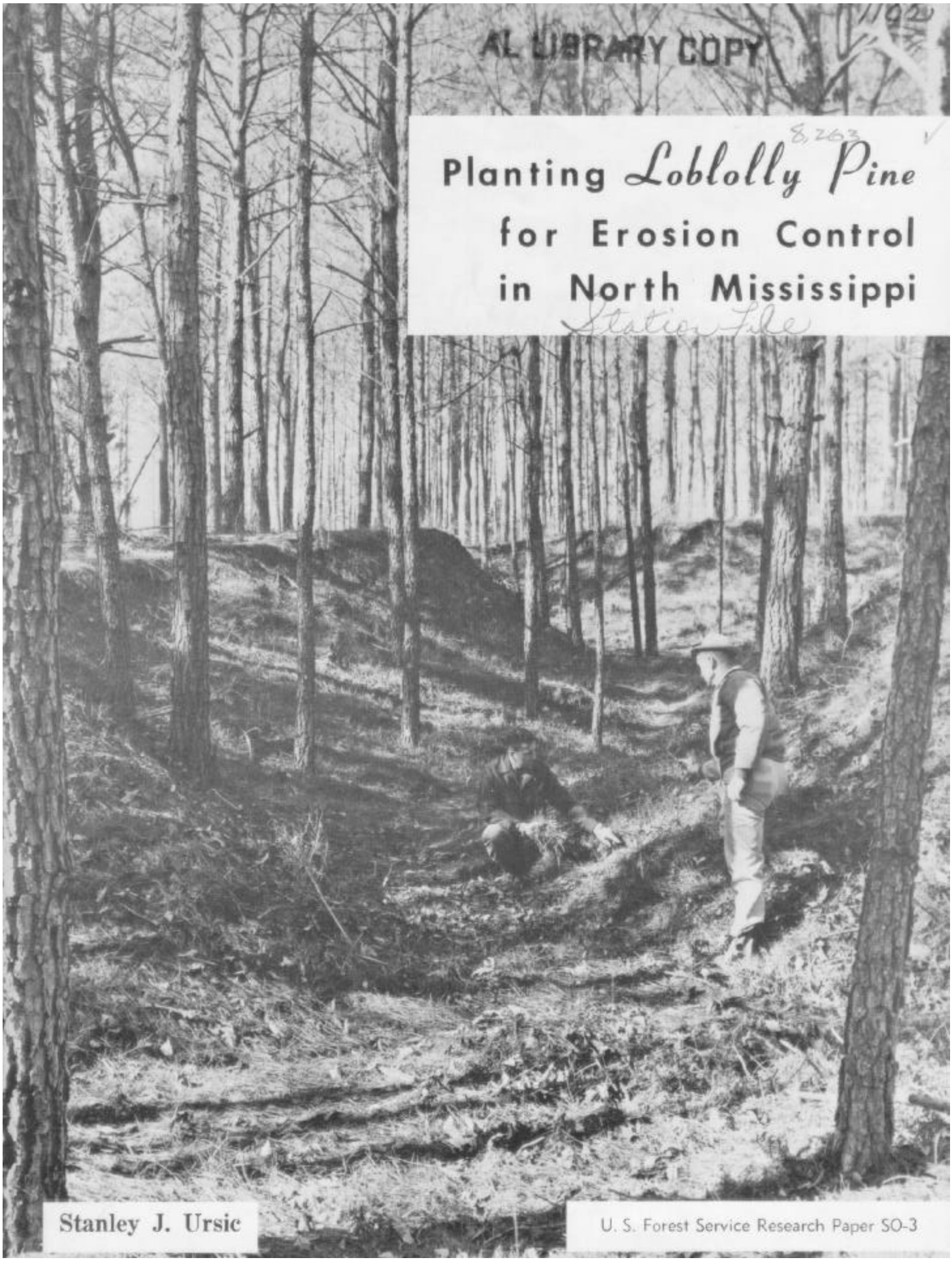
Planting *Loblolly Pine* for Erosion Control in North Mississippi



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Planting *Loblolly Pine*

For Erosion Control in North Mississippi

Stanley J. Ursic

The author is in charge *of* the Coastal Plain Hydrology Project, maintained by the Southern Forest Experiment Station at Ox ford, Miss., in cooperation with the University of Mississippi.

Cover: Gully in former cropland has been completely stabilized for more than 10 years by loblolly pines planted 25 years ago.

Contents

From thousands of acres of eroded hill Land-

come floodwaters and sediment that are ruining much of the fertile bottom land in north Mississippi and west Tennessee

PLANTING LOBLOLLY PINE FOR EROSION CONTROL IN NORTH MISSISSIPPI

Loblolly pine is widely planted for soil stabilization and the rehabilitation of denuded, actively eroding uplands of the upper Gulf Coastal Plain in north Mississippi and west Tennessee. This paper presents methods and specifications that recent research[1] has developed for such planting. It supplements information found in Wakeley's Planting the Southern Pines *(35)*[2] and Wahlenberg's Loblolly pine (*34*) with information specifically applicable on sites where erosion control is a primary objective

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THE PROBLEM AREAS

Starting about 1830, exploitative agriculture on hills of erosive soils changed an area of prime forests of hardwood and pine to the most severely eroded section in the eastern United States. A large proportion of the upland became almost completely unproductive, debris from eroded hillsides buried fertile bottom lands, and excessive runoff produced frequent and serious flooding.

Erosion varies by north-south physiographic belts (fig. 1) corresponding to geologic formations of unconsolidated sedimentary strata ranging in age from Pleistocene to Cretaceous. It is most severe in the areas capped with wind-deposited silt loess. These deposits, underlain by deep sand, clay, and gravel, are thickest at the bluff line bordering the Mississippi River alluvial plain and gradually thin to the east. The deep loess is intricately configured with gullies. The shallow loess, originally up to 4 feet thick, has been removed from extensive areas and the underlying sands flushed in prodigious quantities into drainage systems.

Soils developed from sand, clay, marl, and gravel materials in the Sand and Clay Hills, Tombigbee Hills, and Pontotoc Ridge are more stable, but cultivation of the steep slopes has caused severe sheet erosion and moderate gullying. In the Flatwoods and Black Prairies, where soils are heavy and the relief low, gullying is not a problem.

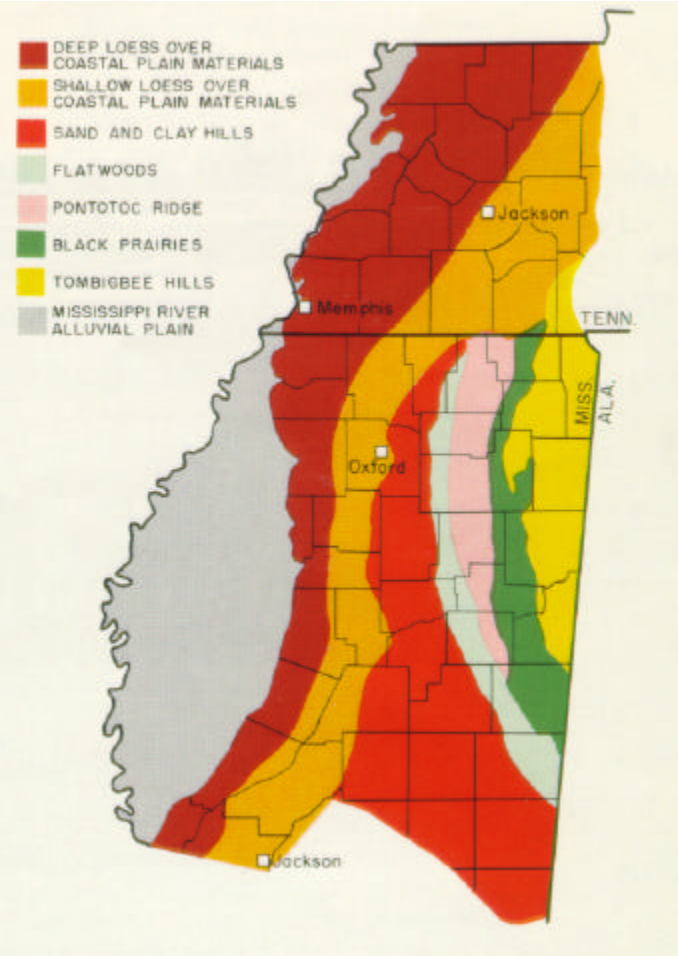


Figure 1.--Physiographic areas of north Mississippi

[1] The research was conducted at Oxford, Mississippi, in cooperation with the University of Mississippi. The Yazoo-Little Tallahatchie Flood Prevention Project of the U. S. Department of Agriculture aided substantially in many of the studies.

[1] Italic numbers in parentheses refer to Literature Cited, p. 19..

Most of the research cited in this paper was on eroded loess, sandy eroded soils of the Sand and Clay Hills, and exposed parent materials. Such areas, interspersed among uplands which remain suitable for tree establishment by normal procedures, are those most in need of erosion control.

The climate of north Mississippi and west Tennessee is mild and humid, with a long growing season varying from 200 to 220 days. Precipitation averages 50 inches annually, and is heaviest during the tree-planting season, December through March. Summer droughts are common, though there is usually a second rainfall peak during July, especially in the southern part of the region (fig. 2) . Autumns are almost always dry.

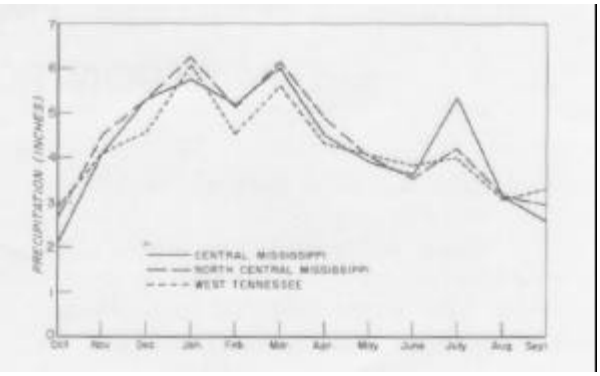


Figure 2. Average monthly rainfall

Many areas in eroded uplands retain sufficient topsoil to permit planting without special measures. Bare and actively eroding gullies are the most difficult planting sites.

Objectives and Materials

The immediate objective of vegetative measures on eroded sites is to provide a protective mat that will prevent further soil loss and site deterioration, lessen overland flows, reduce siltation of downstream channels and flood plains, and improve water quality. The most effective soil cover for this purpose is a layer of litter provided and perpetuated by a forest stand. A continuous, interlaced mat of pine litter one-half inch or more in depth will largely halt soil movement.

A long-term objective is to restore the favorable properties of a forest soil profile. The gradual improvement further increases water intake, thus reducing floods and improving the timing and duration of flows. Timber, wildlife, and other forest values follow from the restoration of vegetative cover.

Severely abused watersheds often require dams to store and regulate streamflow and trap sediment. Such structures give prompt relief to downstream areas, but their useful life is short unless the watersheds are stabilized with vegetation.

By the time pine litter is a half-inch deep, the soil is usually stabilized.

While dams provide prompt protection for downstream areas, they soon fill with sediment unless their tributary watersheds are stabilized by vegetation

Loblolly pine (P*inus taeda* L.) is the most widely planted erosion-control species in north Mississippi. Several other types and species of plants have characteristics adapting them to particular uses, but loblolly combines more desirable traits with fewer disadvantages than any other species so far tested.

Grasses and herbaceous plants.-Good soil stabilizers for some situations in north Mississippi include kudzu (*Pueraria thunbergiana* (S. & Z.) Benth.) , African weeping lovegrass (*Eragrostis curvula* Schrad.) , sericea lespedeza *(Lespedeza cuneata* G. Don), and *Lespedeza* bicolor Turcz.

Kudzu sheds its leaves with the first frost, may be damaged by grazing, and does not accumulate the litter cover that pine does. It is best used to revegetate steep road, stream, and gully banks that are prone to caving. Kudzu is not compatible with forest vegetation and should be restricted to lands adjacent to pastures or cultivated fields.

Lespedezas are used to improve depleted pastures and to establish wildlife food patches in small gullies. 5ericea lespedeza requires cultivation and fertilization for establishment. Once established, it may inhibit conversion to pine.

African lovegrass is the most desirable herbaceous plant. It can be established with a minimum of soil disturbance, is rarely damaged by deer or livestock, and withstands deep and continued siltation. It is a bunchgrass, however, and does not provide the volume or continuity of litter desirable for optimum soil stabilization. Its main uses are to retard soil movement during the first few years of loblolly development and to supplement brush dams. Lovegrass does not appear to inhibit pine.

Loblolly pine.-Pine meets most of the requirements of an ideal erosion-control plant. This was demonstrated by research in the 1930's, when numerous vines, herbaceous plants, and trees were tested to determine their ability to stabilize eroded land in north Mississippi. Pine survived well, grew fast, cast more protective litter than other species, and required little maintenance. Later work demonstrated that loblolly is superior to other pines, even though its native range extends only into the southern and eastern fringes of the area.

On eroded loessial ridges during the severe droughts of the early 1950's, loblolly pine survived better than most other promising conifers and excelled all others in growth (table 1) . Virginia and shortleaf (*Pinus virginiana* Mill., *P. echinata Mill*.) survived almost as well but were severely retarded by tip moth. Because of

Table *1.-Survival and growth of conifers planted on dry ridge sites for four successive years in northern Mississippi*

Species	Survival		Total height	
	5 years	10 years	5 years	10 years
	Percent		*- Feet -*	
Loblolly	56	56	8.0	23.5
Longleaf	10	8	1.1	12.5
Shortleaf	54	54	4.9	14.3
Slash	18	17	6.2	21.6
Virginia	53	53	6.2	12.9
Eastern redcedar	66	65	2.6	7.1

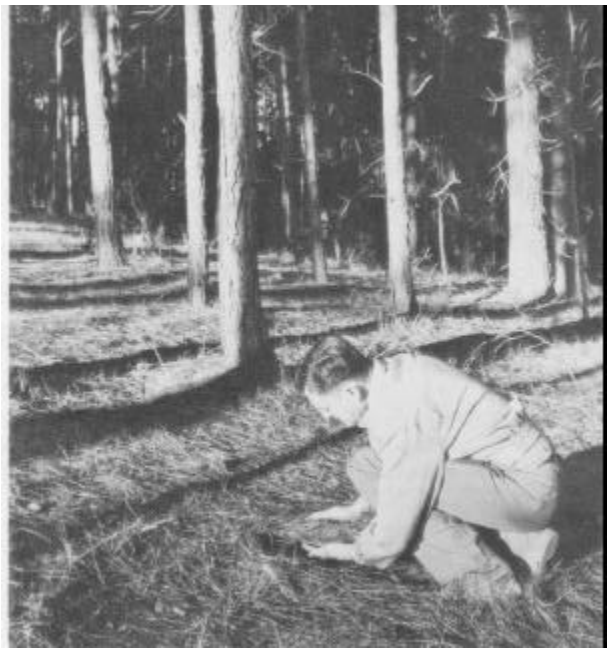
their poor survival and proneness to ice damage, slash and longleaf pine (*P. elliottii* Engelm., *P. palustris* Mill.) cannot be recommended. Eastern redcedar (*Juniperus virginiana L.)* survived well, but grew slowly and was heavily browsed by deer. After 10 to 13 years

African lovegrass is often planted above check dams to increase their effectiveness in trapping sediment on which loblolly pines can be established.

In numerous tests on eroded lands, loblolly has survived better and grown faster than other species. Loblolly on left, shortleaf on right.

loblolly had accumulated 1.12 inches of litter, a depth 44 percent greater than that for slash, the next best species. Weight of the forest floor under loblolly averaged 5.5 tons per acre, 1.3 to 2.4 tons more than under the other pines.

Results were similar in younger and in older stands. During 4 years on bare, compact, Coastal Plain parent materials, loblolly accumulated 4 to 8 times as much litter as Virginia or shortleaf pine (21). In older plantings, loblolly has maintained heavier forest floors than other species and has improved hydrologic



Loblolly pine produces more protective litter than any other species tested.

characteristics of the soil. On severely eroded silt loams in Madison County, Tennessee, and on gullied loess and Coastal Plain soils in north Mississippi, pine plantations developed heavy litter layers and restored organic matter in surface soils. *A1* horizons under loblolly plantations in Mississippi were nearly as deep as those under native timber stands (table 2) . Soil losses and runoff were much less than from

Table 2.-Characteristics of the forest floor and surface soil under pine plantations and native hardwoods

Location and stand	Forest floor		Depth of A_1 horizon	Organic matter in 0-2-inch depth [1]	
	Depth	Ovendry weight per acre[2]		Proportion by weight	Ovendry weight per acre
	Inches	*Pounds*	*Inches*	*Percent*	*Pounds*
32-year-old pine plantations and native hardwoods, Madison County, Tennessee[3]					
Loblolly	1.92	28,400	0.21	2.48	13,280
Shortleaf	1.17	22,960	.37	2.11	11,540
Longleaf	1.70	20,610	.52	...	...
Slash	1.58	19,090	.25	...	...
Hardwoods	1.26	10,210	.61	2.39	10,310
23-year-old loblolly plantations and hardwoods, Lafayette County, Mississippi					
Depleted hardwoods	.75	8,030	.81	3.84	18,230
Loblolly plantations	1.02	12,070	.78	3.12	15,600
Mature shortleaf pine and hardwoods	1.25	11,170	.87	4.84	19,440

[1]Volatile matter determined by loss on ignition.
[2]Combined weight of L (litter) and F (fermentation) layers above the mineral soil.
[3]Basal areas at age 29 ranged from 143 for longleaf to 178 for loblolly. All 4 pine stands were thinned to 100-120 square feet of basal area at age 31. Measurements were made the following year.

abandoned fields with a good cover of broomsedge grass (table 3), and were also less than from areas of depleted hardwoods (*33*).

Table 3--*Average annual runoff and sediment from three cover types in north Mississippi, 1958-60*

Cover type	Runoff		Soil loss per acre, ovendry
	Loess soils	Loess and Coastal Plain soils[1]	
	--Inches--		*Pounds*
Abandoned fields	11.2	3.1	362
Depleted hardwoods	5.4	2.9	254
Loblolly plantations	2.0	.2	36

[1]Average of two watersheds

Loblolly often performs well in other problem areas outside its natural range. It survived well and outgrew four other conifers and seven hardwoods on Coastal Plain soils in west Tennessee (*18*) and is the best species for planting in the denuded Copper Basin (*1*) of the east Tennessee mountains. It is preferred for planting spoil banks in Alabama (*5*), outgrows other conifers on strip-mined land in southern Illinois (*2*), and is the major species for reforestation on the Virginia Piedmont (*9*).

PLANTING STOCK

As eroding sites can rarely be direct-seeded, loblolly must almost always be established on them by planting. Research has shown that planting is most successful with stock from suitable geographic seed sources, of acceptable size, and in a dormant condition.

Geographic Seed Source

Survival, growth, disease resistance, and litter production of loblolly pine vary with geographic strain. Since loblolly is an introduced species it is not possible to follow the usual recommendation to use local seed.

One attempt to locate a source of stock that would perform well on severe sites in north Mississippi compared seedlings grown from seed native to southeast Arkansas, northwest Georgia, and Caldwell and Cherokee Counties, Texas. After 5 years on compact Coastal Plain materials the Caldwell loblolly trees averaged 8.1 feet in height; those from Cherokee County 6.2 feet; those from Georgia 6.4 feet; and those from Arkansas 5.7 feet (*22*). Litter production varied with height, being least for the Arkansas seed source (*21*). Seed from the Texas sources is available only in very limited amounts.

Ten-year results of a TVA seed-source study with plantings inside and outside the natural range indicated that loblolly pines from inland sources survive better than those from the Atlantic Coastal Plain, but there were no significant differences in height between seed sources (*38*). Of the inland sources, northwest Georgia, north and south Alabama, and Tennessee survived best and appeared most suitable for planting outside the natural loblolly range.

Five-year results of the Southwide Pine Seed Source Study indicate that it is better to obtain seed from the east or west of the planting sites rather than from the north or south (36).

In the lack of a proven seed source for north Mississippi, it would appear that seed from northwest Georgia, north Alabama, and northeast Mississippi should be used where available. The next best source probably is central Mississippi.

Grades

Only seedlings meeting Wakeley's specifications (*35*) for grades 1 and 2 (table 4) should be planted for erosion control in north Mississippi.

In test plantings made in 1956-58 on eroding loess and Coastal Plain soils, grade 1 and 2 seedlings survived better and grew faster than grade 3 (cull) seedlings. Although differences were not always statistically significant, they were consistent (table 5) . Survival at the end of the third growing season averaged 10 percent higher for grade 1 and 2 than for grade 3. Grade 1 seedlings grew 18 to 41 percent more in height than grade 3 seedlings during the first three years, and grade 2 seedlings 6 to 31 percent more. Differences in growth were still increasing after 5 years. In associated studies, seedlings with roots pruned to 4 inches grew as well as seedlings with 6- to 10-inch roots, regardless of stem characteristics, but they

Table *4.-Specifications of grades' of uninjured' 1-year-old loblolly pine seedlings*

Grade	Stem lengths	Thickness of stem at ground	Nature of stem	Bark on stem	Needles	Winter buds
	Inches	*Inches*				
1	5 to 12	3 / 16 or larger	Stiff; woody	Usually on entire stem	Almost entirely in 3's	Usually present
2	4 to 7, sometimes 10	At least 1/8	Moderately stiff	On lower part at least, often all over	Part at least in 3's	Occasionally present
3	Usually less than 5	Less than 1/8	Weak; often juicy	Often lacking	Practically all single; usually bluish	Almost never present

Source: Wakeley (35, p. 103).
[1]Grades 1 and 2 usually considered plantable, and grade 3 culled.
[2] Any seedlings with roots less than 5 inches long should be considered as grade 3 (culls), regardless of the quality of the tops.

seemed slightly less able to survive extended soil freezing after planting.

When clipped 1 inch above the groundline, in a manner simulating rabbit damage, grade-1 seedlings also had a higher recovery rate than grade-3 trees.

Table *5.-Survival of loblolly seedlings on eroded soils*

	1956 study		1957 study		1958 study	
Grade	First year	Fifth year	First year	Fourth year	First year	Third year
	- - - - - Survival percent - - - - -					
1	79	77	98	96	93	92
2	69	63	97	94	94	92
3 (cull)[1]	67	58	90	86	85	81

' Seedlings which met requirements for grade 2 except for stem diameter.

Twenty-six percent of the

grade-1 trees survived the first growing season, as compared with 10 percent of the clipped grade 3's. Sprouts were more numerous and vigorous on the large seedlings (23).

Loblolly seedlings can be quickly and accurately graded by stem diameter alone. For eroded sites, their diameter should be at least 1/8 inch. Those that have smaller stems but otherwise meet grade 2 specifications should be reserved for easier planting chances.

Loblolly seedlings to be planted on eroded sites should have a stem diameter of at least 0.12 inch-approximately the size of a kitchen match

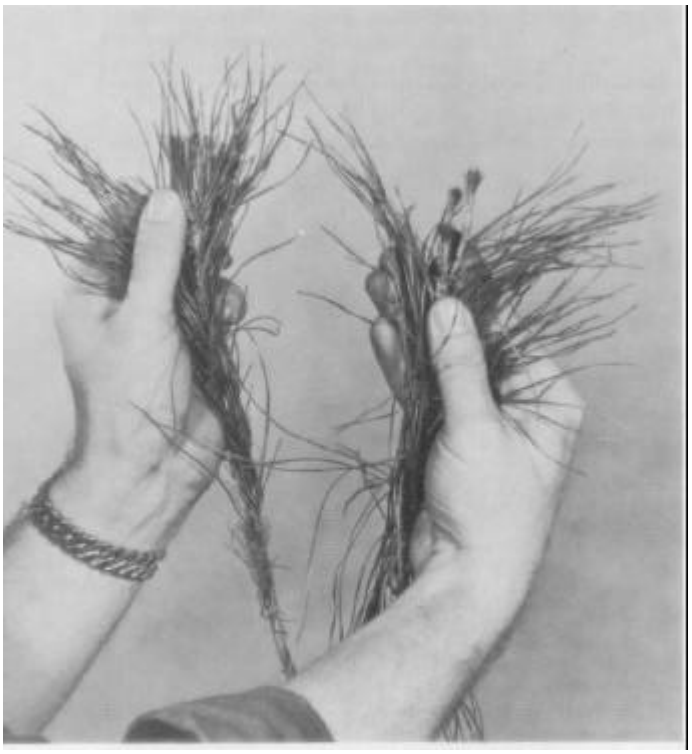
Dormancy

Loblolly is most successfully planted while dormant. A special difficulty in north Mississippi is that most planting stock comes from nurseries south of the area. The longer growing seasons at the nurseries delay hardening in the fall and induce top growth in spring at times when conditions are otherwise suitable for planting.

Seedlings lifted before they are sufficiently hardened are apt to heat in shipment, do not store well, and are subject to winter kill after

being planted. Those lifted and planted in February, at the peak of dormancy, have consistently survived better than those planted earlier, regardless of subsequent temperatures. December plantings have incurred heavy losses from winter freezes.

Seedlings planted after they have resumed top growth may survive well (*12*), but the tender new shoots are easily broken in handling and killed back by frosts.



Fully dormant seedlings survive transportation, storage, and hard freezes better than those lifted after they have resumed growth.

Unless they show actively growing roots or shoots, it is difficult to determine whether loblolly seedlings are dormant. Tight bark, i.e., not readily separable from the wood, has been suggested as an indication (*8*). Generally, seedlings from nurseries in southern Mississippi and Louisiana are not fully dormant until late in December.

Special Nursery Treatments

Special nursery practices have not improved the capacity of loblolly seedlings to survive on eroded soils.

Prelifting pruning at the Ashe Nursery in Mississippi depressed initial survival and early growth and did not improve root morphology. Seedlings were pruned in the beds at the 6-7 inch depth 4, 6, 8, and 10 weeks prior to a second undercut, to a depth of 10 inches, at lifting time. The treatments reduced first-year survival 7 percentage points below the 80 percent for unpruned controls, and lessened 3-year height growth by 0.25 foot. Similar tests in Louisiana also led to a recommendation against prelifting pruning (*15*).

Late-season fertilization of nursery beds with nitrogen has not improved the field performance of loblolly seedlings and may be detrimental (*6, 14,* 25).

Until special nursery practices of definite value have been demonstrated, standard graded stock from proven nurseries is most suitable.

PACKING, SHIPPING, AND STORING PLANTING STOCK

How nursery stock is handled between lifting and planting may make the difference between a successful plantation and a failure.

Packaging

Both standard Forest Service bales (*35*) and double-wall kraft bags have proven highly satisfactory for packing, shipping, and storing loblolly seedlings. The kraft bags, which have an inner lamination of polyethylene, offer some advantages over bales.

In extensive trials in north Mississippi, first year survival was identical (78 percent) for seedlings packaged in bales and bags. The comparisons included seedlings lifted in December, January, and February, and stored up to 9 weeks (31) in refrigerated rooms and in racks in a warehouse that provided shelter from the sun and desiccating winds.

Kraft bags eliminate the need for watering during storage. If the seedlings are to be held in cold storage the bags can be packed with a single handful of moss a procedure which reduces shipping weights about 10 pounds per thousand trees. Packing with conventional amounts of moss is recommended if bags are to be held on sheltered racks more than a few weeks.

Shipping

Seedlings in transit may be damaged by overdrying or by freezing, but the greatest hazard is overheating. Biological activity within large masses of closely packed seedlings can easily raise temperatures to a harmful level. Nondormant stock is especially prone to such heating. Seedlings exposed to package temperatures higher than 122° F. should not be planted (*27*).

Risk of heating in transit can be minimized by shipping only well-hardened stock, cooling before loading, providing air circulation through the load, and hauling at night or in refrigerated trucks. Placing blocks of ice in the sphagnum soaking vats, a common practice in the North (*19*), is recommended for southern nurseries. Bales or bags shipped long distances

To prevent overheating in transport, seedlings should be shipped in refrigerated trucks or loaded so that air circulates between bales.

in unrefrigerated trucks should be unloaded and watered every 8 hours as a matter of regular routine, and immediately if there is indication of heating. Covering the load helps reduce the drying and freezing hazards.

Storage

Methods have been developed for storing seedlings in bales, and such storage is now standard practice throughout the South (4). Choice of method depends largely on facilities.

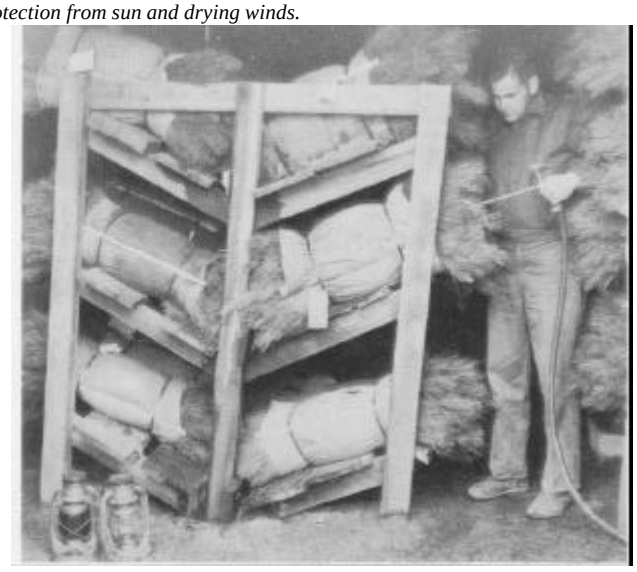
Cold moist storage at temperatures just above freezing is ideal (24). Seedlings packed

Seedlings in *bales or wiaji-j . ethylene bags can be held in cold storage for several months. Those in bales require watering every two weeks.*

in bales and in kraft-polyethylene bags have been kept in prime condition for 6 to 9 week: without attention (*31*). If watered every two weeks, baled seedlings may be held in colt storage for 4 to 6 months.

Seedlings can be stored on racks in cool buildings for 6 to 9 weeks. Those in bale; should be watered every 2 or 3 days, but those packed in kraft-polyethylene bags with adequate moss require no watering. The seedling:

If stored at air temperatures, baled seedlings must be watered two or three times a week. Storage racks should be in a building that affords protection from sun and drying winds.



should be kept from freezing. Although packaged seedlings have sometimes survived freezing, a study in North Carolina found that exposure at 20° F. for 6 to 24 hours reduced survival. Forty-eight hours of exposure at this temperature killed all seedlings. (7).

Where neither cold storage nor warehouse space with water and heat is available, burying Forest Service bales in well-drained pits in sandy soil is a practical alternative (28). The E. L. Bruce Company successfully stored more than a million seedlings in earth pits during the 1960-1961 and 1961-1962 planting seasons. Two men buried as many as 50,000 seedlings per hour. Locating the pits at the planting sites minimized handling.

Loblolly seedlings must be well hardened to withstand storage (8). Seedlings lifted in late January or early February are best for long storage.

To summarize: well-hardened, dormant loblolly seedlings can be packed and stored in bales or kraft-polyethylene bags. The bags hold promise of reducing packing, shipping, and storage costs. Moist cold storage is the best way to hold seedlings. Storage on sheltered racks is highly satisfactory but requires water-

Seedlings can be stored in the field by burying the bales in well-drained, sandy soil.

ing the bales and a means of protecting either bales or bags from freezing temperatures. Burying bales in well-drained sandy soil is practical when cold storage or warehouse facilities are limited.

PLANTING

Spacing

Successful erosion-control plantings require that trees be spaced so that in 5 to 10 years they will develop sufficient litter to stop soil movement.

A 6- by 8-foot spacing (900 trees per acre) is recommended for the ungullied but eroding abandoned fields that make up the bulk of erosion-control plantings. Except when the first .rowing season is very dry, this spacing will yield a satisfactory stand without follow-up planting.

For barren, sheet-eroded, and gullied segments of abandoned fields, and for the first three rows along gully rims, spacing should average 6 by 6 feet, or about 1,200 trees per acre. If suitable natural sites are too few, enough spots should be specially prepared to achieve the desired spacing.

On outwash fans of gullies, a spacing as close as 4 by 4 feet is desirable to form a living dam gnat will trap sediment.

Closer spacing than indicated above is seldom justified. If planting locations are selected or prepared in the ways to be described, survival will be on a par with that on uneroded sites. This was borne out by 47 study installations totaling 25 thousand seedlings planted on a wide range of eroded sites in north Mississippi during a 10-year period. First-year survival for these plantings averaged more than 80 percent.

Time of Planting

Planting in north Mississippi should be delayed until soils are wet to a depth of at least 10 inches. The depth of wetting is readily discernible with a little digging or by use of a soil auger. In the spring, soil moisture is generally adequate into April.

Although soil usually is moist by early December, seedling survival is progressively improved by later planting (table 6) . The improvement results from the shorter interval

Pines should not tie wanted until canter rains have wet the soil to a depth of 10 inches.

between planting and initiation of vigorous new root growth, lower losses to rabbits, and the ability of well-hardened seedlings to withstand shipping, storage, and post-planting freezes.

To take advantage of these factors, planting can be delayed until after January 1. In the past, this has been impracticable, because it would have unduly shortened the planting season. With storage methods now available, however, it is feasible to plant later in the spring by lifting seedlings in February and holding them dormant in cold storage. When stored properly, seedlings from the Ashe Nursery, in southern Mississippi, have survived well when planted in March and early April.

Table 6.-*First-year survival by month o f planting, Yazoo-Little Tallahatchie Project, in north Mississippi*

Planting season	Month of planting		
	December	January I	February
	---- *Percent*----		
1954-1955	74	82	84
1955-1956	56	58	60
1956-1957	81	84	83
1957-1958	57	63	70
1958-1959	71	76	83

Planting Spots

Large-scale site preparation that grossly disturbs the soil is of little value on eroded areas. Leveling of gullies by heavy machinery, for example, leaves unstable conditions on which erosion may be accelerated before the young trees can establish an effective cover. Results are better and costs lower if advantage is taken of the many favorable planting spots that normally are available and by preparing additional spots where needed.

Suitable natural planting spots in gullies include

1. Areas of topsoil or other loose material sloughed from the rims and banks of the gullies and lodged on sideslopes with less than a 1:1 slope, or more often at the toe of the gully walls or banks.

2. Deposits of soil or sediment behind clumps of vegetation or other natural barriers.

3. Vegetated areas.

4. The edges of relatively flat intermittent water courses and outwash soils extending as alluvial fans within the gully or downslope from its outlet.

5. Barren or sparsely vegetated areas having slopes of less than 1:1 and on which the soil is loose and friable enough to be penetrated easily with a planting bar.

Even in *badly gullied areas, trees will survive* in *selected spots at the foot of gully banks, along watercourses, and on gentle slopes where soils are loose* enough: for *roots to* penetrate.

Trees should not be planted on narrow hogbacks without topsoil, on steep slopes and sidewalls, or in intermittent water courses without sediment-collecting barriers. Other areas of parent materials too compact for barplanting require brush dams or topsoil-filled post holes.

Brush Dams

Brush dams are built. on parent materials that erosion has cut into numerous small drainage units. Undisturbed, these dense materials are hostile to plant growth, but when dislodged and collected they have favorable physical and moisture characteristics. Drainage units on parent materials often erode at the rate of an inch or more each year, and several square yards will contribute enough sediment to form a planting spot.

Brush dams require no special equipment and are constructed with materials collected in the vicinity of the sites. Brush is loosely overlapped across the water course and anchored with material from the gully bottoms. Dams are built 12 to 18 inches high, with a slight depression near the center for storm overflow. To aid stability, lovegrass may be seeded at the time of construction or after sediment has collected.

Sma11 brush dams built 6 to 9 months in advance of planting accumulate loose .soil in which *pines survive and grow well.*

Small dams that will collect enough sediment to support one or two seedlings are most effective. Where possible they should be built in series. When constructed during spring and summer they are filled with sediment by fall rains and ready for the winter planting season.

Post Holes

Flats and slopes that have eroded uniformly down to parent materials are unsuitable for brush dams. Here, planting spots are best prepared by digging post holes.

Holes spaced at least 5 feet apart are dug to a depth of 18 to 24 inches with a 6-inch auger, either tractor-mounted or driven by a backpack gasoline engine. They are preferably refilled with the nearest approximation of topsoil in the vicinity, usually from the gully rim. If no topsoil can be found, they are backfilled with the excavated material. A seedling is barplanted in the fill and 4 inches of mulch are placed around it to a radius of 9 to 12 inches.

On slopes eroded to dense subsoil, post holes are necessary to supplement natural planting sites. Holes are refilled with the best soil available, and seedlings should be mulched.

A two-man team can dig holes and plant and mulch 300 to 500 seedlings a day.

While the whole operation can be completed at the time of planting, the holes can be dug whenever the soil materials are moist and then filled and marked for future planting. Settling of the fill is not a problem, for it helps prevent the formation of pedestals as materials around the trees erode.

Third-year results of a post-hole planting study installed over 12 north Mississippi counties (29) are summarized below

	Survival	Height growth
	Percent	*Feet*
Post hole with mulch	86	2.7
Post hole without mulch	76	1.9
Mattock planting	66	1.4

On eroding slopes, mulching is necessary to prevent soil from washing away from the seedling during the first 2 years. The mulched spot should be 18 to 24 inches in diameter.

In another study loblolly planted in post holes averaged 5.3 feet in height after 5 years. Seedlings planted with mattocks on unprepared parent material averaged 3 feet. Mulch improved the survival of seedlings planted by both methods. Once loblolly is established the roots can penetrate surrounding soil materials with bulk densities approaching 2.0-a density twice that of most uneroded soils.

Soil collection trenches have been used successfully to ,establish loblolly on parent materials (13) but they are costly.

Mulch

The chief value of mulch is to protect seedlings from further erosion, primarily by absorbing the kinetic energy of raindrops and preventing spew frost. In addition, it helps maintain high moisture content when applied on loosened soils-as in post holes or trenches. While it keeps light rains from reaching the soil and traps summer heat (*11*), neither effect has proved serious on eroded sites.

In two planting seasons, mulch improved survival and 5-year growth regardless of method and rates of application (table 7) , but spot mulches cost less than broadcast applications,

Table 7.-Survival and growth of mulched and unmulched seedlings bar-planted on barren gully slopes

Date and treatment	Survival		Height growth	
	First year	Fifth[1] year	First year	Fifth[1] year
	Percent		*Feet*	
1956 Installation				
Spot-mulched-hay	80	78	.29	3.09
Broadcast-1 ton hay per acre	89	82	.35	3.08
Broadcast-3 tons hay per acre	80	76	.28	3.90
Unmulched control	64	53	.42	2.58
***1957* Installation**				
Spot-mulched-pine litter	97	94	.40	4.90
Spot-mulched-hay	98	98	.38	4.16
Broadcast-3 tons hay per acre	96	92	.42	4.43
Unmulched control	90	86	.46	3.90

[1]Fourth year for 1957 installation.

last longer, and provide more protection to the seedlings. When trees at a 6- by 6-foot spacing are mulched to a radius of 9 inches, less than a half-ton of mulch per acre will supply three times the depth of mulch afforded by a 3-ton broadcast application.

Mulch should be applied not only to seedlings planted in post holes but also to those barplanted on bare, rapidly eroding slopes. Hay, grain straw, and pine litter are preferred because they mat and remain in place even on

steep slopes. Hardwood litter, sawdust, wood shavings, and similar materials are too easily removed by wind and water.

Seedlings can be mulched either when they are planted or early in the first growing season. A delay of one or two months makes it possible to select those that are jeopardized by soil washing, and to eliminate the useless mulching of short-lived seedlings which die soon after planting.

Planting Techniques

The steep and irregular terrain associated with eroded areas limits planting to hand methods, chiefly bar-planting. Machines can be used on abandoned lands that have eroded uniformly or in conjunction with hand planting on areas with infrequent gullies, but little machine planting has been done on the upper Coastal Plain in north Mississippi.

To prevent exposure of the roots during planting, seedlings are carried in buckets, bags, or trays. Saturated sphagnum moss keeps the roots moist, and only the seedling being planted is removed. Trays permit carrying the seedlings flat and lifting out each one with minimum breakage of roots.

In north Mississippi, as elsewhere, shallow planting has seriously reduced seedling survival (*16, 17, 35*).

Deep planting has not bettered survival, while increases in height growth have failed to offset the loss in initial height at time of planting (*10, 20, 32*). To minimize accidental shallow planting and root exposure from soil washing, however, planting 1 to 2 inches deeper than the rootcollar is good practice.

Most erosion-control planting is done by hand, with a bar.

SURVIVAL

Drought during the first growing season is the major cause of loblolly mortality.

Droughts are most likely during the summer, but winter dry spells may be equally damaging, especially if accompanied by freezing weather. Loblolly seedlings can live for a maximum of about 3 weeks after the soil they occupy is reduced to the ultimate wilting point of more succulent plants (*30*). For a plant to survive dry weather, its roots must grow rapidly enough to maintain contact with moist soil. This is a seasonally dependent requirement. Because root growth until May or early June is largely restricted to the upper 4 inches of soil, winter droughts may cause losses when only the surface layers of soil become dry. In summer, when root systems are larger, drying must go deeper to be lethal, even though rates of evapotranspiration are high.

Extensive plantings on the Yazoo-Little Tallahatchie Watershed have generally survived satisfactorily when rainfall during the growing season (April through September) has exceeded 20 inches (fig. 3) .

Losses after the first growing season are minor. First-year mortality for 25 M seedlings planted in erosion-control studies over a 10year period averaged 19 percent. Second- and third-year losses combined averaged only 6 percent (*26*).

PROTECTION

Animals.-In some north Mississippi plantings, rabbits have nipped the tops from more than 90 percent of newly planted seedlings. When rabbits are abundant, repellents are needed to protect the trees during the first winter.

The most satisfactory repellents tested so far are zinc dithiocarbamate with a wax, asphalt, or latex sticker, and calcium polysulfide with asphalt sticker (3). They are sprayed on the seedlings in the nursery beds, just before lifting. Enough repellent to treat 300,000 to 400,000 seedlings requires 5 gallons of commercial zinc dithiocarbamate (available under trade name Z. I. P.) . The chemical is mixed with either 23.8 gallons of wax emulsion, 120 pounds of asphalt emulsion, or 6.3 gallons of latex emulsion. Then enough water is added to bring the total mixture volume to 100 gallons.

With calcium polysulfide, 11.1 gallons of 30-percent chemical are added to 120 pounds of asphalt emulsion, after which 74.5 gallons of water are added.

Until the trees have grown large enough to shade out heavy grass cover, cotton rats may occasionally damage the plantation. They may be controlled with minimum damage to other wildlife by placing strychnine-treated milomaze in their runways, or by burning the area when fuel is wet enough so that the fire will eliminate the grass without killing the pines.

Livestock should be excluded from the planting areas. Cattle trample pine seedlings and both goats and mules browse them. Trampling by livestock compacts soil, increases surface runoff and sediment production, reduces site quality, and impairs the physical properties of the soil.

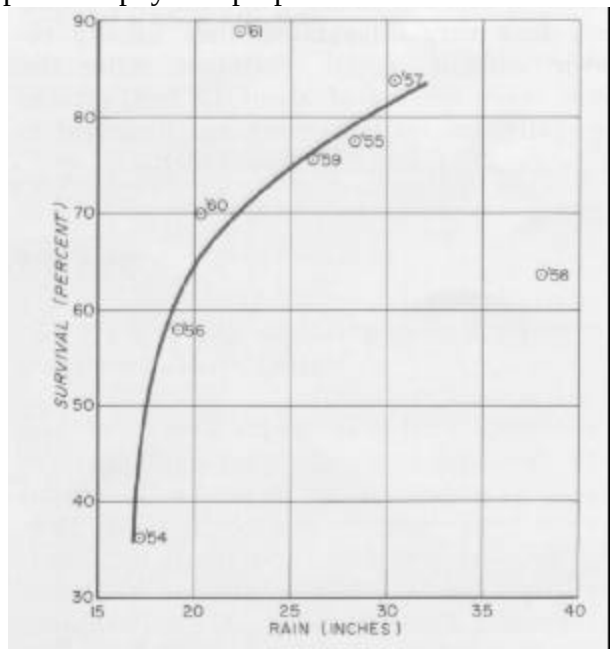


Figure *3.-Trends of first-year seedling survival, 1954-1961, in relation to rainfall from April through September. In 1958, a dry, cold winter depressed survival; in 1961 unusually well distributed rains increased it. Data are from erosion-control plantings in 19 north Mississippi counties.*

Fire.-Wildfire can totally destroy young pine plantations and their erosion-controlling forest floor. Fires are particularly likely to occur on dry, windy days in late fall and early spring. The fire protection organizations of the Mississippi Forestry Commission and the Tennessee Conservation Commission are responsible for detecting and suppressing wildfire, and have reduced the annual burn to about 1 acre in 400. Landowners can help by encouraging fire prevention and can frequently put out small fires unaided. An important aid in preventing fire damage is to disk firebreaks between the plantation and well-traveled roads. I f the plantations are large, they should be divided into blocks of about 40 acres; if streams, roads, and other natural fire barriers do not offer sufficient protection, they should be supplemented by disked breaks. As far as possible, disked breaks should run along the ridges. They should be seeded with rye grass to minimize danger of erosion.

Insects.-The Nantucket pine tip moth *(Rhyacionia f*rustrana) often slows height growth of young loblolly pines and causes excessive branching that sometimes results in forked or crooked stems. While infested stands may look very dilapidated, they usually recover without special treatment. After the trees reach heights of about 15 feet, attacks generally are no longer serious. Shortleaf is damaged more severely than loblolly.

Disease.-Fusiform rust, caused by the fungus *Cronartium fusiforme,* Hedge. & Hunt ex Cumm. kills large numbers of seedlings and weakens the stems of larger trees. Loblolly and slash pines are particularly susceptible. Shortleaf is highly resistant.

Because infected seedlings almost always die within a few years, planters should try to get stock from nurseries where disease is kept under control by a careful spraying program. After the pines are a few feet tall, most new infections will develop on the branches. Branch cankers are not harmful by themselves, but they enlarge toward the stem. In a rapidly growing plantation, many of the lower branches die (and the disease with them) before the stem becomes infected. In young stands, however, and particularly in regions or years of heavy rust infection, it may be good insurance to prune live branches on which cankers are found less than 15 inches from the stem.

Fomes annosus root rot often kills many trees in plantations that have been thinned. Where the disease is prevalent, thinning should be delayed until serious losses from overcrowding are imminent.

Ice.-In stands that are heavily thinned, ice, sleet, or heavy snow may break or deform the trees. Permanent damage can be held to a minimum by frequent but light thinnings that leave the largest, most vigorous trees.

MANAGEMENT

Site protection should be the primary objective of pine plantation management on highly erosive soils (37).

Growth.-First-year height growth of loblolly seedlings in north Mississippi averages about 6 inches. It is generally somewhat greater on silt loams than on sandier soils. During the next few years growth on light-textured soils usually surpasses that on silt loams -especially those eroded to heavier-textured horizons or those with a fragipan. Early growth of seedlings planted along the drainage courses of gullies often equals that of seedlings in adjacent fields.

At 6- by 6-foot spacing trees usually close their crowns in about 5 years, although they may require 10 or more years on parent materials and compact subsoils. Enough litter to stop soil movement is usually produced within the first 10 years, and in the second decade the forest floor builds up rapidly. The pair of photographs on page 17 illustrates typical loblolly development on loessial areas Bullied and eroded to the underlying Coastal Plain parent materials.

Older plantings of loblolly and shortleaf suggest considerable economic promise in addition to watershed improvement. In 1959 a survey was made of pulpwood-size pine plantations established in north Mississippi by the Civilian Conservation Corps. Average annual growth was found to be 0.89 cord per acre for loblolly and 0.58 cord for shortleaf. Maximum annual growth of individual plantations was 2.36 cords

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Top: Gullied area in August 1957, shortly after loblolly pines were planted.
Bottom: Same area in May 1962. The 5-year-old pines have begun to stabilize the site. The expanding crowns will soon cover the remaining bare soil with needle litter

per acre for loblolly and 2.05 cords for shortleaf. Annual growth of the best 25 percent of the loblolly plantations averaged 1.65 cords per acre. The poorest 25 percent of the loblolly plantations had grown 0.21 cord per acre annually.

On experimental plots under management loblolly pine has produced as much as 4 cords per acre annually during a 5-year period following the first thinning.

Thinning.-Thinnings should be light enough to maintain a cover that will control erosion. They should be designed to concentrate diameter growth on selected crop trees and remove poorer trees for pulpwood.

Thinning can start when the trees average 6 inches in diameter and should be primarily from below. Very little cutting should be done in gullies except for salvage, and cutting near gully edges should be light.

Because of the danger of erosion, access roads should be located by a forester. Where feasible, they should follow ridge tops or level terrain. Logging crews should be closely supervised. Wet-weather logging should be avoided if at all possible.

If quality saw logs are the primary objective of management, stands should be thinned to basal areas of approximately 85 square feet on good sites and 70 square feet on fair sites. Basal areas 15 square feet higher than these are recommended if maximum pulpwood production is desired. At least 70 square feet of basal area should always be left on steep terrain.

Early clear cutting of pine plantations is impractical and uneconomical. For one thing, erosion is apt to start again. For another, profits are lost, because annual cord volume growth generally doubles during the years following the first thinning. Periodic thinnings will bring ever-increasing returns, particularly as the stands reach saw-log size-i.e., 10 inches d.b.h. and larger. Thinnings can be continued until the stand is 60 or 70 years old, at which time it can be regenerated by replanting or by leaving 20 to 25 of the best trees to produce seed.

Three and one-half cords of pulpwood per acre were recently thinned from this loblolly pine plantation, which was established 17 years ago on an eroded field. The remaining stand averaged 14 cords per acre. It is growing at the rate of 2 cords per acre annually and will maintain a protective layer of litter.

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