a depth of 6 inches in early August 1955, and was lifted for planting in January. Some stock from each bed was reserved, and root counts were made (fig. 8). The seedlings were outplanted in January 1956 on a deep sand at the Manchester State Forest, in South Carolina. Trees were spaced approximately 6x6 feet and hand-planted by experienced planters.

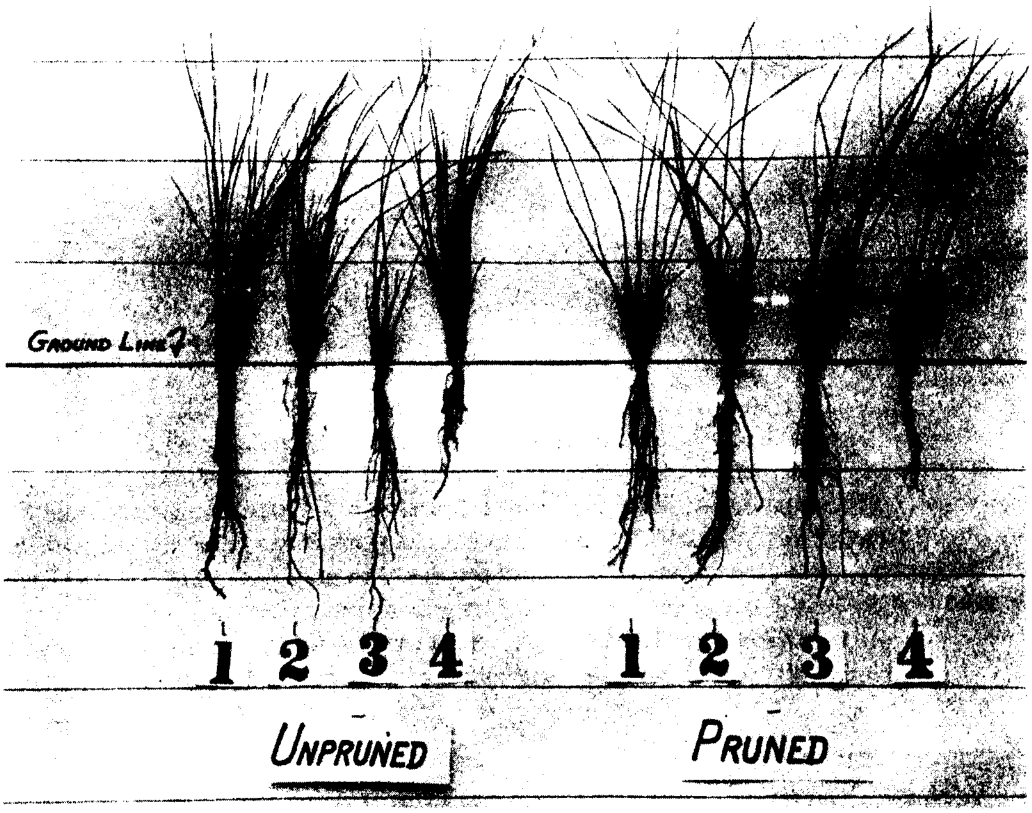


Figure 8. --Stem and root condition of the "average" longleaf seedling, roots pruned and unpruned, produced in four natural soil profiles in nursery beds of the Westvaco Experimental Forest. Distance between lines 4 inches. (1) Sandy loam over clay loam; (2) loamy sand over sandy clay loam; (3) sandy loam; (4) loam over clay loam.

Best survival was obtained on soils 1 and 3, which were predominately sandy loams with a high proportion of sand and low silt-plus-clay content (table 5). Poorest survival occurred on soils 2 and 4, which were mainly clay

Table 5. --Relationship between nursery soil characteristics and first-year longleaf pine survival

Soil profile number	Depth of measurement	Soil characteristics: Texture 1/	Soil characteristics: Sand content	Soil characteristics: Silt plus clay content	First-year survival 2/
	Inches	Class	Percent	Percent	Percent
1	3	Sandy loam	70	30	a7
	10	Clay loam	44	56	
3	3	Sandy loam	76	24	a2
	10	Sandy loam	72	28	
2	3	Loamy sand	a4	16	74
	10	Sandy clay loam	67	33	
4	3	Loam	36	64	50
	10	Clay loam	38	62	

1/ Textural classification: Soil Survey Manual, U. S. Dept. Agr. Handbook No. 18, p. 209.

2/ Basis: 75 seedlings per treatment.

loams with a low sand and high silt-plus-clay content. No significant differences in survival were found between pruned and unpruned seedlings. Soils 1 and 3 also produced the greatest amount of foliage and lateral roots (table 6). The plotted values showed that soils 1 and 3 gave an average of 3.5 lateral roots at a 7-inch depth, while soils 2 and 4 produced an average of only 1.7 lateral roots at the same depth (fig. 9). Thus, quality of longleaf planting stock for planting on Sandhill sites is strongly related to nursery soil textures.

Table 6. --Relation between seedling and seedbed soil characteristics at the end of the first year

Soil profile number	Soil texture	Seedling characteristics: Average stem diameter	Average needle length	Average taproot length	Dry weight material produced: Foliage	Dry weight material produced: Roots
	Class	Inches	Inches	Inches	Grams	Grams
1	Sandy loam to clay loam	0.34	11.4	7.2	26.3	18.6
3	Sandy loam	0.30	10.4	7.6	20.5	15.4
2	Loamy sand to sandy clay loam	0.29	10.6	6.6	19.7	12.2
4	Loam to clay loam	0.24	11.0	3.1	14.0	6.0

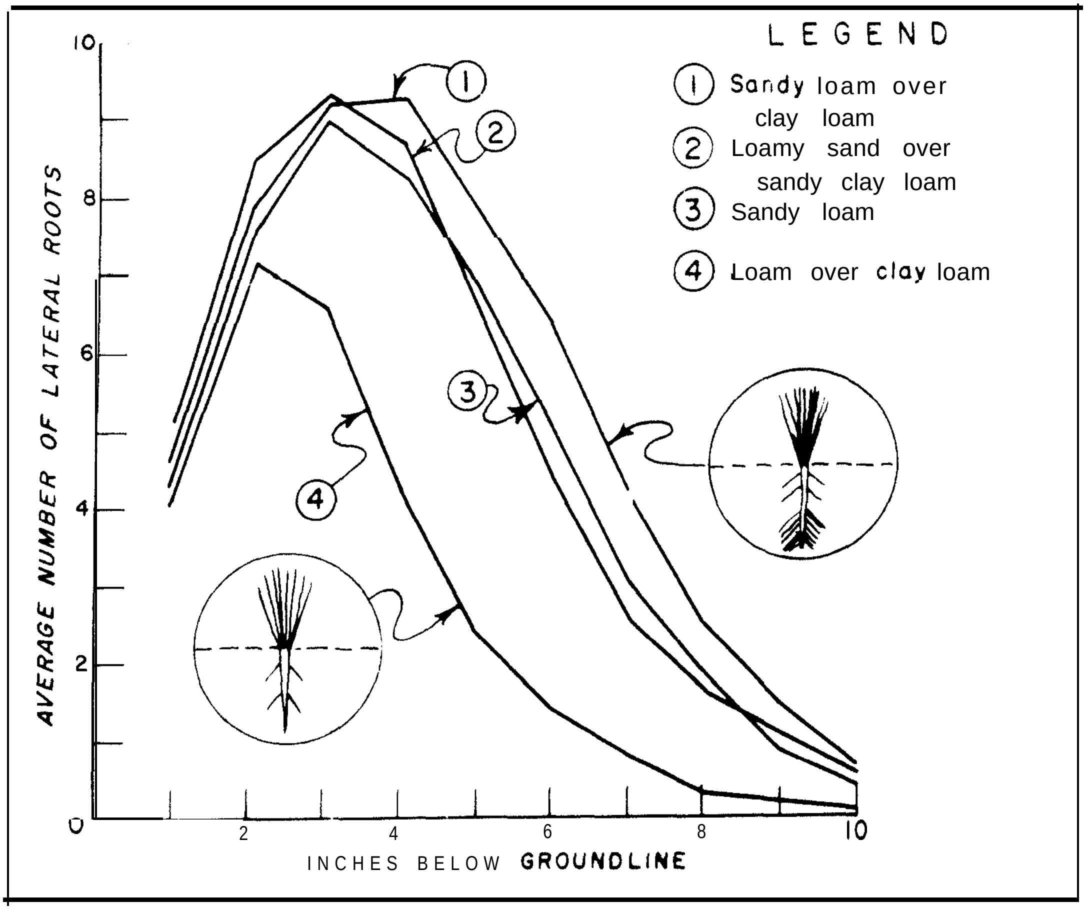


Figure 9. --Frequency of lateral roots of i-0 longleaf pine at different depths when g-own under natural soil profiles.

Seedling Grades

The grading of nursery stock is based primarily upon the capacity of seedlings to survive and grow after planting. According to Wakeley (18), grades of southern pine nursery stock can be judged mainly from their morphology or size. Recently, Wilde and Voigt (20) established analytical procedures for the determination of morphological and physiological characteristics of red pine and other coniferous seedlings. They analyzed 20 properties of stock which may also be useful in estimating quality of southern pine nursery stock. Until this procedure is tested locally, a good criterion for expected survival of nursery-run longleaf pine in the Sandhills is the general appearance, or morphological grade of seedlings.

The results obtained in one of our earliest studies, in cooperation with the Savannah River Project of the Atomic Energy Commission, indicated the practical implications of judging seedlings according to grade or size. Several of these trials have provided the Project Forester with basic information needed for "prescription planting, " now being applied to old fields of the Savarnah River Project.

Our earliest study of nursery stock grades involved the hand planting of 2,400 (1-O) longleaf seedlings from a local seed source at a 6x6-foot spacing on sandy loams and deep sands of the Savannah River Project in South Carolina.

Each plot compared seedlings of grades 1 and 2, foliage clipped and unclipped, and spring (March) versus winter (January) planting on the foregoing soil types. The longleaf seedlings were graded according to the following morphological specifications (18) at the Stuart Nursery in Louisiana, where all Savannah River Project stock is grown:

Grade	Usual height (Inches)	Thickness of stem at ground (Inches)	Needles	Winter buds
1	12 to 16	$\frac{1}{4}$ to $\frac{1}{2}$ or larger	Abundant. Aimosc all 3's and 2's	Usually present; usually with scales
2	8 to 15; 6 to 8 if stem and buds are good	At least 3/16	Moderately abundant; at least part in 3's or 2's	Usually present; usually without scales.

Grade 1 seedlings had significantly better survival than grade 2 seedlings on both soil types (table 7). Both grades of seedlings survived markedly better on sandy loam than on deep sand and survived better when planted in winter.

Table 7. --Second-year longleaf survival, as affected by seedling grade, soil type, and planting season

Seedling grade	Winter-planted		Spring-planted	
	Sandy loam 1/	Sand 2/	Sandy loam	Sand
	Percent survival			
1	76	40	66	38
2	58	18	27	10

1/ 18 inches or less to clay layer.

2/ 36 inches or more to clay layer.

Clipping the foliage to 5 inches in length improved the survival of winter-planted grade 1 seedlings but reduced survival of spring-planted seedlings (table 8).

Table 8.--Second-year longleaf survival, as affected by seedling grade, foliage clipping, and planting season

Seedling grade	Winter-planted: Foliage clipped 1/	Winter-planted: Foliage unclipped	Spring-planted: Foliage clipped	Spring-planted: Foliage unclipped
	- - - - - - - Percent survival - - - - - - -			
	68	48	42	62
2	38	38	18	20

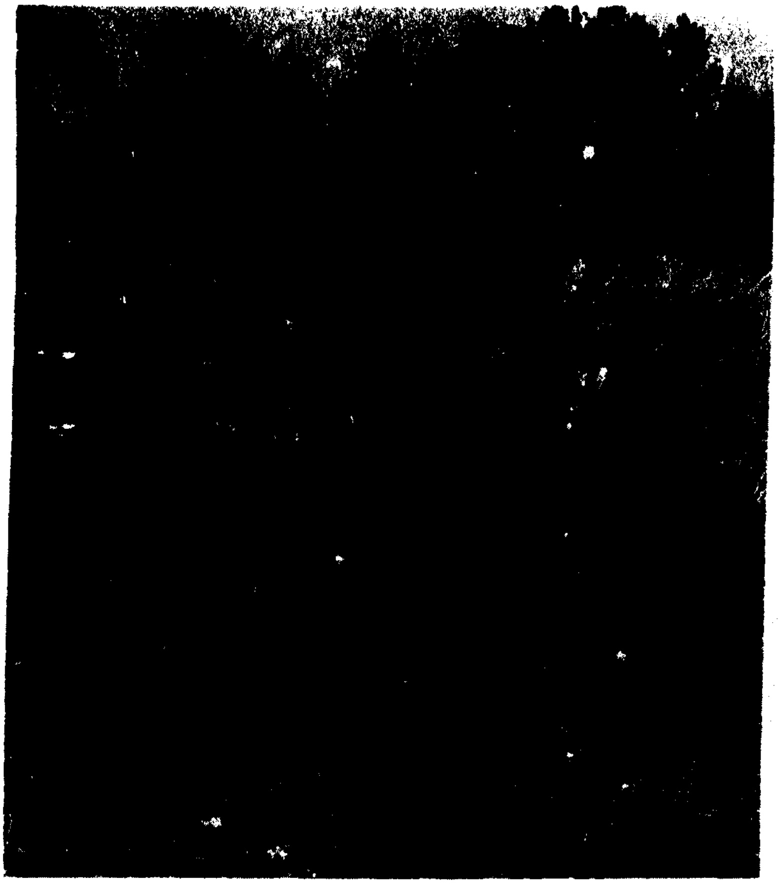
1/ To 5 inches in length.

The effect of seedling grade on the number of seedlings beginning earlv height growth was quite marked; 41 percent of the grade 1 but only 16 percent of the grade 2 seedlings were beginning active height growth at the termination of the third growing season (fig. 10).

A second test of seedling grades in relation to early survival and growth was made in cooperation with the S. C. State Commission of Forestry on State Forest lands, In this test roots were pruned to 3, 5, and 7 inches at planting time. A total of 4,600 longleaf pine seedlings (1-O) from a local seed source were outplanted in randomized blocks on cleared scrub oak areas of the Sand-hills. The effect of planting season was similar to that in the first test. Pruning the roots to 3 inches at the time of planting was obviously too drastic, especially in the spring. Seedlings with roots pruned to 5 and 7 inches survived better with only small differences between treatments (table 9). Furthermore, root pruning to 3 or 5 inches in the spring resulted in much lower survival for the larger (grade 1) seedlings.

Table 9. --Effect of longleaf seedling grade, root pruning and season of planting on first-year survival
(In percent survival)

Seedling grade	Winter-planted and root-pruned to--: 3 in	5 in.	7in.	Spring-planted and root-pruned to--: 3in.	5 in.	7in.
1	62	82	7:	34	58	64
2	59	71	71	46	67	63



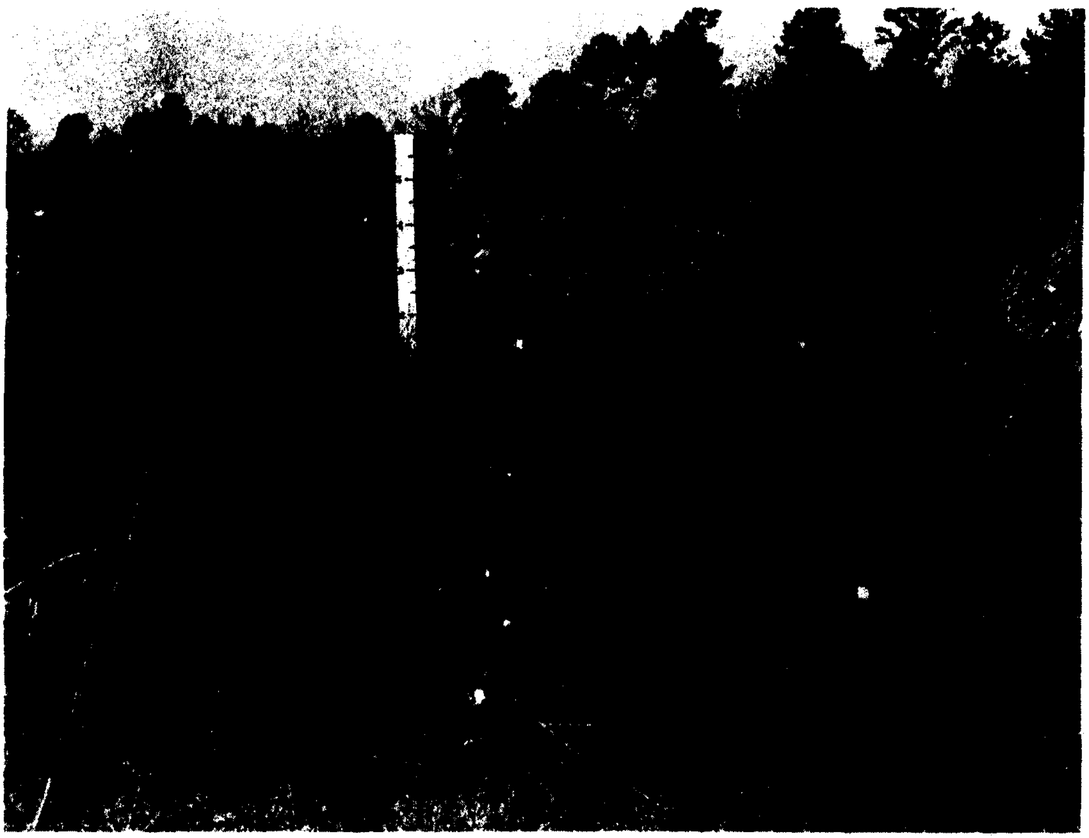


Figure 10.--Longleaf seedlings 3 years after planting on old-field sites, Savannah River Project. Above, grade 2 seedlings, spring planted. Below, grade 1 seedlings, winter-planted.

In determining that larger seedlings generally survive better than smaller seedlings a further question arose regarding the later performance of the high-grade seedling: that is would the larger seedlings continue to grow better than the smaller seedlings after the first year in the field? To partly answer this question, an investigation was begun in 18'2.

Three species of southern pine seedlings -- loblolly, slash, and longleaf -- from a similar seed source were grown at the Horace Tilghman Nursery in South Carolina. The best seedlings in the nursery beds were selected on the basis of the following ratios: the largest 1 in 3,000 of longleaf, and the largest 1 in 10,000 of slash and loblolly. These were outplanted at 6x6-foot spacing with an equal number of "bed-run" seedlings of the same seed source. The select longleaf seedlings ranged upwards from ½ inch in stem diameter; the select loblolly and slash pine seedlings were at least 3/16 inch in stem diameter and 8 and 9 inches in height (figures 11 and 12).

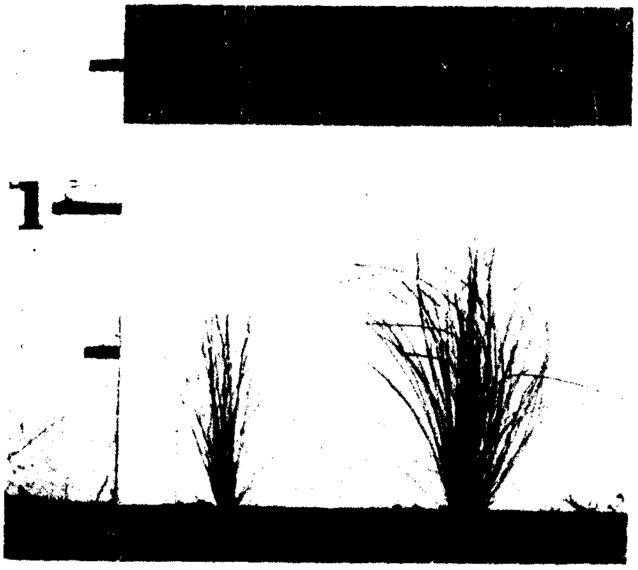


Figure 11. --At right, a **superior longleaf** seedling ½ inch in stem diameter, the best individual selected from 3,000 in beds. At left, a bed-run **longleaf** seedling ¼ inch in stem diameter.

Figure 12. --At right, a superior slash pine seedling 3/16 inch in stem diameter, 9 inches tall, the best individual selected from 10.000 in beds. At left, bed-run slash pine seedling 1/16 inch in diameter, 5 inches tall.

After 4 years in the field the height differences have changed only slightly (table 10). The height growth of both classes of slash pine seedlings continues to be much better than that of either longleaf or loblolly.

Table 10.--Average height of selected bed-run and superior seedlings after four growing seasons
(In inches)

Species	1-year-old seedlings		4-year-old seedlings	
	Bed-run	Superior	Bed-run	Superior
Longleaf	--	--	24.2	35.4
Loblolly	4.0	8.4	51.4	63.7
Slash	4.0	8.4	105.2	110.3

However, a comparison of growth and basal area indicated a better volume on select trees. Basal area of each tree was obtained approximately 2 inches above the ground- line. The results showed that the basal area of longleaf and loblolly select trees was nearly twice that of bed-run trees (table 11). A similar relationship existed for slash pine although the difference in basal area was less marked.

Table 11.--Basal area and volume of bed-run and select seedlings after four growing seasons (1952- 1956)

Species	Average basal area per tree 1/		Average volume per acre 2/	
	Bed-run	Select	Bed-run	Select
	- - Square feet - -		- - Cubic feet - -	
Longleaf	.0107	.0140	13.1	25.0
Loblolly	.0123	.0197	31.8	63.3
Slash	.0369	.0428	195.8	237.9

1/ 2 inches above groundline.

2/ 6x6-foot spacing, or 1,210 trees per acre.

Thus, in terms of volume, the larger or select nursery trees continue to express their dominance (16). It is too early to tell whether this dominance will be maintained through the life of the plantation. However, this investigation shows the desirability of producing large nursery stock, not only because such stock survives better, but also because large seedlings may reach merchantable size sooner.

Age of Stock

Virtually all planting in the Sandhills has been limited to 1-0 nursery-grown seedlings, However, erratic results obtained in past planting of conventional 1-year-old stock on typically poor sites led us to the investigation of older stock. A study was established in cooperation with the South Carolina State Commission of Forestry to grow and outplant 2-year-old stock, including transplants. Some special stock-conditioning measures were included in the test. For example, the conventional 1-0 stock in the nursery had to be lifted and then hand-planted co obtain the larger 1-1 transplant seedlings (fig. 13). Because of the extremely long roots produced by these transplants, root pruning to 6 inches at the time of outplanting was necessary. Half of each stock class was foliage-clipped to 5 inches in length.

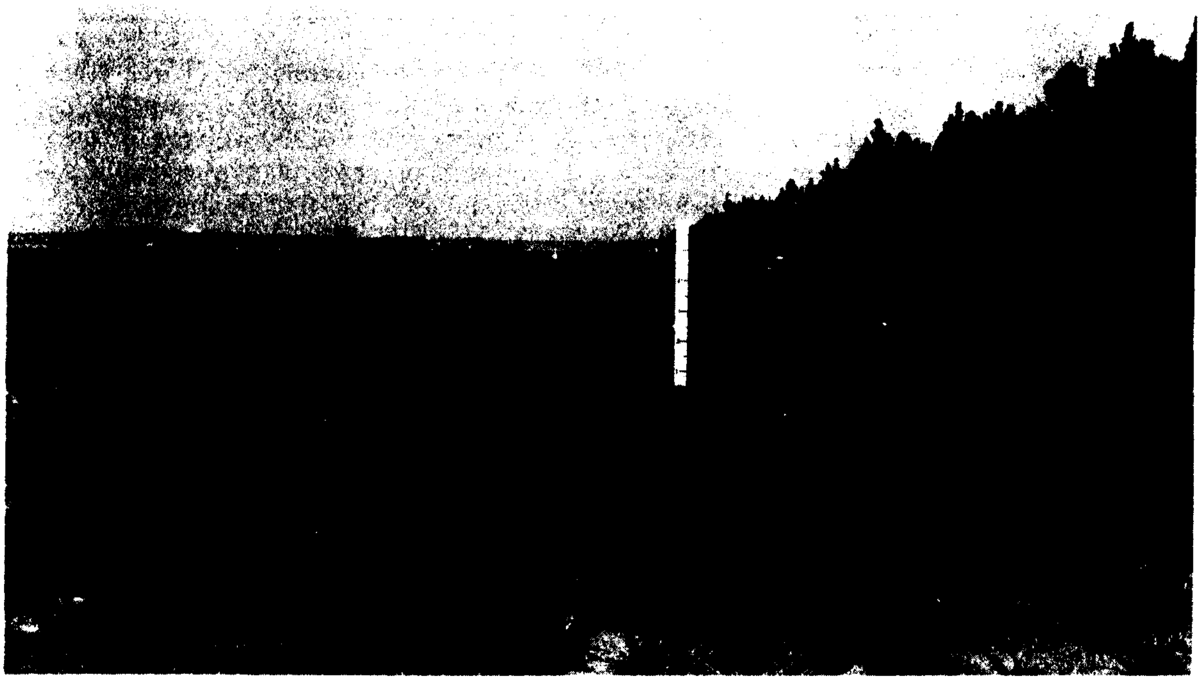


Figure 13. -- 1-1 longleaf pine transplants at time of lifting from the nursery beds. Horace Tilghman Nursery, S. C.

Table 12. --First-year survival of longleaf pine seedlings of different ages when outplanted on cleared Sand hill scrub oak sites

Age of stock	Clipped 5 inches	Unclipped
	- - Percent survival - -	
1-0	84	87
1-1 transplant	66	34
2-0	58	65

The conventional 1-0 stock showed the best first-year survival. Except for the unclipped 1-1 transplants, survival among the older seedlings was quite uniform and fairly satisfactory (table 12).

On the basis of the foregoing nursery treatments, certain general specifications for quality seedling stock can be given as an early guide to planting longleaf under Sandhill conditions. The principal factor is seedling size, or morphological grade. Although size alone does not always assure high survival, lower bed densities and fertilization treatments tend to produce larger stock. Until research can more completely define physiological qualities of seedling grades, a good interim guide for planting on harsh sites is gene. a! appearance or size of longleaf stock.

The most successful longleaf survival in our tests was obtained with 1-0, foliage-clipped, grade 1 seedlings, planted in winter, with roots pruned to no less than 5 inches in length at lifting time. Seedlings should be grown at low to medium bed densities. Proper fertilization and careful root-pruning in midsummer are desirable. When available, fall- sown nursery stock originating from a local or more northerly Sandhills seed source is recommended for planting on Sandhill sites.

By planting seedlings with the above characteristics on prepared sites, the survival of longleaf may be boosted to a point where it will compare favorably with that of slash and loblolly pines on dry sites.

PLANTING ON SCRUB OAK SITES

Plant competition for soil moisture, nutrients, and growing space is very intense on Sandhill sites. In scrub oak or in old fields, this competition should be partially or completely removed to insure satisfactory early survival and growth of planted seedlings.

The intensity of competition from roots is strikingly demonstrated by the effect of scrub oak stands on seedling heights along the borders of old-field plantations. This "sapping effect" was observed on the first three rows of a 6-year-old slash pine plantation, the competitive effect extending 30 feet or more from the scrub oak area (fig. 14).

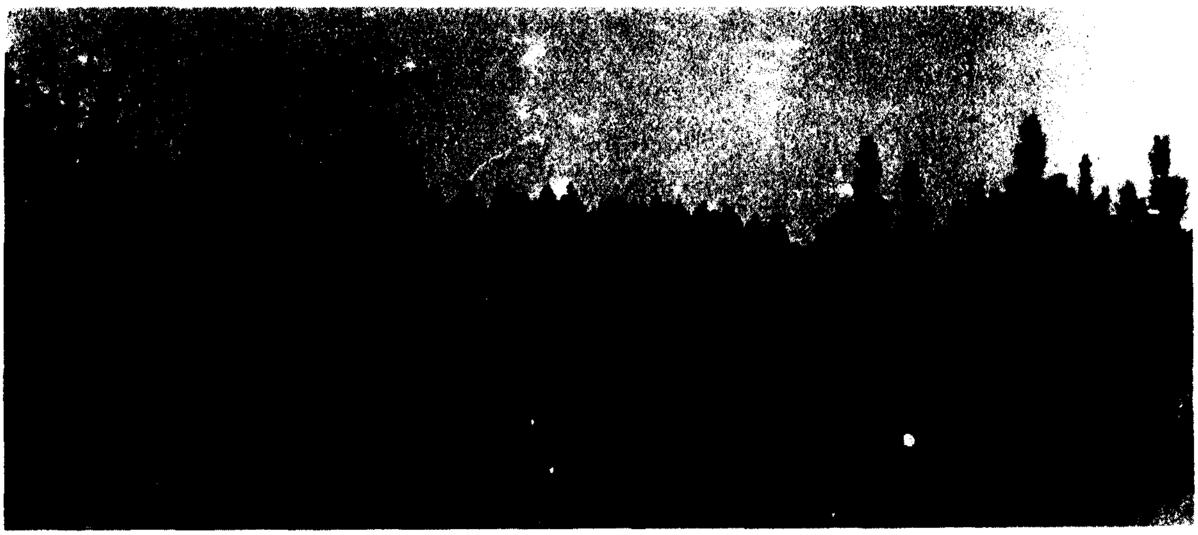


Figure 14. --Scrub oak adjoining a B-year-old slash pine plantation established in an old-field. The border competition from the scrub oak has stunted the first three rows of pine. Sand Hills State Forest, S. C.

Complete Eradication

Complete mechanical clearing of scrub oak on a large scale was begun in 1947 in the Sandhills by the South Carolina Commission of Forestry. Various kinds of equipment, including the Marden brush cutter (fig. 15) or a heavy steel cable drawn between two tractors, are employed to remove the scrub oak. These operations are followed by plowing and disking with a fire-break or gang-disk plow, to further reduce sprouting. Over 800 acres of scrub oak land were cleared on the Sand Hills State Forest in South Carolina between 1950 and 1954. A recent report shows that brush cutting and plowing on these lands has averaged $9.61 per acre, but this figure includes rather low labor and equipment costs. Commercial costs of these methods may average considerably more (7). A portion of this cost can be defrayed by renting cleared areas to watermelon growers 1 year in advance of tree planting.

Recently, the South Carolina State Commission of Forestry has tested a new method of land conversion. This consists of a crawler tractor pulling a triangular-shaped blade which uproots and severs all scrub oak stems below ground and the sprouting portion of the tree. This "undercutter" leaves the residue of stems, twigs, and debris in place. The land is left semirough in a series of broad, V-shaped furrows approximately 8 feet apart (fig. 16). Although the residue may aid in conserving moisture during the first critical year, partly buried debris may make machine planting difficult. Undercutting by this method should be done several months in advance of planting, to allow the scrub oak to decay. Very little first year resprouting has been reported. Site preparation by this method appears promising but may require further testing. In South Carolina over 2,800 acres have been completed on a commercial basis. Contract clearing costs, exclusive of planting, have been reported as low as $11.00 per acre.

Fire as a tool for mass scrub oak eradication has been largely unsuccessful in the Sandhills. The principal reason is the lack of adequate fuel on the ground to carry an effective fire. Also, this method of eradication reaches only the above-ground portions of the stem and has proven to be ineffective in reducing sprouting. In fact, areas have been observed where fire actually increased the number of sprouts from existing root stocks. Recently, fire has been used to dispose of brush windrowed by bulldozing operations. In such instances, fire is a supplemental tool for complete eradication.

Mass eradication by use of chemicals has not been tried extensively. Recent reports from other regions indicate that aerial spraying from helicopters is feasible under certain conditions. At present, chemicals can be used most effectively to release established seedlings on a stem-wise basis.

Soil Stabilization Improves Longleaf Survival

Much of the early planting of longleaf pine on cleared scrub oak areas was generally unsuccessful. On the Sand Hills State Forest, survival seldom exceeded 20 to 30 percent, even when conventional methods of land clearing were used. One factor which may have caused a big difference in the early survival of longleaf plantations was the unstable soil conditions resulting

Figure 15. --Site preparation by complete clearing of scrub oak. Above, as a first step trees are uprooted and chopped with a Marden brush cutter. Below, further preparation is often done with a heavy disk harrow, which leaves the site in the illustrated condition.

Figure 16. --Another land-clearing operation on scrub oak land. Bulldozer blade knocks down larger trees, and a triangular-shaped blade at rear uproots residual scrub oaks and severs roots below ground. Manchester State Forest.

from the clearing and disking operations. Air pockets and soil washing seriously reduced survival unless treated areas were allowed to stabilize for about a year before being planted. In brief, we needed to know what supplemental treatments were required to insure soil stability within a short period of time. Our tests showed that dragging the cleared sites as an additional site preparation measure to speed soil stabilization boosted initial survival by 20 percent over similar undragged areas (table 13 and fig. 17). Comparable survival benefits were obtained by plowing single furrows with a Mathis- type plow in the previously cleared and disked areas, although in this case the primary function of the single furrows may have been improved soil moisture rather than soil stabilization.

After the soils have been cleared and plowed; they should be dragged and allowed to stabilize for a minimum period of 6 months, preferably during fall and winter (table 13). The stabilization period results in better soil compaction and makes it easier to place the seedling in the planting hole. When areas are not dragged or not allowed to settle properly, air pockets and soil washing are detrimental to newly planted longleaf seedlings.

Table 13. --The effect of soil stabilization and site preparation on first-year longleaf survival

Scrub oak treatment	Soil stabilization period	Average first-year survival
	Months	Percent
Complete eradication followed by:		
Disking and dragging	6	82
Single, deep (10-inch) furrows	6	80
Disking (not dragged)	6	63

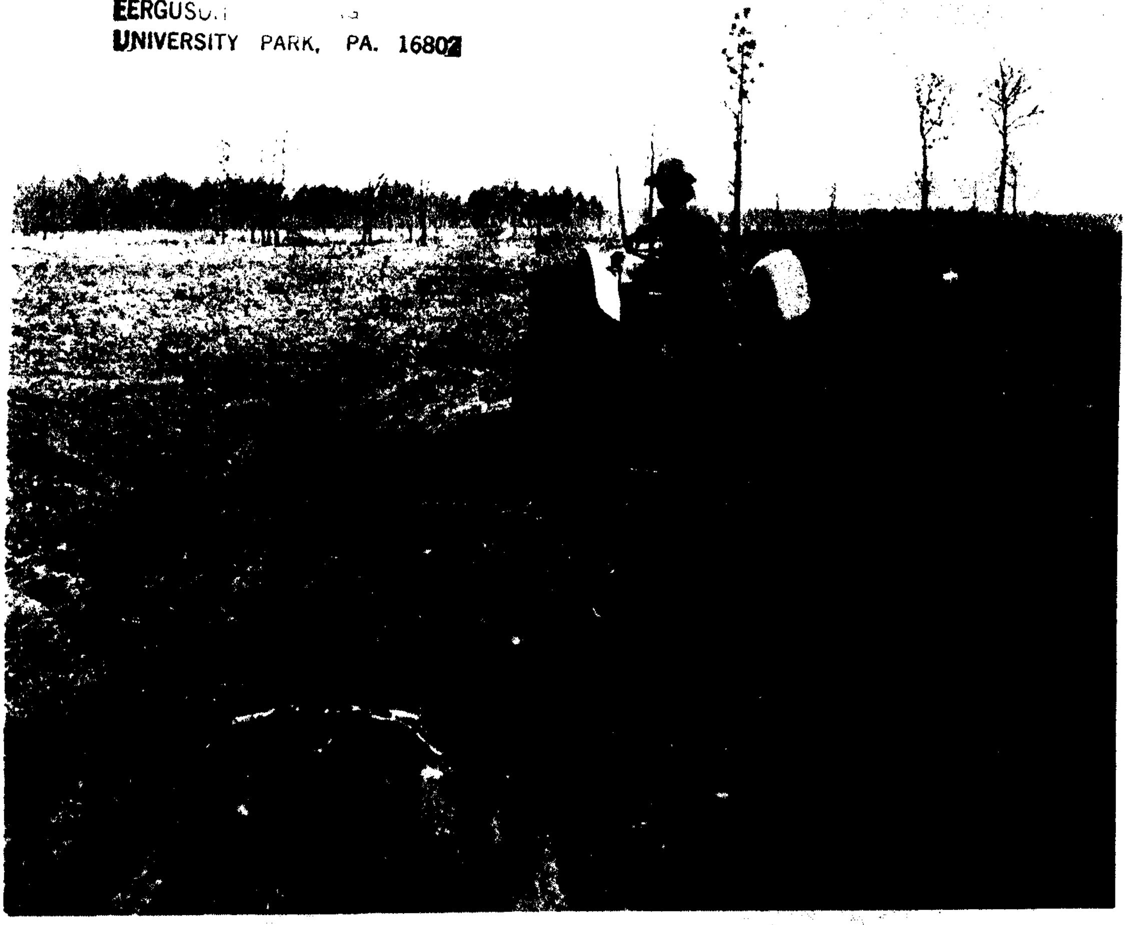


Figure 17. --After clearing and disking, soil stabilization on the former scrub oak site can be hastened by a dragging operation (above), or by furrowing (below).

Partial Eradication- -Furrowing

The high cost of complete scrub oak eradication led to an investigation of furrowing, or partial eradication as a possible low-cost substitute (11, 12). Information obtained from these studies pointed to the fact that deep furrows apparently set up a micro-environment well suited to the establishment of longleaf pine. Furrows offer some protection to the seedlings from drying winds, extremes in temperature, and soil evaporation during the initial critical growing season. This moderating influence probably reduces the transpiration rate of the planted seedlings.

Furrows should be 6 to 8 feet apart, 8 to 10 inches deep, and about 18 inches wide. Such furrows can be plowed by a Sieco double-disk plow drawn by an ordinary crawler tractor. This technique will remove over 80 percent of the scrub oak stems, leaving the remaining stems standing between furrows (fig. 18).

Figure 18. --Partial scrub oak eradication by deep (lo-inch) furrows followed by hand planting. Manchester State Forest, S. C.

Longleaf survival following various methods of scrub oak control, including a 90-day stabilization period before planting was:

Treatment	First-year survival (Percent)
Furrowed (8- 10 inch depth)	81
Complete eradication (plowed, aisked, and dragged)	63
Furrowed (5-inch depth)	61
No eradication (control)	52

As shown in the tabulation, deep furrows in scrub oak followed by hand planting significantly improved longleaf survival. Survival was poorer in the completely eradicated area because 90 days is too short a stabilization period. However, surviving seedlings had high vigor because of more available soil moisture (fig. 19).

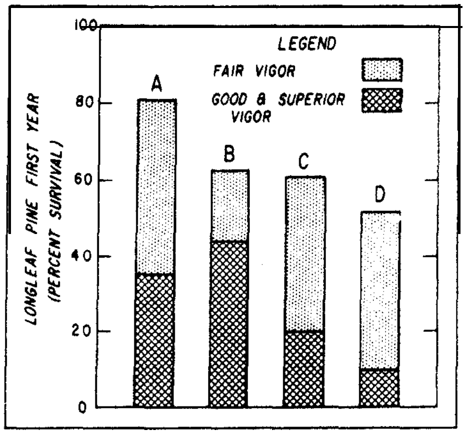


Figure 19. --Good and superior vigor seedlings expressed as a percent of total survival. A, furrowed 10 inches deep, removing 80 percent of ster. . B, complete removal (plowed, disked, and dragged). C, furrowed 5 inches deep, removing 80 percent of stems. D, control, no removal.

Although our early tests with longleaf pine involved a 2-step planting method (site preparation followed by hand planting), private industry has successfully employed a l-step method for slash and loblolly pines in scrub oak areas. The West Virginia Pulp and Paper Company has recently applied this technique to small acreages of Sandhill lands by using a heavy HD-9 crawler tractor and a Mathis plow in tandem with a planting machine (fig. 20). Other public agencies, such as the North Carolina Division of Forestry, employ a 2-step process: furrowing followed by either machine or hand planting. Much of this work consists of constructing shallow furrows 2 - 3 inches deep with a Mathis plow pulled through scrub oak areas by a TD- 9 tractor (fig. 2 1).

Seediing Release After Planting

Even though first-year survival is good, survival and growth in the future may be prevented or limited by sprout competition, especially with the slower-starting longleaf pine. To obtain the maximum growth from established seedlings, some type of release or weeding during the early life of the plantation may be necessary. Under such conditions, questions arise as to when release is most effective, how much is needed, and what are the most efficient and economical techniques.

Photo by West Virginia Pulp and Paper Co.

Figure 20. --One-step method of partial scrub oak eradication and planting. Slash pine planted in deep furrows by HD-9 tractor and a modified Mathis plow in tandem with a tree planting machine.

Figure 2 1. --Scrub oak area furrowed with a Mathis fire plow and crawler tractor. Slash pine planted in the furrows are 2 years old. Release from resprouted scrub oak competition will be needed before pines reach maturity. Bladen Lakes State Forest, N. C.

The need for pine release from sprouting scrub oak exists in two general conditions on Sandhill sites. The first of these occurs where scrub oak has resprouted following mechanical clearing. A second condition exists after furrow planting, where a portion of the scrub oak remains between furrows.

To develop positive control measures for the described situations, a test of chemical control techniques was started in cooperation with the South Carolina State Commission of Forestry. Four methods were applied to a new group of 40 turkey oaks each month for 12 successive months. Stems ranged from $\frac{1}{2}$ to 4 inches in diameter. The methods were: Cornell tool with Ammate (8 pounds to 1 gallon of water); notches with Ammate crystals (1 to $1\frac{1}{2}$ oz. per notch); stump spray; and basal spray. The spray mixture used in the latter two treatments consisted of I gallon of 2, 4, 5-T (4 pounds acid equivalent per gallon) to 20 gallons of oil.

Basal and stump spray results were generally good, with the winter treatments least effective (table 14). A poor kill was obtained in the fall with Ammate applied in notches, but results were extremely good at all other times. A poor kill was obtained with the Ammate-Cornell tool treatment regardless of season of application.

It was not possible to obtain cost data in this study. However, earlier investigations on the Santee Experimental Forest showed that basal spraying with 2, 4, 5-T was almost as cheap as cutting the competing stems with a machete without chemical treatment. In contrast, where the competing stems were cut and the residual stumps sprayed with 2, 4, 5-T, the cost almost doubled (9, 10). Thus, under Sandhill conditions, where extensive acreages of small-diameter stems are prevalent after clearing or furrowing, the basal spray with 2, 4, 5-T appears to be the cheapest, most effective treatment.

Where partial scrub oak eradication or furrowing is employed for improving early survival, the deterring effect of the residual scrub oak on subsequent seedling growth may be substantial. Under a less intensive scrub oak treatment, such as single deep furrows, resprouting and reinvasion of scrub oak roots into the furrows is quite likely. Consequently, the question of the need for releasing longleaf pine from the remaining scrub oak stems left between furrows may be important. When, if at all, should residual scrub oak be controlled”

Table 14. --Dead small-diameter scrub oak stems 2 years after treatment [1]
(In percent)

Season [2] treated	Ammate, Cornell tool	Ammate, notches	Stump spray, 2, 4, 5-T	Basal spray, 2,4,5-T
Spring (March, April, May)	10	87	83	80
Summer (June, July, August)	13	83	70	90
Fall (Sept., Oct. , Nov.)	3	37	87	83
Winter (Dec., Jan., Feb.)	3	80	53	47

1/ Dead is defined as those trees with both stem and roots dead two growing seasons after treatment.

2/ Each season is the mean of 3 months' treatment.

A scrub oak area on the Savannah River Project was used to test the effect of release after two growing seasons. In 1954, (1-O) longleaf seedlings were hand-planted in deep (10-inch) furrows. The furrows were made with a Sieco fire plow. As a result of the site preparation, approximately 85 percent of the small-diameter stems ($\frac{1}{2}$ to 6 inches d.b.h.) were removed. Twenty rows of 25 seedlings each were planted to longleaf pine at a 6x6-foot spacing. First-year survival was excellent, averaging over 86 percent.

In 1956, two growing seasons after planting, one-half of the seedlings were released by poisoning all residual scrub oak with Ammate; the remaining half were left untreated (fig. 22). A vigor tally was made of all seedlings immediately before the release treatment and again 1 year later.

A significant improvement in vigor occurred on released plots. The results showed that compared to untreated areas the release treatment more than doubled the percent of trees beginning active growth. In all instances the effect of release was to move each vigor class toward earlier height growth. No direct comparisons are available at this time of the effect of an earlier release, either at the time of planting or after a single growing season. However, the test indicated that release delayed as long as the end of the second growing season after planting is still highly beneficial.

Early growth of slash pine is generally more rapid than that of longleaf, often averaging 2 to 3 feet in height annually. Under such conditions, a single release treatment, properly timed, appears to be adequate. A second release is generally unnecessary, because 4-year-old slash pine can successfully compete with the remaining scrub oak sprouts (fig. 23). Once crown closure has occurred in young plantations, scrub oak is no longer a problem.

Figure 22.--Above, scrub oak poisoned to release longleaf seedlings. The poisoning was done 2 years after the seedlings were planted. Picture taken 1 year after release; 35 percent of seedlings beginning active height growth. Below, no release. Only 15 percent of seedlings emerging from grass stage.

Figure 23. --Four-year-old slash pine seedlings free to grow after a single release from scrub oak competition.

PLANTING ON OLD-FIELD SITES

The single largest planting program in the Sandhills at the present time is the Savannah River Project of the Atomic Energy Commission. Since 1952, this agency has annually planted an average of 9,000,000 seedlings on old abandoned fields. The total planted to date is approximately 45,000,000 seedlings, and the program is designed to continue planting at this rate for the next 3 years. In addition to the old-field plantings, nearly 30,000 acres of scrub oak land are in need of artificial regeneration.

Removing Competition by Furrowing

Grasses and weeds on old-field Sandhill sites offer considerable competition to planted seedlings, and in most instances appear to be as detrimental as scrub oak roots to early survival. Grass and weed competition on old fields varies according to the period of abandonment or successional stage. In the South Carolina Sandhills many fields are predominantly in wiregrass and broomsedge. Such vegetation competes severely with newly planted seedlings, the mat of surface roots robbing pines of soil moisture during the critical growing season (fig. 24).

Figure 24. --Typical old-field planting site on the Savannah River Project, showing ground cover of 7 to 8 year "rough" of weeds and grasses.

One test was in an old field with a 7 year "rough" of annual weeds and grasses. Four a-acre plots were prepared with a tractor-drawn Sieco plow which made a single furrow about 8 inches deep and 24 inches wide. Four plots were left unfurrowed as checks. In each treatment 1,200 (1-O) longleaf seedlings were planted at a spacing of 4x6 feet. First-year survival on the furrowed plots was 92 percent, in contrast to adjacent untreated areas, where survival was only 59 percent. Vigor on furrowed plots was outstanding, indicative of the better soil moisture conditions in the vicinity of the planted seedlings (13). This test gave good evidence that root competition in old fields should be removed before or at the time of planting longleaf in the Sandhills.

Why Furrow Planting Improves Survival

The effects of furrowing on survival and moisture content of the soil were investigated in a recent cooperative study with the Savannah River Project. Soil moisture determinations were made at approximately 10-day intervals on furrowed and unfurrowed planted areas. Soil samples were taken at 3- and 9-inch depths during the 1956 growing season. On furrowed areas, samples were obtained from the base of the furrow. Soil moisture determinations were made by oven-drying, and a laboratory analysis established the wilting point for the soil.

Results showed that available moisture on furrowed areas remained above that of untreated plots throughout the course of the growing season. In the untreated area, soil moisture was definitely below the wilting point for an extended period (fig. 25). At the 9-inch depth the most critical period was in June, when only 1.1 inches of rainfall was recorded. During the same interval, soil moisture was at or just above the wilting point in the furrows, indicating that some moisture was available at the 9-inch depth during the driest part of the growing season. This all indicates that better moisture conditions exist in furrows and at depths available to roots of planted seedlings.

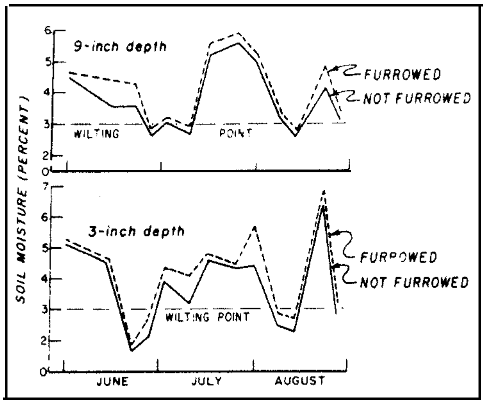


Figure 25. --The soil moisture record on old-field sites during the critical growing season months of 1955 at the Savannah River Project.

"Prescription. Planting"

Our early investigations indicated that the relation of seedling grade to expected survival could have great economic significance in planting. Thus, on dry sites, the choice of spacing in pine plantations would depend upon survival and on the number of trees per acre desired at the time of the first thinning. The number of trees planted should be sufficient to allow for expected mortality.

The effect of seedling grade on survival in our study plots influenced the Project Forester of the Savannah River Project to make survival counts by species, morphological grade, and soil type, beginning with 1953-54 plantations (table 15 and fig. 26). Analyses of these and later first-year survival

Table 15. --First-year longleaf and slash pine survival, as affected by seedling grade and soil type on old fields of the AEC, Savannah River Project

Morphological grade 1/	Soil type	Species and planting season			
		Longleaf pine		Slash pine	
		1953-54 2/	1954-55 3/	1953-54	1954-55
		Percent survival			
1	Sandy loam	24	60	60	100
1	Sand	23	59	50	a9
2	Sandy loam	18	51	49	a9
2	Sand	23	4i	48	75
3	Sandy loam	10	33	43	67
3	Sand	a	11	23	50

1/ Morphological grade specifications according to Wakeley (18).
2/ Driest year of record.
3/ Good rainfall distribution.

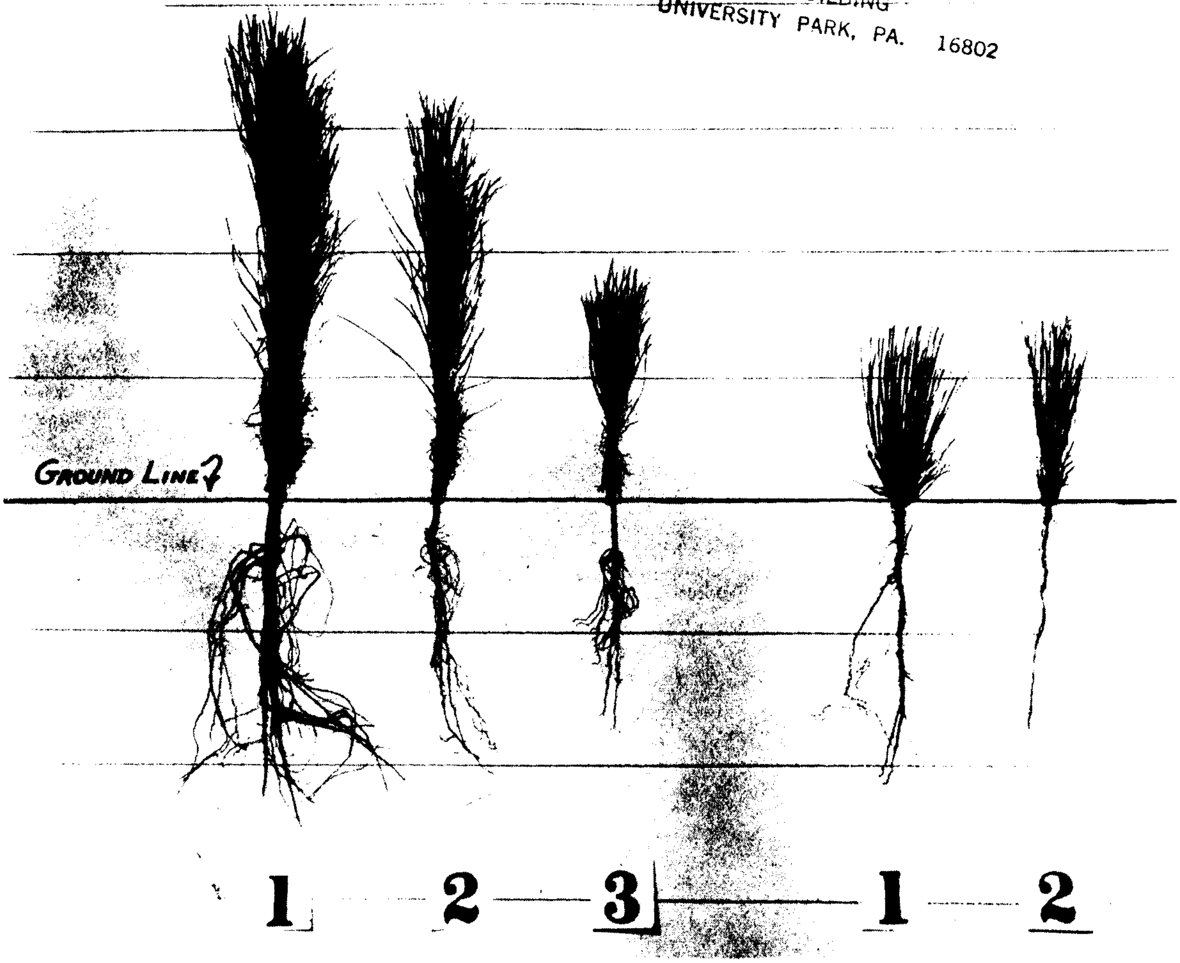


Figure 26. --Comparison of seedling morphological grades. Left, slash pine, grades 1, 2, and 3. Right, longleaf pine, grades 1 and 2.

counts led to the development of a prescription" for planting on old-field sites by Project Forester Hatcher (4, 5), whereby number of seedlings planted per acre is predetermined for each fiela according to expected survival by grades and prevailing soil type. Thus, enough trees of selected grades are planted per acre to insure a successful, manageable plantation. The current prescription for conditions on old fields of the Savannah River Project in South Carolina is given in table 16. The same principles can probably be applied elsewhere by examining survival by species, soils, and site conditions for local young (1- to 3-year-old) plantations, and determining from discussion with nurserymen and from nursery records the approximate grade percentage planted.

Hatcher (5) found that the gain is considerable. For plantations in this area of the Sandhills, the method reduced per-acre planting costs in one year 23.5 percent in spite of supervision and service costs running $1.21 per thousand seedlings over the previous 3-year average. By prescription planting, the seedlings have been spread over a larger area, with a reduction in the cost per acre and without lessening the chances of a well-stocked stand. This is the first large-scale use of prescription planting in the South.

The benefits of furrowing observed in the experimental trials described have led to its use in planting the old fields of the Savannah River Project. Furrows about 14 inches wide and 4 inches deep are made with a 26-inch disk located immediately in front of the planting machine coulter on both single and double planters (fig. 27). In the Sandhills, slash and longleaf pines should be planted at the bottom of the furrow. On slightly rolling areas the planting is done on the contour of the land to prevent washing. Observations made in 1956 indicate that furrow planting is highly successful, in contrast to conventional planting methods.

Table 16. - -Prescription planting on old-field sites

Longleaf Pine - Sandhills Sites

	Grade 1' Expected Survival Unfurrowed	Grade 1* Expected Survival Furrowed**	Grade 2* Expected Survival Unfurrowed	Grade 2' Expected Survival Furrowed- *
Ail sandy soils; deep sands, loamy sands, sandy loams..	40-45%	70-75%	30%	509'0
Spacing (feet). . . , ...	6 x 5	6 x 8	6 x 4	6 x 6

'Grade 1, ¼" plus at root collar; Grade 2, 3/16-¼" at root collar. Root length ot least 5" and well developed lateral roots.
**Seat bottom of bud on top of loose soil raised by planting shoe to avoid silting over bud.

Spacing and number per acre:

6x4	. . 1815	6 x 7	1037
6x5	. 1452	6 x 8	907
6x6	. . 1210	6 x 9	8 0 7

Slash Pine - Sandhills Sites

	Grade 1* Expected Survival Unfurrowed	Grade I Expected Survival Furrowed	Grade 2' Expected Survival Unfurrowed	Grade 2 Expected Survival Furrowed	Grade 3' Expected Survival Unfurrowed	Grade 3 Expected Survival Furrowed	Grade 3 Expected Survival Furrowed & Planted Deep"
Deep Sands..................	60%	80%	50%	70%	30%	50%	65%
Normal Spacing (Feet).	6 x 7	6 x 9	6 x 6	6 x 8	6x4	6x6	6 x 8
loamy Sands.................	65%	85%	55%	75%	30%	60%	75%
Normal Spacing (Feet).	6 x 8	6 x 9½	6 x 6	6 x 9	6 x 4	6 x 7	6 x 8'2
Sandy Loam..	70%	90%	60%	80%	45%	65%	80%
Normal Spacing (Feet).	6 x 8	6x10	6x7	6x9	6x5	6x8	6 x 9

*Grade 1 specification: Top 6-14", stem diameter 3/16" at ground level root collar).
'Grade 2 specification: Top 6-12", stem diameter 1/8-3/16" ground level 'root collar), all secondary needles.
"Grade 3 specification: Top 3-8", stem diameter 1/16-1/8" ground level (root collar), at least 5 bundler of secondary long needler.

Root length at least 5" for all grades, ond well developed lateral root system

Keep roots mci all times with soupy mud or wet moss and covered with wet burlap. Do not let stand in water.

**If grade 3 (small) seedlings ore planted deep in furrows-so just the bud is above ground line—survival is increased by at least 1530%. Planting bar or machine must go deep enough to avoid U-rooting.

Spacing and number per acre:

6x4.	1815	6 x 7	1037
6 x 5.	1452	6 x 8. . . . , ,	9 0 7
6 x 6.	1210	6x9.	807

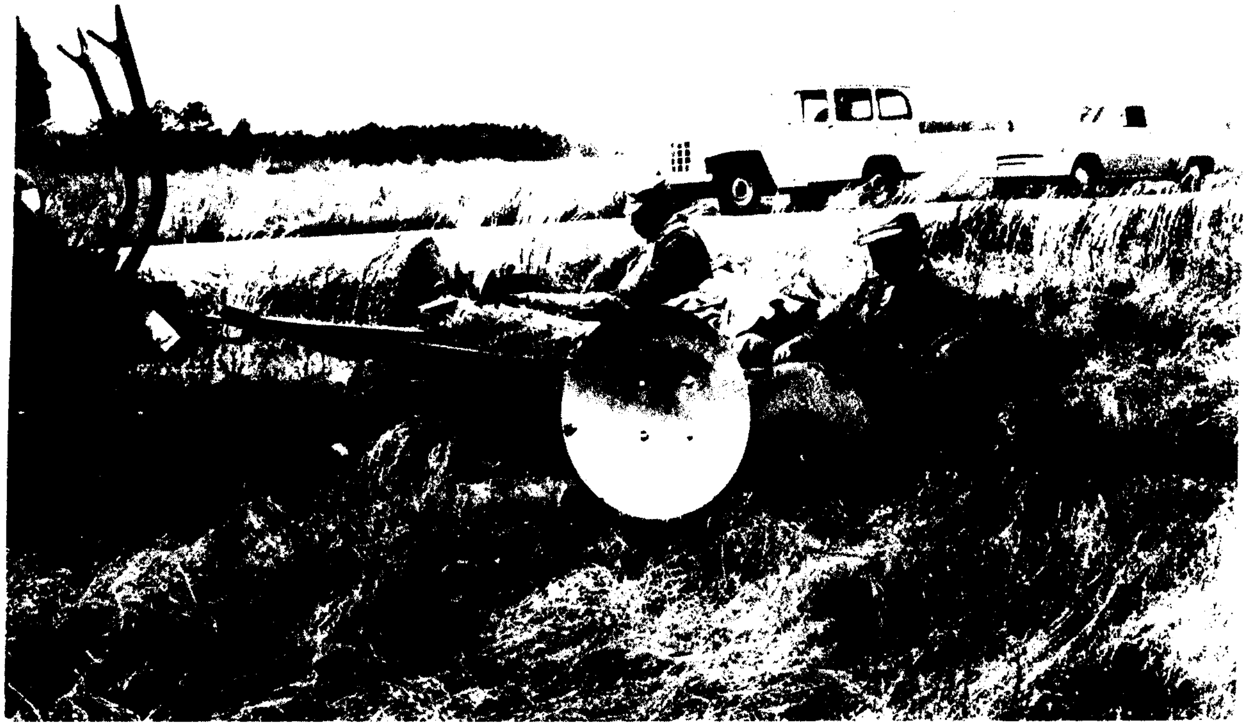


Figure 27. --Furrow planting on old-field sites of the Savannah River Project. Above, double planter employing a 26-inch disk in front of the coulter. Below, completed furrow planting which follows the contour on slightly rolling areas.

SUMMARY

This paper represents 4 years of intensive experimental investigations aimed at finding useable guidelines for Sandhills planters. Some of the information is derived from past experience, but most is the result of critical observations. The research applies principally to longleaf pine, inasmuch as artificial regeneration of this species is one of the most pressing problems. A multitude of experimental plantations have been established throughout the Sandhill Region, mostly in South Carolina. Foresters will be able to follow the development of these plantations for many years to come.

The keys to successful longleaf pine plantation establishment on Sandhill lands are: (1) prepare the site properly by clearing or furrowing, allowing a proper soil stabilization period; and (2) plant the highest quality nursery stock availeble.

<u>Longleaf Pine Planting Guide</u>

Seed source	Obtain longleaf seedlings grown from seed of a local or upper Coastal Plain source.
Planting stock	Use 1- 0 longleaf pine seedlings grown at low to medium seedbed densities, not more than 20-25 per square foot.
	Plant only grades 1 or 2: cull all morphological grade 3 stock [4/] and stock showing brown-spot infection.
	Clip foliage to about 1/3 needle length if naturally longer than 6 to 8 inches.
	Prune long roots to no less than 6 inches at lifting time. Midsummer pruning (July) is advantageous if properly done in the nursery beds.
	Utilize stock which has been given proper applications of NPK fertilizers according to nursery soil requirements.
Site preparation in scrub oak	Completely clear, plow (disk), and drag, using heavy, tractor-drawn equipment. Allow a minimum of 6 months soil stabilization before planting.. .

4/ Needles less than 8 inches long, often scanty; stem less than 3/16 inch thick, and no winter buds present.

or, plow single (8-10 inch) furrows, 6 to 8 feet apart with fireplow or similar heavy equipment. Allow a minimum of 30 days for stabilization; if less, plant seedlings about ¼ to ½ inch higher than usual to avoid excessive silting.

Site preparation in old fields	Plow single furrows 6 to 8 feet apart to a depth of 3-4 inches, either before or at time of planting. If done before planting, allow 30 days for stabilization; if 30 days cannot be allowed, plant seedlings about ¼ to ½ inch higher than usual.
Planting	Machine plant whenever possible, especially in old-field and cleared scrub oak sites. For large areas in scrub oak, furrow planting requires heavy equipment; smaller areas can be hand-planted satisfactorily in single furrows. Winter planting (December and January) is preferred.
Seedling release	On cleared and furrow-planted areas, poison sprout growth or residual scrub oaks in close competition with planted pine. This is best if applied during the growing season, not later than the second growing season after planting.
Chemical release methods	Effective chemical control of small-diameter scrub oak includes: (a) A mixture of one part 2, 4, 5-T (4 lbs. acid equivalentj to 20 parts of fuel oil, applied as a basal spray or to fresh stumps. (b) Ammate crystals applied in notches.

LITERATURE CITED

(1) Ashe, W. W.
1891. The forests, forest lands, and forest products of eastern North Carolina. N. C. Geol. Econ. Surv. Bul. 5.

(2) Cooke, C. W.
1936. Geology of the Coastal Plain of South Carolina. U. S. Dept. Int. Geol. Surv. Bul. 867.

(3) Grelen, H. E.
1956. How about helicopters for Sandhill scrub oak? South. Lumberman 193(2417): 247-248.

(4) Hatcher, J. B.
1956. Annual Planting Report. Savannah River Project of the Atomic Energy Commission. 61 pp.

(5) ____________
1957. Prescription planting. *Forest* Farmer XVI(5): 4-6.

(6) Johansen, R. W.
1955. The effects of certain nursery treatments and site preparations on the vigor and survival of longleaf pine in the deep sands of the Carolinas. MS thesis, School of Forestry, N. C. State College.

(7) Lehocky, A. A., and Lee, R. B.
1954. South Carolina Sandhills can grow pine timber. Jour. Forestry 52: 280-281.

(8) Lotti, Thomas, and Dorman, Keith W.
1949. Good forests once grew in the Sandhills. Forest Farmer IX(1): 7, 10.

(9) Shipman, R. D.
1954. Pine release by various weeding methods. South. Lumberman 189(2369): 125, 126.

(10) ____________
1954. Release of loblolly pine by various weeding methods. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 65, 2 pp.

(11) ____________
1955. Furrows improve longleaf survival in scrub oak. South. Lumberman 190 (2381): 70-72.

(12) ____________
1955. Planting in furrows aids initial survival of longleaf in Sandhills. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 82, 2 pp.

(13) ____________
1956. Furrow old fields to plant longleaf in the Sandhills. U. S. Forest Serv. Southeast. Forest Expt. Sta. Res. Note 98, 2 pp.

(14) ____________ and Scott, H. R.
1957. Chemical control of small-diameter scrub oak. South. Lumberman 194(2422): 64-66.

(15) Southeastern Forest Experiment Station
1956. Annual Report, 1955. U. S. Forest Serv. Southeast. Forest Expt. Sta
8 pp., illus.

(16) ______________
1957. Annual Report, 1956. U. S. Forest Serv. Southeast. Forest Expt. Sta.,
84 pp., illus.

(17) U. S. Department of Agriculture
1938. Soils and Men. Agr. Yearbook 1938. 1232 pp., illus

(18) Wakeley, Philip C.
1954. Planting the Southern Pines. Forest Service, U. S. Dept. Agr. Monog
233 pp., illus.

(19) Wells, B. W., and Shunk, I. V.
1931. The vegetation and habitat factors of the coarser sands of the N. C. Coastal
Plains: An ecological study. Ecol. Monog. 1: 465-520.

(20) Wilde, S. A., and Voigt, G. K.
1954. Morphological and physiological analyses of nursery stock (Syllabus). Forest
Insect and Disease Conference. Univ. Wis. 4 pp.