DIRECT-SEEDING PINES IN THE SOUTH

Harold J. Derr and William F. Mann, Jr.

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DIRECT-SEEDING PINES IN THE SOUTH

by

Harold J. Derr and William F. Mann, Jr.[1]

Direct seeding of the southern pines is a versatile reforestation technique that is being widely accepted by land managers. On many sites it is more economical than planting nursery-grown seedlings or waiting for natural reproduction. It is applicable on some sites where access, terrain, or drainage conditions make planting difficult. Commercial trials have proved it fast and reliable with all the important southern pines and in operations ranging from a few acres to units of 35,000 acres (*68*).[2]

While the technique for direct seeding is new, the basic concept is not. For more than a century, foresters throughout the world have been intrigued by the apparent ease and simplicity of starting stands by sowing limited quantities of seed at the right time on a suitable forest seedbed. Through the years pioneers in the regeneration of southern pines conducted sporadic trials, but their occasional successes were far outnumbered by failures. Usually work was stopped after a few setbacks. The early attempts clearly showed, however, that seed depredation by birds and rodents was the biggest obstacle.

In 1947, scientists of the Southern Forest Experiment Station began a concentrated, continued effort to make direct seeding a reality. The research, which was centered at Alexandria, La., was aimed chiefly at finding a practical method of protecting seed from birds, since in the South both resident and migratory species are usually numerous when pine seed is sown. Rodents, though a problem, were regarded as easier to cope with. Ways of improving and speeding germination were studied with a view to reducing the time seed is exposed to predators and weather. Information was also sought on the best seasons for sowing the various species and on methods of seedbed preparation.

The first breakthrough came in 1953, when sublimed synthetic anthraquinone and an imported commercial repellent containing anthraquinone were found to be effective, nontoxic bird repellents. In the first successful field demonstration of a chemical bird repellent, longleaf pine (*Pinus palustris* Mill.) seeds coated with the commercial preparation and sown at the rate of about 12,000 per acre yielded 4,500 seedlings in contrast to 195 for the uncoated seeds (*70*). Birds destroyed most of the untreated seed within 10 days.

In the next few years, thiram formulations, as well as several more anthraquinone compounds, were also found to protect seed from birds. By the fall of 1957, a seed coating that was repellent to birds, rodents, and many insects had been thoroughly tested. Pilot trials were undertaken immediately by industrial landowners, mostly in Louisiana where the research had been done. Pioneer operations succeeded so well that 75,000 acres were sown in the State during 1959—only 2 years after the first operational seedings (*67*). The practice quickly spread to other parts of the South, and within 10 years almost 1 million acres were direct-seeded. The recommendations developed

[1] Silviculturist and principal silviculturist, respectively, at the Southern Forest Experiment Station's field headquarters at Alexandria, La.

[2] Italic numbers in parentheses refer to Literature Cited, p. 62.

initially have proved basically applicable in all parts of the region and to the major southern pine species.

This handbook summarizes information from intensive research and operational direct seedings made under a broad array of conditions within the South. It includes published and unpublished information that has accumulated from 20 years of research and usage. Undocumented statements represent the best opinion of qualified observers with wide practical experience. The first section is intended largely for the land manager who makes policy decisions. It describes site conditions under which seeding is or is not feasible, and it weighs the alternatives of seeding, planting, and depending upon natural regeneration. Following sections provide detailed information for those who will be planning, executing, and evaluating a direct seeding. Experience has been greatest with longleaf, loblolly (*Pinus taeda* L.), and slash pine (*P. elliottii* Engelm.); but enough work has been done with shortleaf (*P. echinata* Mill.) and Virginia (*P. virginiana* Mill.) pine to permit firm recommendations. Because it has been seeded in the southern Appalachians, white pine (*P. strobus* L.) is also discussed. Careful adherence to prescriptions is suggested, especially in early trials for consistent success with this reforestation technique.

DIRECT SEEDING IN SOUTHERN PINE MANAGEMENT

Direct seeding should be regarded as another technique, along with planting and natural regeneration, for restoring depleted forests and for restocking lands promptly after cutting. As such, it affords the manager substantially more flexibility and, in many situations, greater economy in maintaining full productivity of his forests than he had previously. Rising costs for planting, an increasing shortage of labor, and the demand for prompt restocking to insure maximum timber production all are reasons for giving this technique careful consideration.

Landowners have shown great imagination and ingenuity in adapting direct seeding to many situations. It has been effective from Virginia to Texas, in the mountains and in the Lower Coastal Plain, on wet and dry sites, on lands with heavy grass sods or with dense stands of worthless hardwoods, on areas where seed trees failed to restock pines, and on sites with heavy debris from salvage cutting of stands damaged by fire or storm. Landowners of all types have used it, and several firms seed on contract and guarantee stocking.

A few landowners have switched completely from planting to seeding. Others believe planting is the better method for attaining their objectives. Most are using both techniques to maximum advantage by fitting each to situations where it is best suited.

Direct seeding is as reliable as planting when operations are executed according to recommendations. Most of the failures recorded over the last 10 years were due to human error. Use of poor seed, sowing too late, and attempting to seed sites on which planting had failed repeatedly have been major reasons for avoidable failures. Unfortunately, some landowners have judged seeding on hearsay from these trials, without learning the full reasons for the outcome. In other instances, managers have marked off their own efforts as failures when casual inspection (instead of systematic inventories) appeared to indicate an inadequate stand. Dozens of seeded areas have been planted before it was recognized that their stocking was already adequate. The only way for a manager to appraise the reliability of seeding is to conduct trials on his own land, making certain all recommendations are followed precisely.

Seeding Situations

Sites that can be seeded advantageously are numerous and extensive in the South. Practically speaking, they fall into two classes: open lands and those partially or wholly occupied by brush or low-value hardwoods.

Open lands with heavy grass sods (fig. 1), found predominantly in the Lower Coastal Plain, are often seeded with loblolly, slash, or longleaf pines (*24, 71, 72*). Such sites are relatively inexpensive to plant, but the speed of seeding large acreages has prompted many operations. Most longleaf pine has been sown on these sites. As longleaf is difficult to plant, seeding is the most practical means of reforestation.

Included in the category of open sites are abandoned fields and land on which timber has recently been clearcut. Normally, these sites can be seeded after a preparatory burn to reduce surface litter.

Direct seeding has also proved useful in restocking stands destroyed by wildfire and windstorms. Salvage cutting scarifies the soil, creating an excellent seedbed. Tops, stumps, and other impediments to planting are no obstacle to aerial seeding (fig. 2). Thousands of acres throughout the region have been regenerated in the same year in which their stands were destroyed (*16*).

Many open areas are on sandy flatwoods sites in the Atlantic and Gulf Coastal areas. Soils are wet most of the year, and a high water table in winter seriously impedes planting. These are among the easiest seeding chances, because there is ample soil moisture for germination and first-year survival. Outstanding results have been achieved on large tracts with no more site preparation than is needed for planting. If there is a medium to heavy growth of gallberry and palmetto or a dense sod of native grasses, disking or furrowing after burning usually improves survival and early growth. This is especially true for loblolly and slash

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Figure 1.—Cutover sites with dense grass sod have been sown extensively with longleaf, slash, or loblolly pine.

pine; if palmetto and gallberry are sparse, longleaf normally can be seeded on open sites without mechanical preparation.

Lands occupied by brush and hardwoods predominate in the South. They include a tremendous range of stand conditions—from cull stands of commercial species to dense thickets of low-value species and shrubs such as myrtle, gallberry, and titi. Some of the cover variations are due to regional differences in soils, drainage, and species composition; others are the result of previous management and fires.

Throughout the Lower Coastal Plain, pines have been sown extensively on sites preempted by low-value hardwoods (fig. 3). Grasses, which would compete vigorously with seedling pines, are largely shaded out by the hardwood canopy. Where the hardwoods are large, mechanical site preparation is unnecessary; individual stems are deadened soon after the pines germinate. Seeding has rarely failed on these sites.

Sites with small, dense hardwoods are more costly to regenerate, but they do not involve any greater risk. Usually the hardwoods are

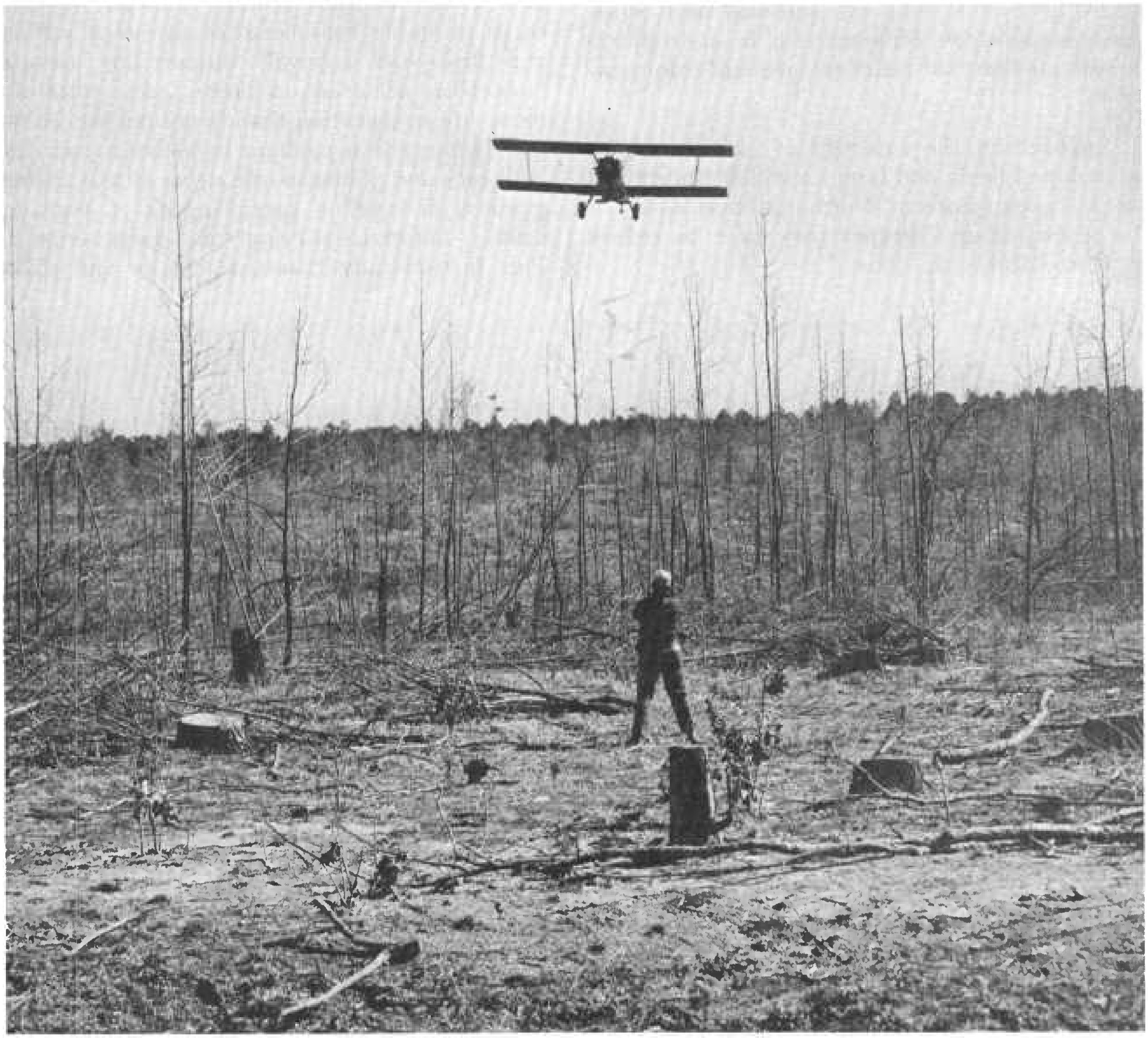

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Figure 2.—Salvage cutting of pine stands destroyed by fire often leaves so much debris that aerial seeding is the best method of reforestation.

destroyed in advance of sowing by chemical sprays or mechanical treatments like chopping, disking, or shearing. Mechanical control of the brush also prepares a seedbed; burning may be necessary when foliar sprays are used. Heavy debris from hardwood control does not hinder aerial sowing. In contrast, windrowing is often necessary before machine planting.

In the Southeast, titi flats and pocosins with heavy brush (fig. 4) are being seeded with consistent success (fig. 5); high water tables provide ample moisture for seedling establishment and survival. Mechanical reduction of hardwoods followed by hot fires gives sufficient site preparation for seeding. Debris from the hardwoods, a wet organic layer 12 inches or more deep, and thick masses of roots just below the surface make these sites difficult and costly to plant.

Stands of cull hardwoods in the Piedmont and the mountains of Georgia, Tennessee, and Arkansas have been converted to pine in large-scale seeding operations. They are treated like similar areas in the Coastal Plain, although soils are often rocky and the terrain is steep (fig. 6). Since dense, small hardwoods usually are present also, heavy machinery has been used for site preparation in advance of sowing (*38*).

Figure 3.—Upland pine sites occupied by low-value hardwoods can easily be seeded to pine. Hardwoods must be deadened soon after pine germination is complete. (Photo by Louisiana Forestry Commission.)

In Alabama, direct seeding has been successful on spoil banks left after strip mining (Fig. 7). The steep, rocky slopes are almost impossible to plant. Sowing at normal rates has given good stands of loblolly, shortleaf, Virginia, and longleaf pines. Even embankments with slopes of 70 to 80 percent have been reforested; apparently many seeds become lodged behind stones and in crevices that prevent them from washing away. Seeding has been more successful on fresh spoils than on those left for 5 or 6 years, probably because competing vegetation is absent. However, low soil pH has caused planting and seeding failures on some spoils where overburden from just above the coal seam was put on top of the banks.

On substantial acreages in the South, heavy clays compose the surface soils. They are virtually impossible to plant either by machine or hand; problems are encountered both in opening and closing a slit for the trees. These sites are readily seeded, and survival is usually high because the soils have excellent moisture-holding capacity.

Some soil or terrain conditions are unsuitable for direct seeding or require special treatment. Most prevalent, perhaps, are localized tracts of deep upland sands whose surface dries so rapidly that moisture is inadequate to sustain germination of broadcast-sown seed (fig. 8). On these sites, seeds must be covered with ½ to ¾ inch of soil (*39, 43, 75, 92*).

In addition, there are general areas where recurrent droughts or soils with poor moisture-holding capacity make pine regeneration difficult to achieve by any means. In such places, notably the extreme western portion of the southern pine belt, planting probably is more reliable than seeding.

Sowing should not be attempted on steep slopes if soil or cover conditions allow excessive washing of the seed in heavy rains. Slopes of 30 to 40 percent ordinarily are not too steep even

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Figure 4.—In the Southeast, heavy stands of saw-palmetto, gallberry, and titi must be reduced with machines and then burned before pines are seeded.

where erodible soils are relatively bare. On more stable soils, especially those with some cover to hold seed in place, and on spoil banks, slopes up to 80 percent have been seeded successfully. Finally, sowing should not be attempted on poorly drained sites where the seed or seedlings will be under water for more than 1 or 2 weeks (*60*, *78*). Practical means of preparing wet areas include drainage, elevating seedbeds by disking, or creating artificial tussocks. In some situations, sowing can simply be deferred until danger of seasonal submergence is past.

In summary, sites suitable for direct seeding include most of those available for commercial pine production in the South. Among these sites there are wide variations in soil and cover conditions. Usually some site preparation is

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Figure 5.—Wet coastal sites support dense titi (right) that must be destroyed with herbicides and fire before pines can be seeded. Slash pines at left are 3 years old. (Photo by Buckeye Cellulose Corporation).

needed; it may vary from intensive treatment that is essential for survival and growth to simple methods used primarily for increasing the probability of getting adequate stocking.

Plant or Seed?

Most of the sites described above can be planted or seeded with equal reliability. Why then choose seeding? There are two compelling reasons: lower costs, and a growing shortage of labor.

Costs of broadcast seeding vary by species and site conditions, ranging from about $4 to $8 per acre. The price of seed is the big item of expense, and many companies have cut costs substantially by collecting their own seed. Reports of row seeding (done with machines that prepare seedbeds and sow simultaneously) sometimes quote costs of about $3 per acre, primarily because less seed is required than for broadcast sowing. Of course, outlays for equipment are greater for row sowing than for sowing done with aircraft. None of these prices include hardwood control, which generally costs the same for seeding as for planting.

As a general rule savings from seeding are greatest where planting costs are highest. Differences average from $3 per acre on well-drained, open land to $15 or $20 per acre on rough sites where debris from hardwood control would slow down planting crews. Though seedbed preparation and control of hardwoods are the same for both methods in most situations, there are two major exceptions. First, disking is often needed before seeding on well-drained grassy sites, whereas pines can be planted directly in the rough. Second, felled hardwoods must be windrowed to allow movement of planting machines, while sowing can be done without this added expense.

Seeding has economic advantages in addition to lower direct costs. Large capital outlays for supplies and equipment are unnecessary (*49*). Contractual services are available for seed procurement and treatment, and for sowing. Then, too, large tracts can be seeded so rapidly that supervisory personnel are freed for other duties in a relatively short time.

Labor is becoming scarce. In many places, it is no longer possible to obtain hand crews for planting large tracts that are too rough for

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Figure 6.—Direct seeding is effective in regenerating steep, rocky sites such as this one in north-central Alabama. The pines are longleaf.

machine planting. In consequence, many companies with long-standing planting policies have been forced to start seeding.

The major objections to direct seeding are that it gives less control of stocking than does planting, and that trees are not established in rows when sowing is by broadcast methods. Many forest managers believe that regulation of the number of trees per acre justifies the higher costs of planting, since stocking influences tree size and time of first thinning. Moreover, well-defined rows are desirable for mechanical harvesting systems, which are gaining acceptance in the South.

These reasons are valid. It should not be overlooked, however, that stocking can be partially

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Figure. 7.—Spoil banks left from strip mining con be seeded reodily.

controlled by adjustments in sowing rate, although not so precisely as in planting. Row and spot seeding are alternatives for those who want trees in well-defined array (fig. 9).

The growth of seeded and planted trees has often been compared and, though data are limited to young stands, there is no evidence that the densities commonly achieved in direct seeding affect growth and yield (*28, 34, 47, 50, 80*).

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Figure 8.—Localized upland areas of deep, sterile sand are difficult to seed—or to plant. If seeding is attempted it should be done with machines that cover the seed.

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Figure 9.—These 3½-year-old longleaf pines demonstrate that row seeding gives good control of stocking.

Much tree improvement work is in progress, and in coming decades seed orchards will produce quantities of seed from selected superior trees (*106*). Will such seed be too scarce and expensive to use in direct seeding? It is doubtful that all production anticipated from orchards already established can be used in planting. Some form of spot or row seeding may be feasible. Possibly the elite seed can be mixed with some of lower quality, for if the seedlings from elite sources are truly superior they will dominate the stand. The others will be readily identifiable and can be removed whenever they have served their purpose as fillers.

Natural or Artificial Regeneration?

Artificial regeneration is becoming more important in the management of southern pine forests as the demand for wood increases. Consequently, greater effort will be expended to increase productivity on existing ownerships. Acquisition of new lands, the usual recourse in the past, will slow down because the acreage for sale is comparatively small and prices are high.

Silvicultural systems aimed at securing natural regeneration have been used widely throughout the South. The seed tree, shelterwood, selection, and strip-cutting systems have all been tried. Where summer rainfall is abundant, seed crops are frequent, and trees are not harvested until they are over 50 years old, natural regeneration will be relied upon for a long time. But these conditions are lacking in much of the region. In the middle and western portions, summers tend to be dry and some areas have not had a seed crop in 12 years. Furthermore, as management intensifies, the average rotation may be shortened to less than 50 years.

Natural regeneration is not always obtained cheaply or easily, especially by the seed-tree and shelterwood methods. Lightning, wind, and insects take a steady toll of the reserved trees (fig. 10), and since these are usually choice stems the loss of even a few per acre is costly. Harvest of the seed trees often damages the reproduction, and stumpage prices are usually less than for trees cut initially.

The success of natural regeneration hinges primarily on early occurrence of a seed crop. While crops fail or are delayed, sites remain unproductive, seedbed scarification from logging rapidly disappears, and dense brush may develop. The presence of seed trees also limits the intensity of fires that may be set for hardwood control and hampers mechanical control. During this unproductive period, taxes and management costs continue.

Naturally seeded stands are often patchy, with densely stocked and open areas interspersed. It is very difficult to fill the voids, and precommercial thinning is the only means of

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Figure 10.—Natural regeneration area with about eight loblolly seed trees per acre. While the forester awaits a seed crop, brush is invading the site and a high-quality tree has been killed by lightning.

regulating the overdense patches. If a bumper seed crop occurs immediately after logging, stands may contain as many as 20,000 pines per acre (fig. 11).

Many landowners have already recognized the shortcomings of natural regeneration and have started to liquidate seed trees, prepare sites, and restock pines by artificial means. In many parts of the South, natural regeneration probably is doomed to disappear as lands are managed intensively to obtain the full growth potential.

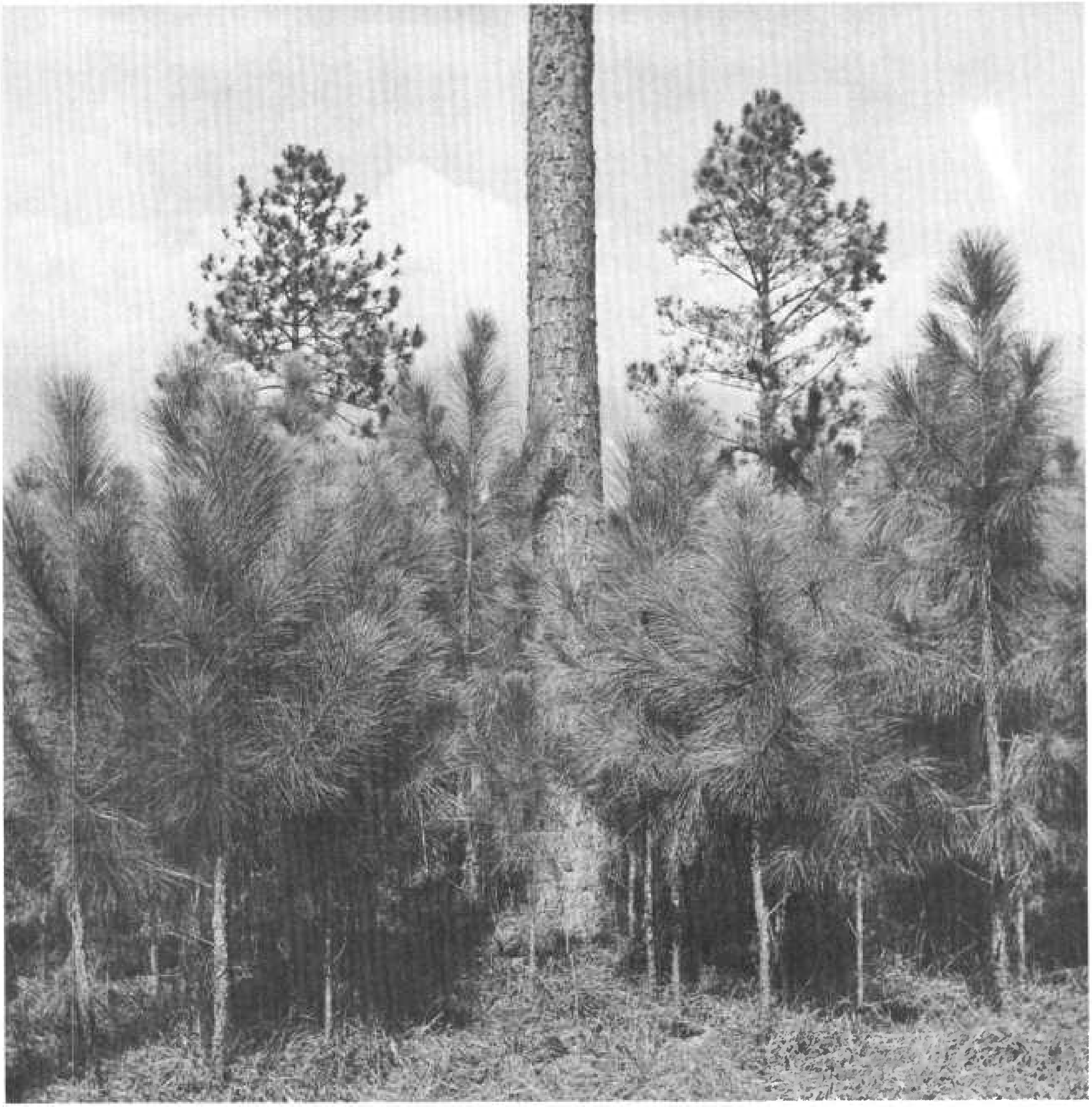

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Figure 11.—Little control of stocking is possible when stands are regenerated naturally. Here slash pine seed trees have produced a stand averaging 12,000 trees per acre.

CHOICE OF SPECIES

Choice of the best species is difficult on some sites; on others one species is clearly superior. In the coastal flatwoods, for example, slash pine has proved to be best suited. On the Upper Coastal Plain, where terrain is rough and hardwood competition is aggressive, loblolly pine is best. But there are broad areas where both species grow well on the same sites and where longleaf pine can also be used. Where there is a choice, the best course is to take the species that is superior in growth and yield. This is generally safer than following the oft-repeated rule of using the species that formed the original stand. Management problems such as disease, wildfire and unrestricted grazing are sometimes considered in selecting species.

On occasion, a mixture of two species has been sown, generally in the hope that if one failed the other would provide adequate stocking. Slash-loblolly mixtures have been tried, but with no clear advantage over either species alone. Conceivably, mixtures of loblolly and shortleaf and of loblolly and Virginia pine also could be used, but it is doubtful if the stands would excel those of a single species carefully selected for the site. Good separate stands of two species have been established adjacent to each other within fairly small areas. For example, longleaf has been seeded on upland ridges and slash pine has been planted on the interspersed lowlands where seeded longleaf does not compete well with dense grasses and sedges.

Basic direct-seeding procedures do not vary greatly from species to species. The same repellent formulation can be used, sowing methods are essentially alike, and all but one of the six species discussed here should be sown in the same season. There are, however, species differences in fruiting habits, seed size, seed dormancy, and site requirements. These and other relevant species characteristics are discussed in the following sections.

Longleaf Pine

Because it germinates rapidly and in cool weather, longleaf is often regarded as the easiest species to seed. It can be sown in the fall, when moisture in the surface layer of soil is less variable than in the spring. Fall-germinated longleaf seedlings survive early summer droughts better than seedlings that germinate in spring. Spring sowing is preferable, however, where danger of frost heaving or other winter damage is great.

Longleaf produces large quantities of seed at intervals of 3 to 5 years, and somewhere within the species' range there is a collectable crop nearly every year (*101*). Cones are easy to gather; yields of 10 bushels or more per tree are common in good years. Seeds are the largest of the southern pines and the least expensive when collected in quantity. Partially dewinged, they average about 4,500 per pound. They are never dormant, even after storage.

In planning for direct seeding, several characteristics of longleaf should be considered. First are its site requirements (*99*). While it does well on a wide variety of soils, its survival and early growth are best on well-drained sandy loams and sandy clay loams (fig. 12). It does not tolerate the dense herbaceous competition common to many poorly drained sites, and it requires prompt and complete release from overstory hardwoods.

A second important characteristic is its need for intensive protection and management during its grass stage—normally 3 to 6 years. It must be fully protected against hogs, sheep, and goats; and grazing by other animals should be regulated (*14*, *62*). Within their respective ranges, Texas leaf-cutting ants (town ants) and pocket gophers favor well-drained sites where longleaf pine is most likely to be used. These pests must be controlled before longleaf can be established. Most seedling stands require one or more prescribed burns for control of brown-spot needle blight, caused by the fungus *Scirrhia acicola* (Dearn.) Siggers. Longleaf's early tolerance of fire is an advantage in areas where the incidence of wildfires makes other species a risky choice.

The natural range of longleaf pine extends from Virginia to Texas and from the Gulf of Mexico to the mountains of north Alabama. The Southwide Pine Seed Source Study, which was undertaken during the early 1950's, has

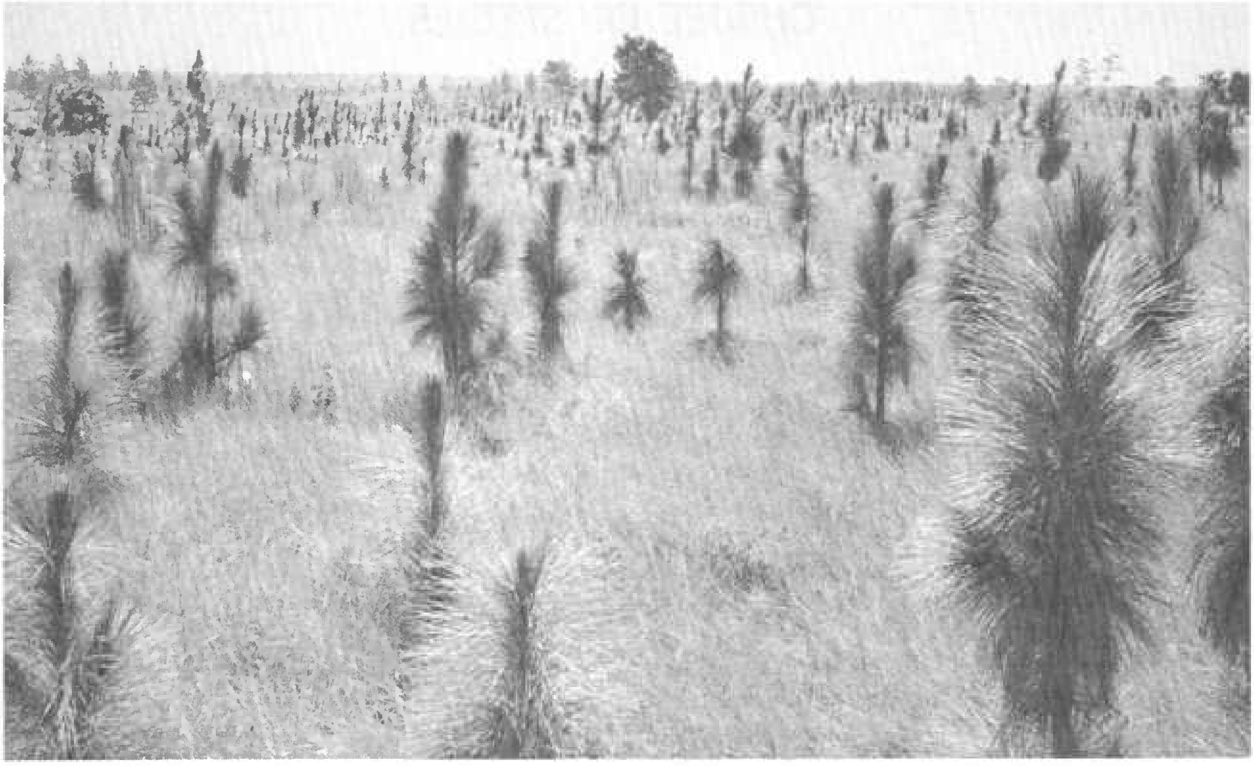

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Figure 12.—Aerially seeded longleaf starting height growth on an open, well-drained site.

shown that within this range there is substantial genetic variation associated with physiography and climate, and that some geographic sources are superior in specific planting zones (*103*).

Loblolly Pine

Its wide geographic distribution and adaptability to a broad array of sites—in particular those on which hardwoods are aggressive—make loblolly pine the most widely sown species (fig. 13).

Loblolly pine stands produce seed abundantly, but with somewhat less frequency than either longleaf or slash pine. Cones are most difficult of the three to collect; consequently, seed costs are highest. Cleaned, dewinged seed averages about 18,500 per pound.

With few exceptions, fresh or stored lots of seed are dormant and require stratification for maximum field germination (*57*). Unlike longleaf, unstratified loblolly seed does not germinate during fall or winter. Fall-germinated seedlings from stratified seed are often destroyed by freezing weather. Though fall sowing of unstratified seed for spring germination is possible, a more effective course is to break dormancy through artificial stratification, then sow in the spring when temperatures are reaching levels needed for germination (*71*). Juvenile seedlings are sensitive to drought in late spring or early summer but develop considerable tolerance of drought later in the summer. They are relatively intolerant of competition from dense grass or low brush; in fact, seeding loblolly is seldom advisable without some form of site treatment, such as disking, to reduce competition.

Within the main part of its range, loblolly is adapted to most sites capable of supporting pine. In many situations, management is not as demanding as for longleaf, though loblolly requires complete fire exclusion for the first 5 to 10 years. It grows best in soils with poor surface drainage, a deep surface layer, and a firm subsoil (*99*). It is a questionable choice for dry ridgetops, such as those occurring throughout the original range of longleaf pine, and on poorly drained soils having a hardpan (fig. 14). It can be established on these sites, but growth

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Figure 13.—Loblolly pine can be reliably seeded on sites dominated by cull hardwoods.

or tree form may be poor. Loblolly is attacked by the Nantucket tip moth (*Rhyacionia frustrana* (Comstock)) and the southern fusiform rust (*Cronartium fusiforme* Hedgc. & Hunt ex Cumm.). Both may be locally severe, and adverse sites tend to increase the hazard, particularly from tip moth. As neither pest can be controlled economically, each is a factor to be considered before loblolly is chosen for areas where it is not a prevalent species or for specific sites where it does not occur naturally.

Geographic variability within the broad range of loblolly pine has been recognized for many years; thus, all sources of seed are not equally adapted to a particular locality (*101*). Ten-year results from the Southwide Pine Seed Source Study have shown tentative possibilities for maximizing growth, survival, and fusiform-rust resistance by moving seed beyond local zones (*103, 104*). Forest managers who must utilize nonlocal seed should review carefully the latest reports of the Committee on Southern Forest Tree Improvement, which is sponsoring the Southwide Study.

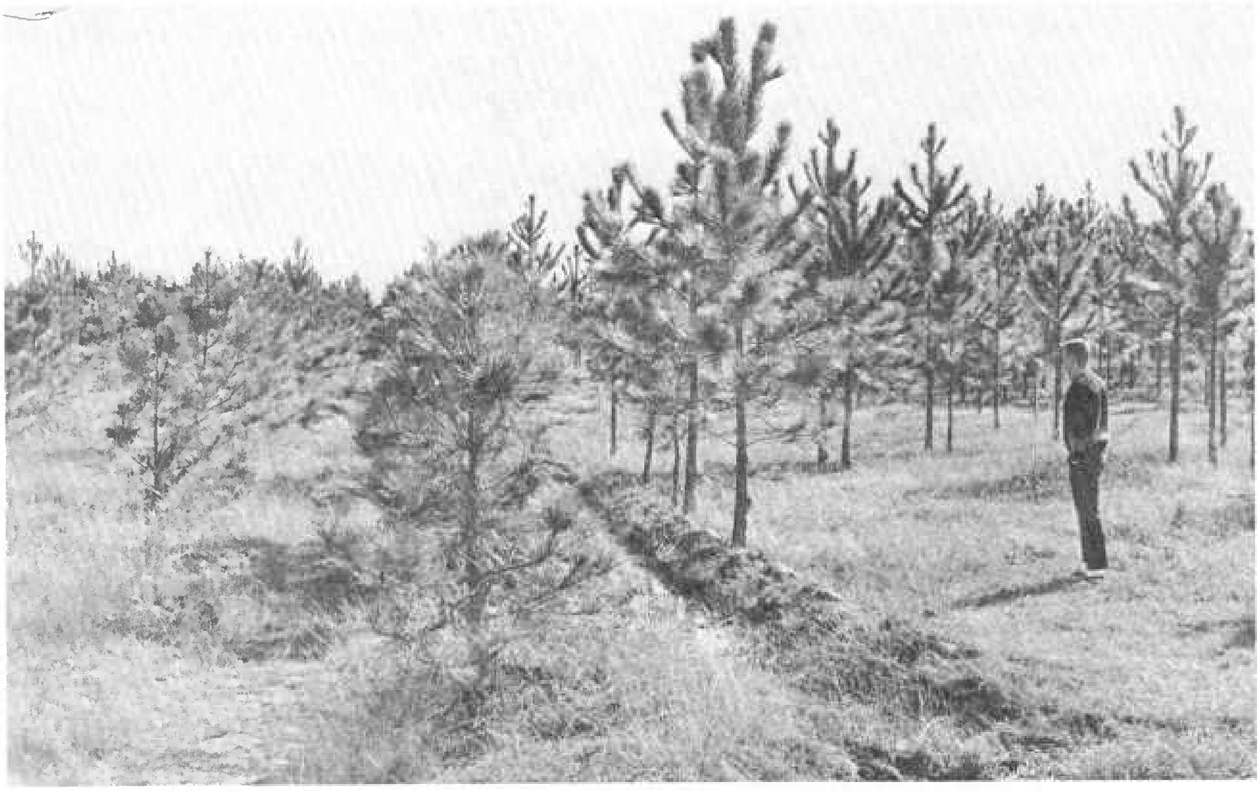

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Figure 14.—Loblolly pine (left) does not grow as well as slash (right) on poorly drained soils having a hardpan layer. These planted trees are 9 years old.

Slash Pine

Slash pine was the last of the three major southern pines to be used extensively in direct seeding, though for no clearly apparent reason. It is easy to start from seed, and many good stands have been established (fig. 15).

Some seed is produced within the slash pine range nearly every year, and cones are collected readily from standing trees. Consequently, seed costs are moderate, generally about midway between those for longleaf and loblolly seed when all three are available in commercial quantities. Cleaned, dewinged seeds average about 13,000 per pound. Seeds vary in their requirements for stratification. Some lots do not need it; others benefit.

If soil moisture is adequate, seed will germinate during warm periods in the early fall. Usually only a fraction of the sown seed germinates, the balance overwintering until late February or March. Spring sowing is favored in most places because fall germination is unpredictable and a winter-long delay reduces effectiveness of the repellent coating. In the extreme southern portion of the Gulf Coast States temperatures are high enough so that germination can usually be expected throughout the winter, and here fall sowing is recommended (*72*).

Juvenile seedlings grow rapidly, developing tall, succulent tops early in spring. They are sensitive to early droughts, and therefore benefit greatly from site preparation treatments (*88*) that reduce competition, conserve soil moisture, and permit rapid root development (fig. 16).

Slash pine is versatile. It has been planted and seeded on dry, sandy ridges as well as on heavy, poorly drained flatwoods soils. It is, perhaps, the best species for soils having a shallow claypan or hardpan, slow internal drainage, or a high water table. It has been used extensively outside its natural range, especially on former longleaf sites west of the Mississippi River. Northward extension of its range is limited principally by susceptibility to stem breakage in ice storms. Like loblolly, it is very susceptible

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Figure 15.—Seeded slash pine grows rapidly on mony sites. These are 5-year-old trees on wiregrass-polmetto lond in Georgio.

to fusiform rust, but it is resistant to tip moth attack and thus has been favored for areas where this pest abounds.

Of the two recognized varieties, var. *densa* does not thrive in continental United States outside its limited natural range in south Florida.

Typical slash pine, var. *elliottii,* has the smallest natural range among major southern pines. There is apparently continuous variation in Florida between variety *densa* in the south and variety *elliottii* in the north. The result is that genetic potential for fast growth and good survival decreases the farther south seed is collected in peninsular Florida (*96*). Several old seed-source plantings within the natural range of the species have shown that there is little geographic variation in volume growth, rate of infection by fusiform rust, or oleoresin production (*8, 23, 93*) among trees grown from seed collected along an east-west transect through the slash pine range from South Carolina to Louisiana. If plantings are planned very far outside of the slash pine natural range, however, seed from northern Florida and southern Georgia has less potential for growth and survival than seed from Mississippi, Louisiana, or South Carolina. The caveat also applies if seed is to be collected in old slash pine plantations, as practically all of them established before 1940 and many even later were from seed collected in northern Florida or southern Georgia (*93*).

Shortleaf Pine

Shortleaf pine has been seeded mainly in the northwestern part of its range, where it is the principal coniferous species. In the large Midsouth region where shortleaf and loblolly pine are associates on many sites, landowners favor loblolly. There are many reasons for their choice; from the standpoint of direct seeding, cost and availability of seed are the main ones. Though shortleaf has exceptionally heavy seed crops periodically, its cones are small and difficult to collect. Cleaned, dewinged seeds average about 45,000 per pound. They resemble loblolly in many of their characteristics—they normally germinate in the spring, they tend to be dormant, and they respond to stratification.

Shortleaf is a wide-ranging species, both geographically and among the many site conditions that occur within its range. Its best growth is on silt loams or fine sandy loams with good internal drainage, found mainly in

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Figure 16.—Site preparation enables slash pine seedlings to extend their roots rapidly and thus achieve a measure of protection against early drought. These 3-month-old seedlings had roots more than 10 inches long.

the flood plains of small streams (*99*). Hardwood competition is a common problem in shortleaf pine seeding. If soil moisture is critical, seedlings may benefit from shade during their establishment period, but they require release fairly soon after that (*82, 99*). Shade is not prerequisite, however, and stands have been established on sites completely cleared in advance of sowing. As with most broadcast seeding of pine, exposed mineral soil is needed for maximum catch.

Shortleaf is commonly regarded as drought-resistant, possibly because it colonizes dry sites where other species fail. The ability of young trees to sprout vigorously after a fire also helps perpetuate it under adverse conditions. It is relatively immune tc fusiform rust, but is attacked by tip moths and bark beetles (*99*). On heavy soils in some parts of the range, littleleaf disease has discouraged use of shortleaf pine in all forms of stand regeneration.

North-south geographic variation in shortleaf pine growth has been suspected for many years. These impressions have been confirmed by the Southwide Pine Seed Source Study, and seed-collection and planting zones have been proposed to enable land managers to take advantage of the inherent geographic variation in the species (*103*).

Virginia Pine

Virginia pine was long regarded as a low-value tree because of its poor form and persistent branches (fig. 17). Its ability to colonize and grow on impoverished sites and to produce pulpwood on short rotations has generated interest. Direct seeding is appealing because many of the sites to which it is suited are rocky and steep, hence difficult to plant. Seed is abundant because good crops occur frequently. Occasionally, there are good crops in two successive years, and normally some seed is produced every year (*98*). Cones and seeds vary greatly in size; the number of seeds per pound range from 40,000 to 78,000, averaging about 45,000. Virginia pine is unique among southern pines in that its seeds become viable at least 2 months before the cones open. Viability is indicated by a change in color of the cones from green to dark purple, and usually occurs in September. For cones collected at this time, however, a period of afterripening storage improves viability (*29*). Seedfall normally starts in late October and continues for approximately 3 months.

The seed normally germinates in the spring following seedfall. It is not as often dormant as loblolly pine seed, but some lots respond to stratification, and hence all lots should be routinely tested for dormancy. Delayed germination has been observed on several seedings, often until summer droughts ended in July or August of the first year (*95*). Apparently, the seed can maintain its viability through dry weather.

Virginia pine has been described as a disaster species, since it readily invades areas denuded by fire, storm, or cutting. It grows well on a variety of soils, but does best on well-drained clay, loam, or sandy loam soils. It readily invades impoverished sites such as eroded old fields, and is commonly the prevalent species on the poorer ridgetops, especially on soils derived from shale (*99*).

Virginia pine is intolerant, especially to overhead competition for light. That successful direct seeding requires fairly intensive site preparation was indicated by a series of 23 trials in West Virginia (*94, 95*). In these, various sites were prepared by methods that gave several degrees of competition control. Best results were achieved with treatments that eliminated grass sod as well as woody vegetation. On the Cumberland Plateau in Tennessee, Virginia pine can be seeded beneath hardwoods, where grass is sparse (*32*). Complete control of competing hardwoods in the first year is essential on such sites.

White Pine

Direct seeding of eastern white pine in the southern part of its range—the southern Appalachians in North Carolina, Tennessee, and Georgia—has been limited mainly to small trials. White pine has a good seed crop at intervals of 3 to 5 years (*99*), but lapses of 10 or more years may occur locally if attacks of cone insects are heavy or weather is adverse (*59*). Cleaned seeds average 27,000 per pound. They require prolonged stratification for optimum germination; 30 to 60 days or more is recommended (*18, 31*). Seed can be stored for 10 years or more (*84*).

FS-518986

Figure 17.—Virginia pine has poor form, but is a good pulpwood species on many sites. This 5-year-old stand was established beneath hardwoods, then released.

Much of the effective direct seeding in the northern part of the white pine range has been done on scarified spots, usually with soil covering the seed. Fall sowing of unstratified seed has been favored (*2, 3, 5*). Spring sowing of stratified seed has been effective in the southern Appalachians, and in at least one trial maximum germination (75 to 80 percent) resulted from a soil covering of ½ to 1 inch (*41*).

In the southern Appalachians, white pine grows at 1,200 to 3,500 feet above sea level, and is generally restricted to northerly aspects, coves, and stream bottoms. The ideal seedbed has been described as one with exposed mineral soil, roughened surface to facilitate seed coverage, and a light plant cover to cast patchy shade (*59*). Complete removal or drastic reduction of hardwood competition is considered essential, and old-field sites are not regarded as good seedbeds after heavy grass sods develop. Seedlings benefit from low shade during the establishment period, but later respond to full release.

Initial growth of seedlings is slow. On the Cumberland Plateau, 4-year-old trees from seed were as tall as planted seedlings of the same age (*87*). In this test satisfactory stocking was achieved by broadcasting about 10,000 full seeds per acre in early April on a hardwood-dominated site that had been scarified with a light disk (*33*). Much of the experimental work indicates that this relatively tolerant species may be better adapted for stand conversion than to the harsher conditions found on abandoned fields or on completely cleared sites (fig. 18).

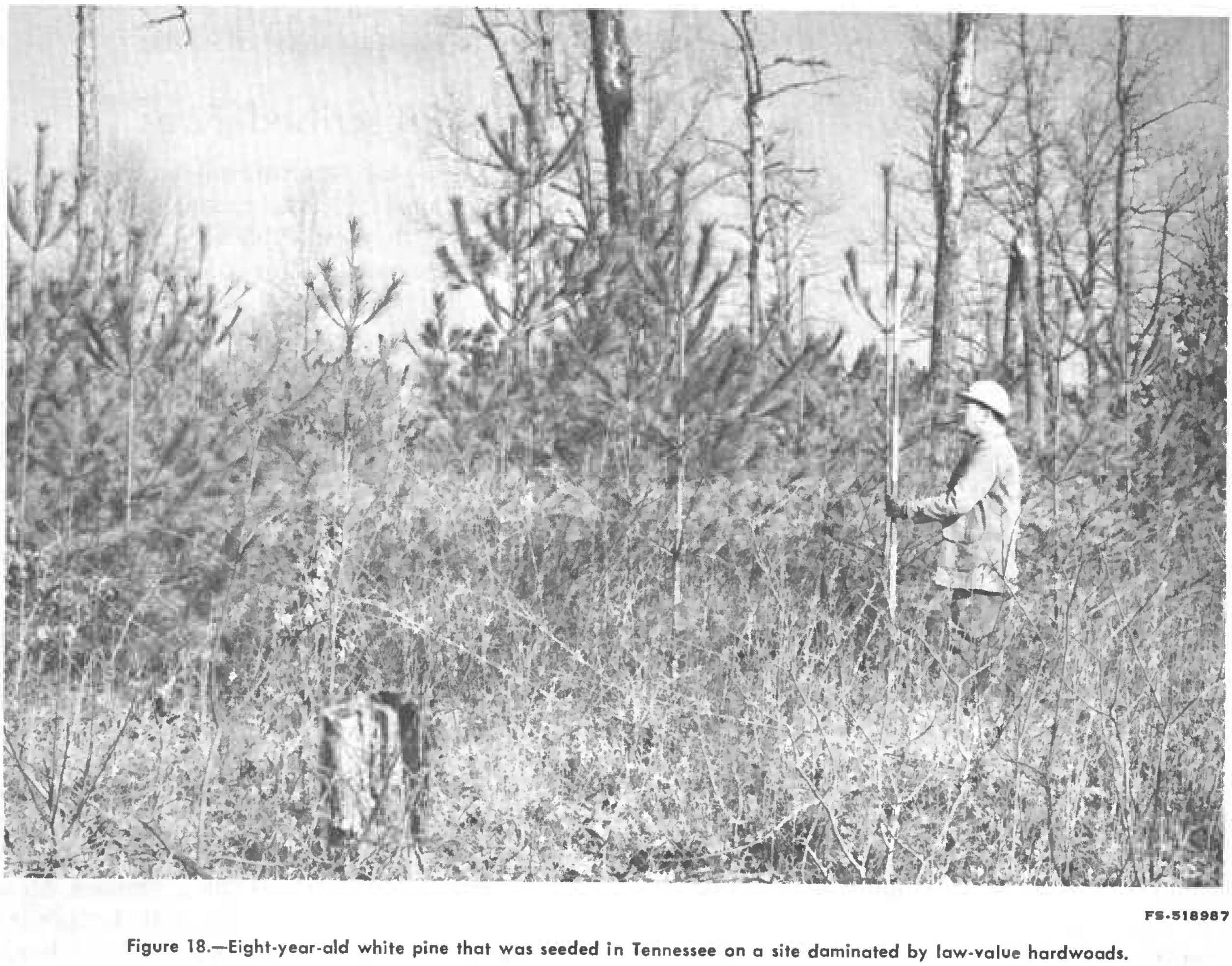

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Figure 18.—Eight-year-old white pine that was seeded in Tennessee on a site dominated by low-value hardwoods.

SITE AND SEEDBED PREPARATION

Selecting sites that can be seeded to pine and choosing presowing treatments are closely related planning tasks. Sites cannot be judged without considering the cost, time requirements, and silvicultural effects of the treatments needed to put them in shape. Methods vary in cost and intensity, but in most cases conditions on the site determine the method that must be used. Undertreating a site is more common than overtreating, for it is easy to overestimate the long-range effect of a single treatment—especially on sites with aggressive, fast-growing weed hardwoods. Increasing demand for land and raw materials is moving pine regeneration efforts onto sites heretofore neglected because of adverse terrain or preemption by worthless and low-value species. Such sites require expensive preparation, whose justification or long-range impact on land and timber values is beyond the scope of this handbook.

Site preparation has two objectives, usually achieved concurrently: to expose the mineral soil that pine seeds need for germination, and to control competing vegetation that will interfere with the survival and early growth of the new stand.

Fire is the simplest and least expensive method of site preparation, and on open sites it is often sufficient by itself. On areas with hardwood trees or brush, it is combined with mechanical treatments like disking, chopping, or shearing. Whatever means are chosen, fairly complete removal of competing hardwoods is usually requisite, even where the trees occur in groups and pine seeding is restricted to openings. All southern pines, including Virginia pine, can be established beneath hardwoods, but none can survive much beyond the first year without considerable mortality and loss of vigor. Figure 19 and table 1 illustrate the point for loblolly pine, which is relatively tolerant of hardwood competition. In appraising a hardwood-dominated site, the likelihood of sprout growth must be considered. If the trees are large enough to be treated individually with a chemical, sprouting is not likely to occur. But if a dense stand of small stems is treated superficially, as by light disking or single chopping, sprouts may develop rapidly and in such abundance as to overwhelm the pine seedlings.

Table 1.—*Effect of time of release on survival and height of seeded loblolly pine* [1]

Treatment	Survival after—			Height after—		
	1 yr.	2 yrs.	3 yrs.	1 yr.	2 yrs.	3 yrs.
	Pct.	*Pct.*	*Pct.*	*In.*	*In.*	*In.*
Seeded February 1959						
Released May 1959	51	43	35	5	13	31
Released April 1960	58	45	37	3	7	23
No release	57	46	36	3	4	7
Seeded February 1960						
Released May 1960	72	51	39	5	17	39
Released April 1961	58	48	41	3	9	25
No release	59	50	33	3	5	9
Seeded February 1961						
Released February 1961	79	71	[2]	5	15	[2]
Released May 1961	75	61		5	16	
Released April 1961	78	62		3	7	
No release	88	71		3	4	

[1] From Hatchell (*35*). Release was obtained by injecting hardwoods with chemicals.

[2] No third-year data—study terminated.

Prescribed Fires

Prescribed—i.e., controlled—burns may be made on almost any site except in the mountains, where they are difficult to control and may induce erosion. Low coastal areas with deep organic soils may be so wet that fires are impossible during most of the year. They are normally burned just ahead of sowing—that is, in fall and winter for spring seeding. For early fall sowing of longleaf pine on grassy sites, burning should be done one growing season in advance. The light grass rough that then develops provides a better germination environment for longleaf than does a newly burned site (*24*).

While exposure of mineral soil is the main effect of a presowing burn, there are additional benefits. For longleaf seeding, fire removes brown-spot infected foliage from natural seedlings. On sites with a heavy grass rough it destroys the habitat of troublesome rodents such as the cotton rat. Contrary to popular belief, burning does not have much effect on most other common species of small mammals. Most trapping studies have shown only temporary reductions in animal numbers following a burn,

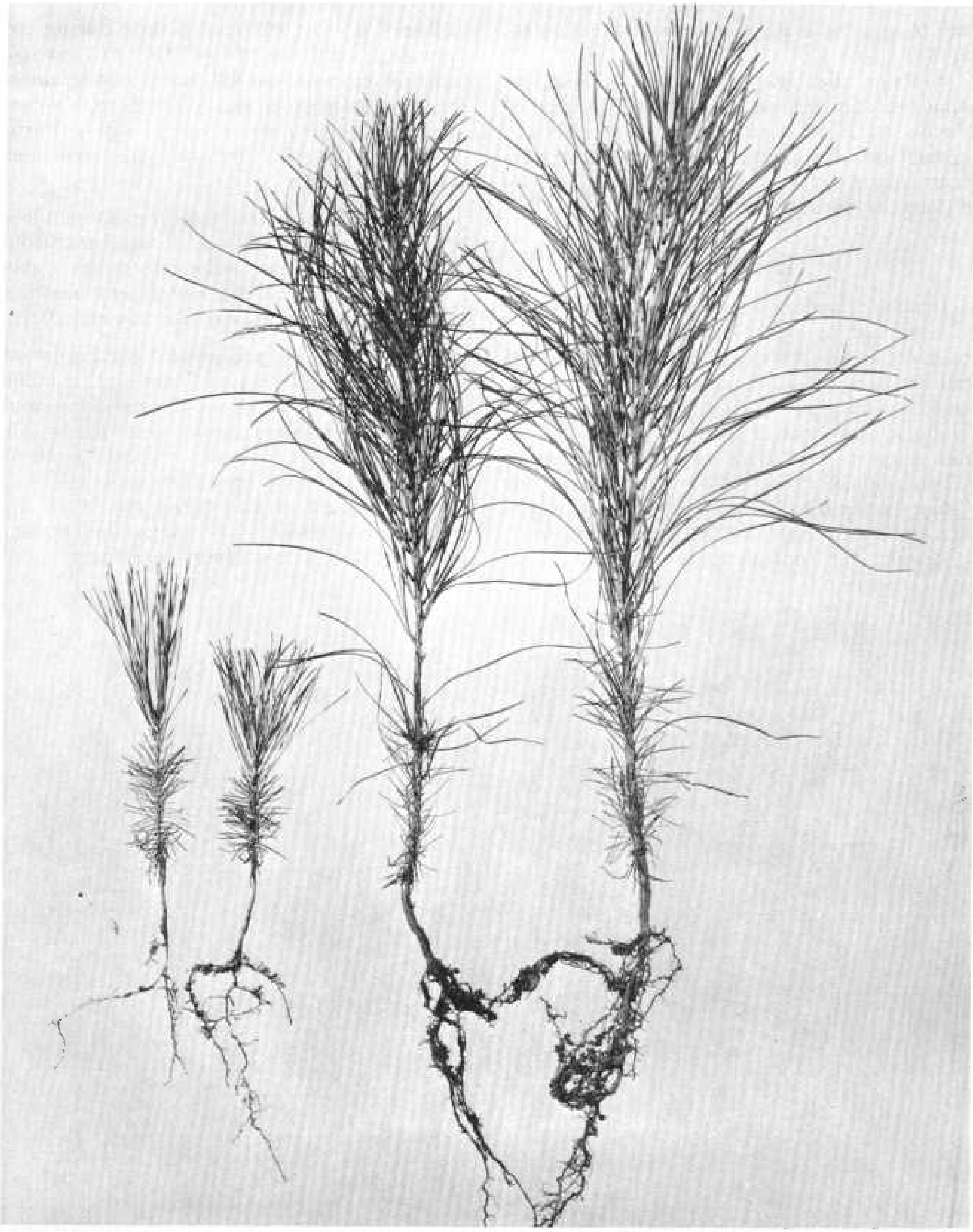

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Figure 19.—Early release from overtopping hardwoods is essential for rapid pine growth. One-year-old loblolly seedlings on the right were released in June; smaller ones were not released.

and in some cases numbers have increased (*10, 36, 91*).

A single burn will also reduce competition somewhat, but will not give sufficient control of shrubs, small hardwoods, and palmetto. Though a well-timed fire normally kills the aerial portions, sprout regrowth is often rapid. Thus additional preparation may be needed.

Disking

Disking is a more intensive treatment that is widely used on open, grassy sites or where palmetto and gallberry are abundant. It exposes mineral soil and reduces competition—the amount depending on its timing and intensity. A single pass with a heavy-duty agricultural disk harrow is sufficient on most grassy sites. When confined to strips—separated by 6- or 7-foot undisked balks—this treatment has been accomplished for about $2.50 per gross acre.

Disking for control of grass, palmetto, or gallberry is most effective if done during the summer or early fall. Hot weather and low soil moisture increase the kill, and there is ample time for the loosened soil to settle, thus reducing the proportion of seed lost by silting. Burning ahead of disking increases effectiveness of the cutting blades.

Several studies with longleaf, slash, and loblolly pine have shown that disking markedly benefits first-year survival in dry years (table 2). In two studies the subsequent seedling growth was also improved (fig. 20a and 20b).

Heavy disks have proved useful in hardwood stands in the northern part of the southern pine range. The disks, which weigh several tons and require large tractors, uproot small hardwoods and at the same time expose a seedbed by turning under the heavy layers of leaves and duff that are typical of such sites (fig. 21). The disks are also effective on heavy soils that cannot be worked with ordinary machinery.

FS-518989

Figure 20a.—These slash pines were seeded on disked beds. At 6 years of age they averaged 3 feet taller than those shown on the opposite page (fig. 20b), which were established in a grass rough on the same area.

Table 2.—*Average survival and height of seeded pines on disked and untreated secdbeds on open grassy sites; data are from four studies*

Species and seedbed	First-year survival [1]	Height of dominants	
		At 5 yrs.	At 9 yrs.
	Pct.	*Ft.*	*Ft.*
Slash pine			
Disked	28	8.2	---
Untreated	10	5.4	---
Loblolly pine			
Disked	58	---	19.2
Untreated	37	---	15.2
Longleaf pine			
Disked	65	---	---
Untreated	10	---	---
Slash pine			
Disked	22	---	---
Untreated	<1	---	---

[1] The first summer was dry during all trials.

Disking elevated seedbeds is a common practice on sandy flatwoods sites where water tables are high (fig. 22). Competition from wiregrass, titi, gallberry, and palmetto is greatly reduced, and the soil is mounded for good seed germination and seedling growth. This treatment requires a special implement that throws the soil inward from both sides, in contrast to the flat, offset disks used in most situations.

While disking often improves survival and early growth, initial seedling catch usually is somewhat less than on comparable undisked, burned beds, because some seeds are silted over deeply by loose soil. Such losses can be partially avoided by letting disked soil settle before pine is sown, but usually they must be compensated for by a higher sowing rate. Simple broadcast sowing is effective on disked ground, though greater yields can be achieved with machines that drop seeds in rows and have packing wheels that put them into firm contact with the soil.

FS-518990

Figure 20b.

Figure 21.—A 3½-ton disk destroys small, dense hardwood in preparation for direct seeding in Tennessee. (Photo by Tennessee River Pulp and Paper Company.)

Furrowing

Another intensive seedbed treatment is furrowing with middlebreaker plows. It is costlier than disking because the production is considerably less for the same expenditure of power. On many soils, deep furrows create drainage problems as well as a surface roughness that hampers vehicle travel for fire control or other purposes. Consequently, furrowing as a separate operation is usually limited to small areas or to well-drained sands. Furrowing plows, however, are an integral part of many row-seeding machines that have been developed for preparing seedbeds and sowing in one operation.

The principal advantage of furrows is the complete removal of nearby competing vegetation. If sites are droughty, furrows usually are superior to any other method of seedbed treatment. They are particularly advantageous on some deep sandy soils. The firm soil at the bottom of the furrow has more moisture than untreated or disked surface soil and is ideal for operation of equipment that sows seed at precise depths. Occasionally, furrow-making equipment is used to elevate a seedbed; seeds are then placed on the common ridge between two adjacent furrows.

On heavy soils, siltation or standing water may cause substantial loss of seed in furrows. Applicability of row seeders on such soils is limited, because there is no time lapse for initial melt-down of the loose soil. The problem has been alleviated somewhat by attachments that elevate a small ridge within the furrow, but such ridges do not protect the seed if furrows impede natural drainage or if erosion occurs on slopes not properly contoured. On deep infertile sands, such as occur in western Florida, furrowing may reduce seedling growth by displacing essential topsoil (*89*). In more northerly areas, deep furrows may expose heavy subsoil on which seedlings are subject to frost heaving. Furrows, therefore, should be cut no deeper than necessary to remove competing vegetation.

Site Clearing

Where disking or furrowing are inadequate or impossible to apply, much more expensive treatments are used. These are essentially land-clearing operations and include removal of vegetation by bulldozing, chaining, shearing, or cutting with heavy drum choppers (fig. 23). Except where erosion is a hazard, a burn is generally made to reduce the debris (after it has dried) and kill sprouts. Usually these treatments create a mineral seedbed, but occasionally the cleared site is also worked with a heavy disk. Chaining and bulldozing are most effective on sandy soils, where large hardwoods are easy to uproot. Shearing and chopping are in greater use on all types of soils and sites. All these methods give adequate control of hardwoods up to 12 inches in diameter, and there is little apparent advantage between them. Shearing is cheaper in some situations that would require a double pass with a chopper.

Heavy-duty machines can be recommended only for large-scale operations, after thorough study of alternatives. They are most applicable when a massive treatment is required to reclaim sites from invading hardwoods and a large volume of material must be removed or reduced. They provide excellent conditions for direct seeding, and have been used to convert many thousands of acres to pine.

F9-518991

Figure 22.—Disking elevated beds improves tree growth on flatwoods sites with high water tables.

Site Amelioration

Direct seeding has been extended to sites that require modification for optimum growth of pine. Site modification, sometimes referred to as site amelioration, includes drainage, high bedding, and creation of artificial tussocks. Two or more of these treatments may be applied to the same site. They are often necessary in low coastal areas and other places where drainage is slow and water tables are high during much of the year (*42*). Pines have shown a striking growth response after sites were drained by canals (*61*). Drainage has proved beneficial on both sandy and deep organic soils.

High bedding (fig. 24) is an intensive disking or furrowing treatment done with equipment that elevates the seedbed about 5 inches. In a modification of the treatment, small mounds are created at regular intervals by pushing up topsoil with a bulldozer blade. Seedlings established on the elevated beds have grown faster than those on untreated sites. In some wet areas, mounds or tussocks are the only places where pine seedlings will survive and grow (*17*).

FS-518992

Figure 23.—A heavy drum chopper preparing a site in north Georgia.

F8-518993

Figure 24.—Where surface flooding occurs, elevated beds can be made with furrowing plows.

DIRECT-SEEDING TECHNIQUES

This section is for the guidance of those responsible for the sowing phase of the direct-seeding job—the men on the ground. It summarizes research and operational experiences in procuring, testing, and treating seed; in selecting the optimum date and rate of sowing; and in distributing seed accurately by various methods.

Seed Procurement

Only good seed should be used. If stocks do not meet reasonable standards of quality, seeding should be deferred. Frequently, sowing is done with seed that becomes available at the last minute, or with "bargain" lots of dubious quality—often on sites not properly prepared.

Some of these attempts succeed, but most fail, and often it is the seeding technique itself that is ultimately blamed for the failure.

Experience has shown that 85 percent viability is a realistic minimum when procuring seed. Properly handled, most lots meet this standard; mishandling or improper storage should be suspected for lots that do not. If seed viability falls much below 85 percent—to 60 percent, perhaps—vigor may be declining fast and field sowing may be futile except under ideal conditions. Frequently, sowing rates are raised to compensate for low seed viability. This procedure may be used for lots having 70 to 85 percent viability, but lots below this range should be diverted to nursery sowing, where germination conditions are under some control.

Purity or cleanness of the seed is also of concern. Foreign material or a large proportion of empty seed reduces accuracy of all metering equipment, and, of course, lowers the number of sound seeds per pound. Modern seed-cleaning machines are capable of removing most impurities. A reasonable specification for commercial seed is less than 2 percent impurities by weight. A minimum of 95 percent sound seed should also be specified, along with a moisture content of 10 percent or less.

Commercial dealers have furnished the bulk of the seed sown to date. Most of them have modern facilities for handling large quantities of cones, for dewinging and cleaning seed, and for storing it. Consequently, they have been able to supply seed in large quantities and at reasonable cost. The main disadvantages of depending on commercial sources are the uncertainties of supply in poor seed years, nonavailability of local seed, and the possibility that seed was collected from trees of poor form and vigor.

While dealers may not always have "local" seed, they can generally identify the geographic source for lots available. Seed should be tested for purity, germination, and moisture content before it is purchased, and price should be based on dry seed (10 percent moisture content or less) without a coating. Costs of stratification and repellent treatment, if furnished by the vendor, should be negotiated separately. Both treatments add considerable weight to a lot of seed.

Some landowners have economized by collecting their own cones. Such collections are especially effective when supplies for several years can be obtained from a bumper crop. In addition, local seed is assured. On the other hand, large-scale collections require an organization trained to obtain needed quantities in a few weeks. Equipment for drying cones and processing seed must also be available, unless this work is contracted to a commercial firm.

A landowner should try to collect cones from the best stands. When such stands are not producing cones or cannot be cut to facilitate seed harvest, the only possible control of quality is to avoid trees that are obviously defective or of poor form (fig. 25). Open-grown trees often bear the most cones and are a good source for species that can be gathered by climbing—longleaf, slash, and in some cases loblolly pine. The quality of individual open-grown trees is hard to judge, because all tend to have large crowns and coarse branching, but if the defects illustrated in figure 25 are absent such trees may be considered acceptable. Most collections from loblolly, and practically all those from shortleaf, Virginia, and white pine, are made from felled trees. Coordination of cutting operations is necessary, so that the cone-bearing trees are felled after the seeds are ripe but before cones begin to open. With longleaf and slash pines, mechanical tree shakers, of the kind used in pecan orchards, are an alternative to climbing or felling.

Cone and seed yields can be estimated in advance. There is, for example, a consistent relationship between the total yield of cones from a tree and the number visible from a single position on the ground. On loblolly and slash pines a careful man with binoculars can count one-half of the total cones from a single observation point (*100, 102, 105*). Several investigators have developed formulas for estimating the number of full seeds per cone from the number of sound seeds exposed when sample cones are bisected longitudinally with a sharp knife (fig. 26). Table 3 illustrates relations between count of exposed seeds and seed yields from cones of the major species. Since yields per bushel of cones vary widely, these techniques are useful in locating collection areas well in advance of cone maturity.

Cones should be allowed to mature on the

FS-518994

Figure 25.—Forking, low branch angle, and disease are obvious defects to avoid in selecting trees for cone collection.

Table 3.—*Seed yields per cone, as estimated from number of seeds exposed when cones are bisected longitudinally*

Average number of sound seeds exposed	Total sound seeds per cone for—				
	Longleaf,[1] Louisiana	Loblolly,[1] Louisiana	Slash,[1] Louisiana	Slash,[2] Ga.-Fla.	Shortleaf,[3] Virginia
	No.	*No.*	*No.*	*No.*	*No.*
2	23	31	20	31	12
4	35	44	35	50	22
6	47	57	50	69	31
8	59	70	65	87	41
10	71	83	80	106	51
12	83	96	95	124	60
14	95	109	110	143	70

[1] From McLemore (*55*).
[2] From Asher (*4*).
[3] From Bramlett and Hutchinson (*11*).

tree. Premature collection is a common error; it reduces seed yield per bushel and probably also depresses seed vitality for all species except perhaps Virginia pine (*51, 101*). Cones may be considered mature when their specific gravity drops to 0.89 or less. As dates of maturity vary from tree to tree, a fairly large sample is needed to estimate this stage for a stand. Wakeley's method of estimation—when sound, fresh cones from 19 out of 20 trees float in SAE 20 motor oil—has stood the test of time and is the easiest to apply (*101*).

Cones are often stored for varying periods—either through necessity or to allow some predrying before kilning. The length and condition of storage should be controlled. Bagged cones stacked loosely on racks in a well-ventilated

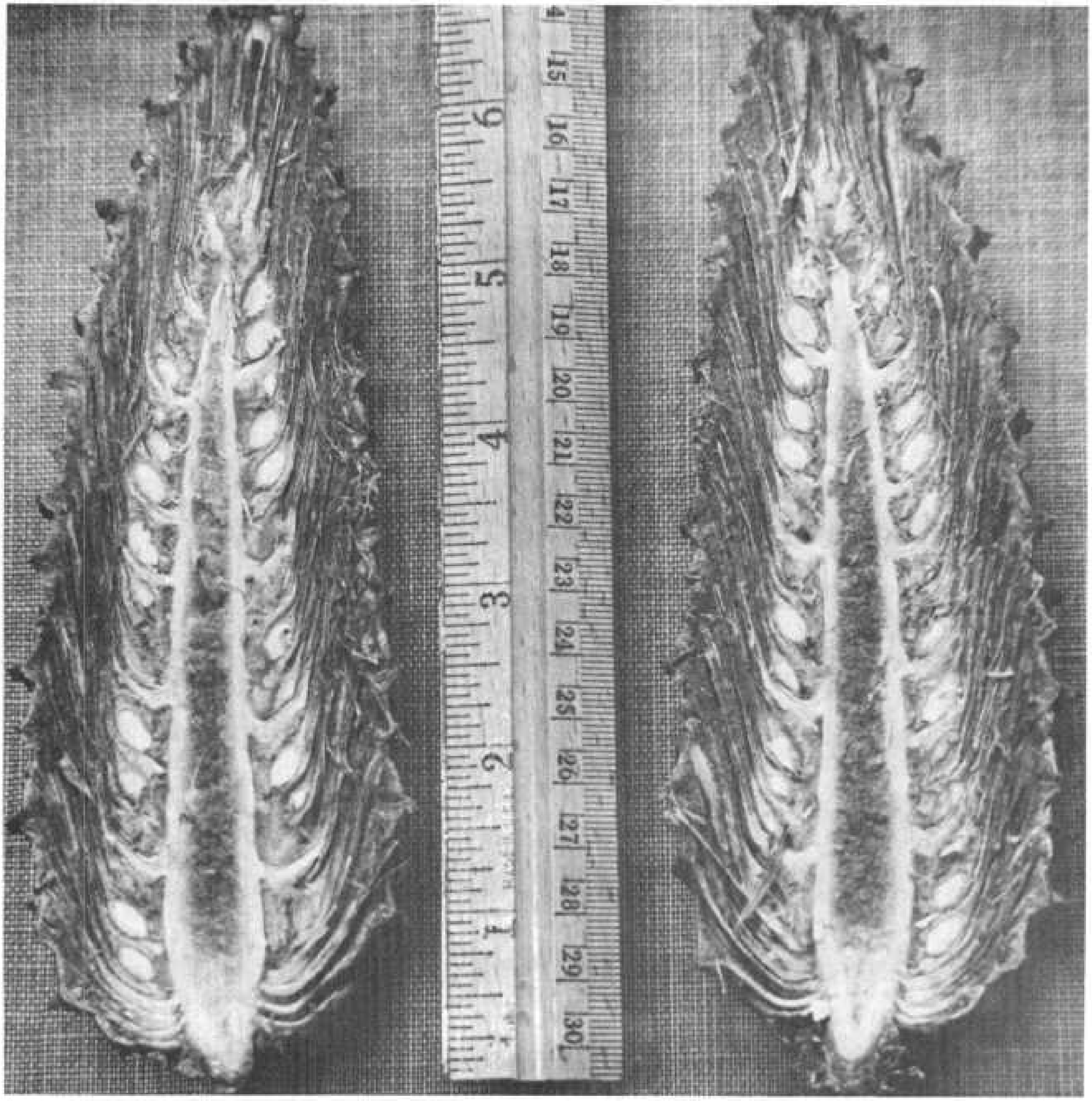

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Figure 26.—A longleaf cone sliced longitudinally to expose sound seeds, which are counted to predict seed yields.

building or an open shed can usually be held for 30 days without loss of seed yield or vigor (*15*). Longer storage may affect quality of the seed (*52*), and any condition that allows molding of the cones is detrimental.

Gas-fired kilns, developed in recent years, are capable of drying large quantities of cones quickly. The final drying needed to open a cone is often accomplished in less than 48 hours. Small kilns, suitable for research and for the landowner with 1,000 bushels or less to process annually, have been developed (*53*). Local extraction also requires a tumbler for removing seed from opened cones, a dewinger, and a small fanning mill for cleaning the seed. Tumblers and dewingers must be built locally. If improperly designed or operated, dewingers will damage seed. Inspection of models in operation is recommended before one is constructed.

Seed Storage and Testing

At one time, fresh seed was considered essential for direct seeding, but it is now known that seeds of all species can be used after storage for 10 years or more. Some species retain their viability better than others, but all have essentially the same requirements for storage. These are prompt drying after extraction to a moisture content of 6 to 10 percent (based on dry-seed weight), followed by storage in sealed containers at a temperature between 0 and 32° F. (*44, 46*). Seeds of longleaf are the most difficult to store; they deteriorate faster and are more sensitive to improper storage. High viability can be maintained for long periods (*54*), however, and good stands of longleaf have been established with stored seed (*6*).

Proper storage in the few days or weeks during or immediately before seeding is important, though frequently neglected. The safest procedure is to place seed immediately after receipt under refrigeration at 34 to 36° F. However, most lots, including stratified ones, can tolerate a few days or even a week in a cool, dry, well-ventilated warehouse. Common errors include storage on damp floors, in warehouses where temperatures exceed 80° F., and in compact piles. Individual bags should have free ventilation to permit some drying and to prevent heat buildup. For stratified seed, it is advisable to repackage into sublots of 50 pounds or less if short-term storage is necessary and cold-storage facilities are not available. Lots should be examined frequently for evidence of heating or molding, which can destroy viability in a short time. If trouble is detected in time, the solution is to spread the seed in thin layers for aeration and drying, then repackage in smaller containers.

Routine storage of repellent-coated seed is not recommended, but occasionally seeding is delayed by adverse weather or other factors after the seed has been stratified and coated. Several tests of repellent-coated, stratified seed of loblolly, shortleaf, and slash pine have shown that cold storage for 40 to 120 days is not detrimental (*45, 74, 76*) ; storage for 1 year is also possible (*56*). Slash pine, however, should be dried to 10 percent moisture content before storage. Restratification after storage is not necessary for seed of any species. If storage of loblolly and shortleaf pine becomes necessary after stratification is completed but before the repellent is applied, the seed should also be dried before storage. Repellent-coated longleaf seed, which is never stratified, can be stored for a year if the moisture content is reduced to 10 percent or less (*7*). The recommended post-treatment storage temperature for all species is 25° F. Chemical analyses of the repellent coating have shown no loss of effective material during 1 year of storage (*56*).

Hazards of the repellent coating should be kept in mind in selecting storage space. Thiram is not ordinarily considered dangerous, but the endrin component is highly toxic. Treated seed must be stored where it is inaccessible to livestock, pets, or children. It should not be placed in cold lockers with unsealed food items.

Before use, seed lots should be carefully tested to determine if (1) viability meets minimum standards, (2) sowing rates must be adjusted, and (3) stratification is needed for spring sowing. Therefore, the tests must include representative samples of both stratified and unstratified seed and must be timed so that results are available when needed. For example, loblolly seed that may need 30 days of stratification must be sampled at least 3½ months before the planned sowing date. Facilities of specialized seed-testing laboratories should be used. In sand-flat tests on an office window-ledge, variations in temperature, moisture, and light may invalidate results. The Forest Service's Eastern Tree Seed Laboratory (P. O. Box 1077, Macon, Georgia 31202) and some State seed laboratories perform all tests needed to evaluate purity and viability, and their fees are nominal. Such laboratory tests also provide a firm basis for judging the value of seed offered for sale. Seed destined for long-term storage should be tested before storage begins, and at yearly intervals thereafter.

Stratification of Seed

Cold stratification usually improves the speed and completeness of germination if seed is dormant (table 4). Rapid germination is desirable

Table 4.—*Field germination of cold-stratified and unstratified loblolly pine seed in three studies*

Year of study and seed treatment	Germination after—			
	17 days	27 days	37 days	60 days
	Pct.	*Pct.*	*Pct.*	*Pct.*
1952				
Stratified	12	27	31	32
Unstratified	0	1	5	9
1952				
Stratified	24	36	38	38
Unstratified	0	2	4	14
1953				
Stratified	26	30	30	39
Unstratified	9	16	26	32

in spring sowing, because it reduces the time seed is exposed to predators, assures maximum germination while weather conditions are optimum, and gives seedlings time for development before the onset of hot, dry weather. Early germination of stratified seed often improves total seedling yield. In one study in which loblolly pine was spring-sown on four seedbeds, stratified seed germinated promptly, but untreated seed gave low initial stocking when drought reduced surface moisture below levels needed for germination (table 5). Stratification is unnecessary in fall seeding, since seeds overwintering on the ground are adequately conditioned.

Table 5.—*Initial stocking from stratified and unstratified loblolly pine seed sown at the rate of 1 pound per acre*

Seedbed condition and seed treatment	Seedlings per acre	Increase from stratification
	No.	*Pct.*
Heavy grass		
Stratified	518	367
Unstratified	111	---
Light grass		
Stratified	3,666	22
Unstratified	3,000	---
Disked		
Stratified	1,556	460
Unstratified	278	---
Burned and disked		
Stratified	2,333	75
Unstratified	1,334	---
All seedbeds		
Stratified	2,018	71
Unstratified	1,181	---

Stratification usually improves total germination as well as speed of germination. Occasionally a slight reduction in total germination occurs, but long periods of stratification are usually no more harmful than short ones. Substantial reductions have been observed only in lots of such low viability that they were unsuited for direct seeding. Apparently the weak seeds are killed soon after stratification starts.

Longleaf seed, which germinates promptly, never requires stratification, but the other southern pines usually benefit (*18, 30, 31, 58, 64, 65, 90*). Optimum length of treatment varies by species and lots. Fresh, well-handled seed is usually less dormant than seed that has been stored or mistreated. The only sure way to determine stratification needs is to compare laboratory germination of sublots stratified for various periods.

How are test data interpreted when deciding whether and how long to stratify? There are no hard-and-fast rules. Properly conditioned seed should reach peak germination in 7 to 10 days, and germination should be essentially complete in 15 days. (Peak germination is the highest value obtained by successively dividing number of days of test into cumulative germination percent (*57*).) If stratification shortens time to peak germination by 1 or 2 days in laboratory trials, a greater improvement may result in the field where germination is slower and differences between lots are accentuated.

If tests to determine stratification needs are infeasible, blanket recommendations are to stratify loblolly pine seed for 60 days, shortleaf for 45 to 60, and slash, Virginia, and white pine for 30 days. In emergencies, shorter periods—10 to 15 days—are better than no treatment.

Stratification can be accomplished in several ways. The main requirements are to keep the seed moist and at a temperature between 34 and 36° F. Seed should not be allowed to freeze, and when large lots are treated, frequent inspection and other precautions are needed to prevent heating and molding.

Granulated peat moss may be used to maintain moist conditions; a suggested procedure is:

1. Cut drainage holes in the bottom of a metal container (a 55-gallon steel drum will handle about 150 pounds of seed), then support upright container on three or four bricks to allow free drainage of excess water.
2. Weigh out 25-pound sublots of seed, putting each sublot in a separate cloth bag. Tie the bags loosely so that they can be spread to a uniform thickness in the drum. Dip each bag in water to wet seeds thoroughly.
3. Pulverize granulated peat moss, soak it, and squeeze out excess water. Place a 4-inch layer in bottom of container and tamp firmly.
4. Place a bag of seed on top of the moss and spread it evenly so that the layer of seed is not more than 2 inches thick.
5. Continue alternating layers of moss and seed; each layer of moss, including the top one, should be at least 4 inches thick.
6. Refrigerate the filled containers at 34 to 36° F. Inspect drums weekly, and add water at 2-week intervals to keep the moss wet but not saturated.

In another method, used for small lots and becoming popular for large ones, lightweight polyethylene bags are substituted for the container and peat moss (*25, 40, 48, 63*). Seeds are soaked in water for about 12 hours, then placed in the bags and refrigerated at 34 to 36° F. The sealed, impervious bags hold in moisture. However, they must be inspected frequently and the seed re-wetted if its surfaces become dry. The amount of seed per bag should not exceed 25 pounds; larger quantities may heat or mold. Bags should be stacked one layer deep, and turned weekly.

The stratification methods described are not new; they have been used for many years. Seed dormancy is the subject of much research, and developments may be expected. Ways of shortening the period of treatment would be desirable, but to date no shortcut methods have proved reliable. For example, soaking in hydrogen peroxide, citric acid, or water has some stimulating effect but usually fails to give the fast and complete germination that is desired in direct seeding.

Seeds gain considerable weight during stratification. If the 25-pound sublots are kept intact, the subsequent repellent treatment and field sowing can be done easily on a dry-weight basis.

Coating Seed with Repellent

Only one repellent formulation is described in this handbook; others that were recommended for southern pines in earlier reports are either obsolete or no longer available through commercial sources. The current formulation containing thiram and endrin gives a high degree of protection against all important species of seed-eating birds, deters small mammals, and destroys troublesome insects common to most southern pine sites (*1, 21, 73, 85*). Scores of field studies, tests with caged animals, and operational seedings since 1956 have confirmed the repellent properties of these chemicals. Typical results are given in table 6, which compares initial stands from properly coated seeds with those from untreated seeds. The trials were on sites having normal populations of birds and rodents.

Table 6.—*Seedling yields in field studies comparing repellent-coated seed with untreated seed*

Year	Species	Seedlings per acre from—		Tree percent [1]	
		Thiram-endrin repellent	Untreated control	Thiram-endrin repellent	Untreated control
		No.	*No.*	*Pct.*	*Pct.*
1956	Longleaf	8,220	55	51	<1
1956	Slash	2,335	705	10	3
1957	Longleaf	8,720	0	75	0
1957	Slash	4,705	330	30	2
1958	Loblolly	10,185	1,590	54	8
1958	Longleaf	5,610	170	38	1
1959	Longleaf	8,670	0	67	0
1959	Longleaf	6,080	110	47	1
1962	Loblolly	5,670	640	28	3
1962	Slash	5,140	440	26	2

[1] Percent of total seeds that produced a seedling.

Thiram is the bird-repellent component in the formulation. It is a commonly used seed-treating fungicide that is available in many forms. A water suspension of finely ground thiram, equivalent to the proprietary material called Arasan 42-S,[3] is best for treating pine seed

[3] Mention of trade names is solely for information. No endorsement by the U.S. Department of Agriculture is implied.

(*22*). It contains no harmful additives, creates no dust problems, and forms a hard coating.

Wettable endrin is blended with the bird repellent for control of small mammals and insects. It is a toxic material that must be applied at a carefully controlled, low dosage rate, and always in combination with the bird-repellent chemical. Studies in various parts of the South have invariably shown that endrin is needed. Rodents are nearly always present in sufficient numbers to destroy or severely damage a seeding. Furthermore, endrin provides protection against damage by insects of many species. Proposed seeding projects should be reviewed with State Fish and Wildlife and State Health Departments to determine possible adverse effects on non-target animals. Some species of birds and other wildlife feeding on treated areas may not be repelled by the thiram, and occasionally there may be ingestion of a lethal amount of endrin.

Endrin is marketed in several forms, some of which cannot be blended into the thiram suspension. The form most successful is a 50-percent wettable powder, equivalent to the Stauffer Chemical Company's Endrin 50-W Seed Protectant.

A latex sticker must be added to bond the repellents to the seed. Though a number of such adhesives are available, only one has been used with the liquid suspension. It is Dow Chemical Company's Latex 612 (formerly Latex 512-R), which was selected initially because it is widely available, has good adhesive properties, and does not affect germination.

The final ingredient in the repellent formulation is aluminum powder applied as an overcoating to hasten drying and to lubricate the treated seed. It is produced in many grades. A 100-mesh leafing powder has proved satisfactory. A proprietary product is Varnish Lustre Powder M.D. 2100, manufactured by Metals Disintegrating Company, Inc., Elizabeth, N. J.

The repellent formulation must be prepared by the user. A mixture containing ½ pound of Endrin 50-W and 5 fluid ounces of undiluted Latex 612 per gallon of Arasan 42-S has proved satisfactory for treating all species. A simple four-step procedure for preparing about 6 gallons follows, and smaller amounts can be mixed in a similar manner:

1. Place 2½ pounds of Endrin 50-W in a coated-metal or glass container, add 2½ gallons of Arasan 42-S, and stir slowly with a paddle until the powder is wetted. *Caution: Endrin is highly toxic. Wear rubber gloves while treating seed and use a respirator during the mixing phase when endrin dust is present. Clean or destroy empty containers so as not to endanger man or animals.*
2. Beat to a smooth lump-free mixture with a paint stirrer attached to an electric drill having a no-load speed of at least 1,200 r.p.m.
3. Add 25 fluid ounces of undiluted latex to another 2½ gallons of Arasan 42-S and stir briefly with paddle.
4. Blend the two mixtures by pouring from one container to another about 10 times.

The final mixture is a heavy water suspension of thiram and endrin solids that tends to thicken in storage but thins out quickly with a little stirring. No additional water is required for thinning. The formulation is stable and can be prepared several days in advance. However, it must be mixed and stored at above-freezing temperatures and in the original coated-metal cans or in glass containers.

Figure 27 illustrates the main steps in preparing the repellent and coating the seed. Small concrete mixers are excellent for applying the repellent. The model illustrated will handle 25 pounds of dry longleaf seed per batch and at least 50 pounds of the small seeded species.

The amount of liquid repellent required for an optimum seed coating varies by species and moisture content of the seed. Small-seeded species need less than the big, light seeds of longleaf; stratified seeds take less than unstratified. Consequently, it is advisable to do some testing initially. As a start, about 1 gallon of the mixture can be applied to 50 pounds of seed. The first batches should be examined carefully to determine if all seeds are fully coated with no surplus. The dosage should be increased or decreased until a complete, uniform coating is obtained. If too much is applied, seeds will stick together in large clumps.

A batch can be coated in about 3 minutes. Once seeds are thoroughly coated, continued tumbling does no further good and may be harmful. The aluminum powder overcoating

Figure 27.—Directions for preparing repellent and applying it to seed.

FS-518996

Add 2½ pounds of Endrin 50-W to 2½ gallons of Arason 42-S.

FS-518997

Stir with wooden paddle.

FS-518998

Beat with paint stirrer.

FS-518999

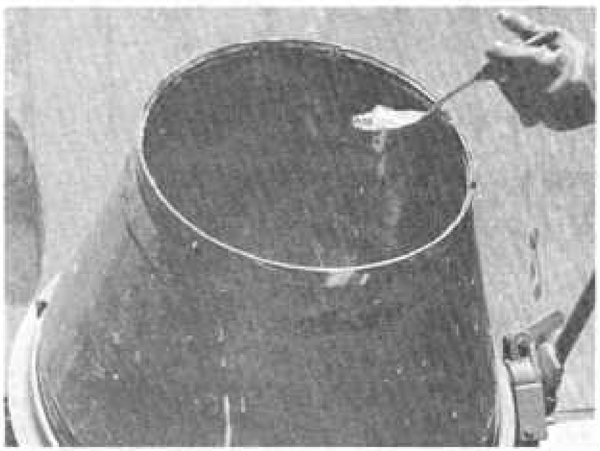
Add 25 fluid ounces of undiluted Dow Latex 612 to another 2½ gallons of Arason 42-S.

FS-519000

Blend by pouring from can to can about 10 times.

FS-519001

Pour finished repellent directly onto seed as mixer is turning. Tumble about 2 min.



FS-519002

Add aluminum powder and tumble for another minute.

FS-519003

Seed is fully coated; it should be spread out to dry.

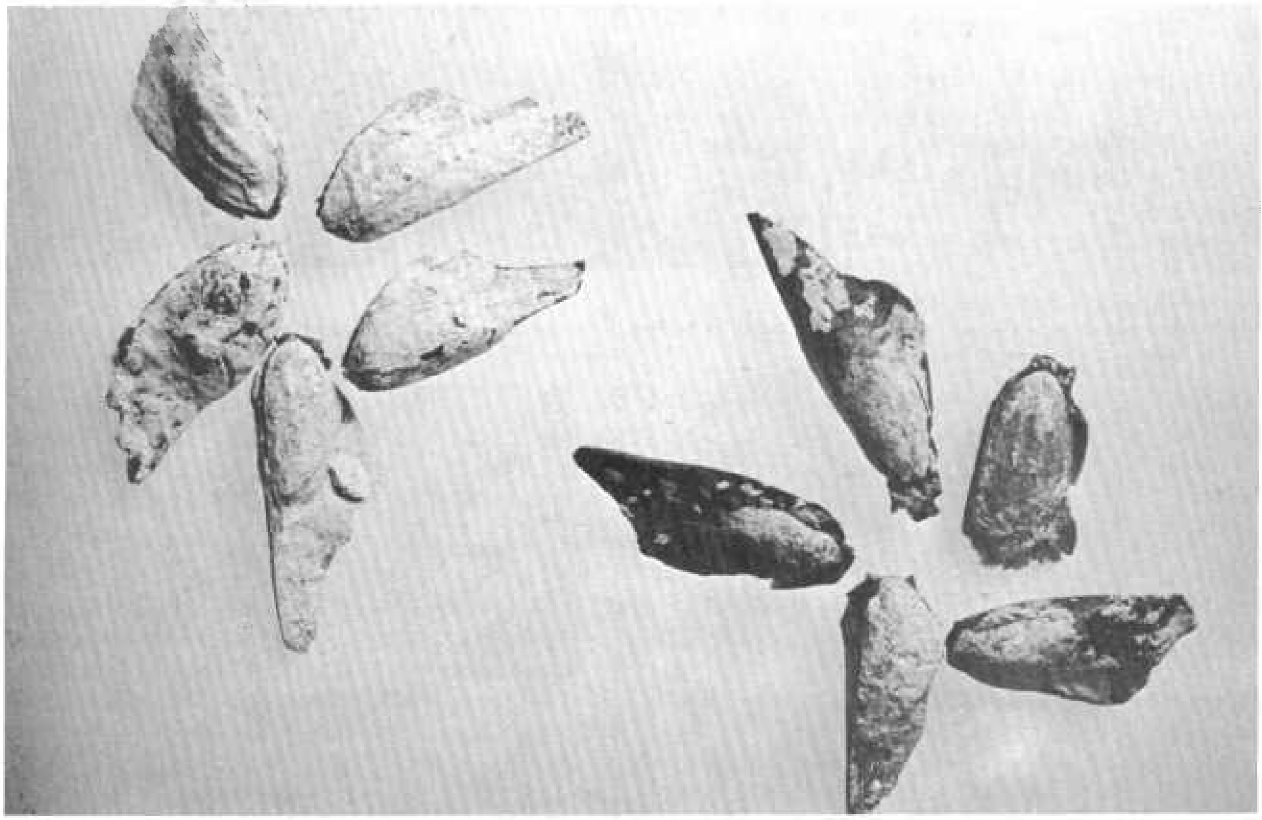
should be applied as the last step—in the final minute after seed and repellent have been thoroughly mixed. It should be put on at the rate of about 8 tablespoons per 50 pounds of seed.

Small lots can be treated in an open container by stirring seed and repellent with a ladle. About 3 ounces of repellent will treat a pound of seed. The aluminum is added last, just as with large batches.

The coating should cure for several hours; it is similar to latex paint, which dries rapidly but requires setting time before it can withstand exposure. Freshly treated seed can be spread out on a floor in a layer 3 to 4 inches deep and stirred frequently with a rake during initial drying—until the color of the coating changes from gray to white. The raking reduces clustering. Seed can also be dried in bags in forced-draft kilns if kiln temperature is held to 100° F. or less. However, this procedure favors formation of clusters, which must be broken apart before the seed can be sown.

The type and amount of adhesive represents a compromise between durability and permeability. The coating must hold up in the field, but it must also permit passage of moisture and gases needed for normal germination. A coating should remain effective for 3 or 4 months under field conditions. With poor application, its lifespan will be shorter.

All coatings, whether applied on the job or by a commercial dealer, should be checked for durability. After the coating is thoroughly dry, a simple test can be made by placing a representative sample of several hundred seeds in a food strainer, holding them under a cold-water faucet for 2 minutes, and then redrying. If the coating remains on at least two-thirds of each sample seed, the repellent will weather satisfactorily (fig. 28). If the loss is greater, or if 20 percent or more of the seeds lose their coating entirely, application was unsatisfactory and the seed should be thoroughly washed and re-treated. Common causes of poor durability are improper mixing of the repellents, inade-



FS-519004

Figure 28.—Rapid field loss of repellents from improperly treated seed (right) can be predicted by washing a sample in cold running water. Properly treated seed (left) loses very little coating.

quate amount of sticker, or use of latex that has deteriorated in storage or has been damaged by freezing (*20*).

When the repellent treatment is to be furnished by a vendor on a custom basis, coating ingredients and treatment methods should be specified exactly. It is not sufficient to specify "repellent-treated seed," as this term properly applies to seed treated with several materials and to a wide range of dosages.

There has been a tendency to alter the treatment to save money, or from a belief that the recommended maximum amounts are not required.

Labor cost is nominal; a three-man crew using a small concrete mixer can easily treat a ton of seed per day, and altering the treatment seldom speeds the work much. Cost of materials runs about *21* cents per pound of dry seed. Skimping on chemicals therefore saves only pennies per acre. For example, cutting the amount of thiram from 8 to 2 percent saves 12 cents per pound of seed. While the lower rate has been used with some success, it rarely is as effective as the higher one. This was clearly demonstrated in a series of trials in Virginia where the 8-percent concentration consistently outperformed a 2-percent concentration, sometimes with twice as many 1-year-old seedlings from the same amount of seed (*79*).

The recommended dosage for endrin is 0.5 percent active ingredient, by weight. A 50-percent reduction in this rate will save only 2.5 cents per pound of seed, and the lower level will not afford adequate protection.

Thiram is slightly phytotoxic to seeds of the southern pines. Germination is often adversely affected in laboratory tests, where seeds are concentrated in a small tray. But in numerous field trials germination of thiram-coated seed has equalled or exceeded that of untreated seed. Seeds of some species may not tolerate thiram as well as do the southern pines, and the dosages recommended here should not be applied to other conifers without preliminary testing under field conditions.

Time of Sowing

There are two distinct sowing seasons—spring and fall—over most of the South. Fall is generally recommended for longleaf pine. Seeds of the other species—loblolly, slash, shortleaf, white, and Virginia pine—have been sown in both seasons, but spring generally gives the best results. Germination characteristics of the individual species were described earlier (p. 13); of concern here is selection of the best date within each season.

The best time for fall sowing is the earliest date after natural seedfall and after soil moisture has been recharged by 2 to 4 inches of rain. With rainfall as a factor, the date may vary considerably from year to year. The alternative is to sow on a preselected date regardless of soil moisture, but then the hazard is that initial rains may be sufficient to start germination but not adequate to sustain it.

If rains are delayed, longleaf can be sown well into December, though temperatures for germination usually are better in November. Longleaf will, in fact, germinate throughout the winter, but cold weather from mid-December through mid-February slows the process and lowers seedling yield.

Slash pine can be sown for fall germination if moisture supplies become adequate when temperatures are still warm. The best months are October and November. If conditions delay sowing beyond December 1, the seed should be held in storage until spring. Near the Gulf Coast fall sowing is more reliable than elsewhere in the species' range. It is hazardous where winter temperatures drop well below freezing, because the young seedlings may be killed by cold weather.

The spring season, for direct-seeding purposes, is defined as the transition period between winter dormancy and appearance of new foliage—about the time first blooms appear on redbud and red maple. It varies by latitude and is generally about February 15 in the latitude represented by a line from Shreveport, La., through Jackson, Miss., to Macon Ga. Normally, prolonged periods of freezing weather are past, soil moisture is adequate, and daily temperatures are reaching levels needed for germination. Stratified seeds of loblolly, slash, shortleaf, and Virginia pine sown in mid-February usually complete germination by mid-April, though prolonged cool weather or drought can extend germination into May.

Delays in spring sowing are likely to affect results adversely (*37*). If dates for seed delivery or performance of contractual services are uncertain, it is best to schedule the work earlier than the desired date. On the other hand, danger of seed submergence may justify postponement for as long as 60 days. Flatwoods sites, for example, often have standing water in early spring, and sowing must be deferred until they dry. Similarly, the chance of flooding in or adjacent to creek bottoms and other water courses may dictate late sowing.

Sowing Rates

Sowing rates vary considerably, even within species. They are influenced by quality of the seed, method of sowing, and stocking desired by the individual landowner.

As table 7 indicates, general recommendations for broadcast sowing are 3 pounds of seed per acre for longleaf pine, 1 pound for slash and loblolly, and 0.4 pound for shortleaf and Virginia pine. These rates provide between 12,000 and 19,000 viable seeds per acre. They have proved to be realistic; under average conditions, initial stands have ranged between 2,000 and 5,000 seedlings per acre. For sowing strips, rows, or spots the rate is much less.

The rates proposed in the table are for dry, untreated seed with viability of 95 to 100 percent and for average numbers of seeds per pound. Counts per pound vary considerably, and precision can often be improved by determining the count for an individual lot and then adjusting the sowing rate.

Strip seeding, as envisaged for the table, means broadcasting seed only on disked strips and not on the undisked balks between strips. If the disked and undisked portions are of equal width, the rates recommended for broadcast sowing can theoretically be halved. It has been found in practice, however, that disked ground requires a slightly higher sowing rate to compensate for seed lost by silting. Hence, 0.6 as much seed as required for complete broadcasting is a realistic quantity per acre for strip seedings in which one-half of the total area is prepared. Other ratios of prepared to unprepared ground are handled similarly, except that where the strips are very narrow the operation becomes a form of row seeding.

Table 7.—*Average number of seeds per pound and suggested sowing rates per acre*

Species	Seeds per pound [1]	Weight of dry seed per acre for seeding—			
		Broadcast	Disked strips [2]	Rows [3]	Spots [4]
	No.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Longleaf pine	4,500	3.00	1.80	1.60	1.33
Slash pine	13,000	1.00	.60	.55	.46
Loblolly pine	18,500	1.00	.60	.39	.32
Shortleaf pine	45,000	.40	.24	.16	.13
White pine	22,000	1.00	.60	.33	.27
Virginia pine	45,000	.40	.24	.16	.13

[1] Dry, untreated seed, with viability of 95 to 100 percent.

[2] Seeding restricted to disked ground, which is assumed to be 50 percent of the total ground surface.

[3] Six feet between rows.

[4] One thousand spots per acre.

In row seeding, the sowing rate is controlled by the number of seeds per chain (66 feet) and the distance between rows. That is, number of seeds per acre equals $\frac{660}{x} \times S$, where x is the average distance between rows in feet, and S is number of seeds per chain of row. Experience has shown that placement about 1 foot apart is usually adequate. For rows spaced 6 feet apart, as assumed in table 7, this provides more than 7,200 seeds per acre.

In spot seeding, the objective is one established seedling per spot. Extra trees are superfluous, though clustering of several per spot does not affect growth of the most vigorous one (*13*, *81*). To achieve this objective consistently requires sowing about six seeds per spot (*69*). If site conditions permit, about 1,000 spots per acre are desirable. In terms of seed requirements, spotting is roughly equivalent to row seeding.

The weight of seed per acre must be increased when a lot contains material amounts of nonviable seed. If a lot of shortleaf pine seed tests 80 percent viable, for example, a pound containing 45,000 seeds would have only 36,000 viable seeds. The weight of seed required to give 45,000 viable seeds per acre would be 125 percent of the recommended weight (45,000/36,000 × 100), or an increase of 25 percent.

Control of sowing rates in the field is normally based on weight of dry untreated seed, because treated seed, especially if stratified, changes weight constantly. Such control is facilitated if dry-weight records are retained for each bag of seed. When this information is not available the treated weight must be used to control the rate of sowing. In these situations, a current estimate of the number of treated seeds per pound is helpful in determining the weight required per acre.

The rates suggested here are for average sites and normal weather. They can be reduced locally after enough experience is acquired for prediction of yield. A prerequisite for such "prescription sowing" is an experience record of sowing rate and subsequent first-year survival by soil types and cover conditions (*9*, *79*). Conversely, higher rates are sometimes desirable on adverse sites or where there has been a substantial investment in site preparation. If a higher rate will insure success, the cost of extra seed usually is less than the cost of retreating an inadequate stand.

Distributing Seed–Ground Methods

Hand sowing is the oldest form of direct seeding. By this method, hundreds of research plots were seeded as well as many of the early practical trials. The term, as used here, includes broadcasting, sowing with hand-operated cyclone seeders, and spot seeding with or without special scalping and seed-dispensing tools. In this age of mechanization, hand seeding is limited to small areas and to those where soil or cover conditions prevent operation of larger equipment.

Simple broadcasting by hand i mentioned only because it is a way of scattering seed over disked strips when the intervening undisked ground is to remain unseeded. It is not very accurate; with small-seeded species an extender, such as sawdust, is needed to keep sowing rates within rough limits.

For broadcasting on areas up to several hundred acres in size, hand-cranked seeders are very efficient (fig. 29). They have a simple metering device which, if properly adjusted, will regulate seedflow to within 10 percent of the desired rate. Their effective swath is about 16 feet; thus, to sow an acre requires ½ mile of walking. Where movement and swath control are easy, a daily production of 15 acres per man is common. On rough terrain or in heavy brush, the rate averages about 10 to 12 acres per man-day. Crew organization is simple and flexible; men can be used singly or as a team with up to six walking abreast. Larger crews are difficult to control accurately. Operators need training to walk in proper alignment and to maintain a uniform rate of seedflow through the machines.

FS-519005

Figure 29.—Hand-operated grain seeders can be used for tracts up to several hundred acres in size.

Vehicle-mounted broadcast seeders designed for seeding pastures and forage crops can be adapted for pine. Their use has been limited, because the large open areas where they are most effective also are good opportunities for aerial seeding. A common type mounts on the front or rear of a tractor and has a centrifugal slinger similar to that of a hand-cranked seeder. Preferably the slinger is driven with an electric motor. Connection to the power takeoff is less desirable, because a constant engine-to-ground speed is difficult to maintain on rough sites. These machines will seed a ½-chain swath (33 feet), and on favorable terrain can cover 10 to 15 acres per hour.

Spot seeding is a good alternative where vehicles cannot operate and especially good where other seedbed treatments, including fire, are impractical. A spot is raked, hoed, or kicked free of vegetation and litter, and six seeds are dropped and pressed into mineral soil with the foot (fig. 30). Several hand tools have been developed to ease the task (*12*, *66*). Most combine a scarifying blade with a metered container that releases the proper number of seeds onto the spot when a lever is pulled.

Spot seeding is better adapted to areas with a ground cover of hardwood litter than to sites with grass sod. Prepared spots should be at least 1 foot in diameter—larger where hardwood litter is deep—and the cleared-off debris should be scattered to prevent blowback. Burn-

FS-519006

Figure 30.—Spot sowing, in which six seeds are placed on hoed or raked spots and pressed into firm contact with mineral soil, is a good method for small tracts and rough terrain, or where other seedbed treatments cannot be used.

ing before spotting eliminates blowback and makes the work easier.

At the recommended minimum rate of 1,000 spots per acre, 2 to 4 acres can be covered per man-day.

Mound or tussock seeding, a variation of spotting, is useful in the swampy or flooded portions of the Lower Coastal Plain. Seeds are dropped by hand on clumps of grass or rotten logs, at the base of stumps, and on any other suitable spots above water level.

Some exposure to the repellent chemicals is inevitable with all methods of hand seeding. Precautions should include use of rubber gloves for direct handling of treated seed, thorough washing of hands before eating or smoking, and a daily change of clothing.

While the methods just described are useful in many situations, most seeding from the ground has been done with row-seeding machines. Many types of row seeders have been developed. Some simply drop seed in rows on previously prepared ground, but most plow a furrow or pulverize a narrow strip with disk blades and then meter out seeds and press them into the mineral soil with packing wheels. Hence the term "row seeder" usually denotes a machine that prepares beds and sows in a single operation. Width and profile of the treated strip vary considerably.

The first successful machine of this type (fig. 31), still in use, combines a conventional fireplow, a mounding or hilling device, and an agricultural seed dispenser (*19*). It has proved effective in fairly heavy brush and on a variety of soils, except poorly drained ones. Heavy power requirements and high maintenance on the plow limit its usefulness. A production rate of 15 acres per day has been reported, but it is doubtful if this rate could be sustained for long periods.

A row seeder that has been widely used in sustained operations is illustrated in figure 32. The front-mounted V-blade cuts a broad, shallow furrow and makes a shallow groove in the center of it. Seeds are dropped into the groove, and a dragplate at the rear of the tractor covers them lightly with soil. This machine is designed for light sandy soils; it operates effectively where hardwoods are small enough to be uprooted with the V-blade.

Several compact row seeders have been developed. They are designed for fast operation with minimum power requirements. Consequently, they cut a narrow, shallow furrow for placement of the seed. They operate best on sandy soils and can maneuver around large hardwoods. All current models have a device for covering the seed. Several deposit the seed in a shallow trench that is opened by an agricultural sword and closed by a packing wheel. On one, a small set of rolling blades cuts shallow slots into which the seed is dropped; the slots are partially closed by a packing wheel but full coverage is dependent upon movement of soil by rainwater. None of these seeders assure coverage to a uniform depth, but they are superior to machines that simply drop seed on loosened soil.

In row seeders of still another type, disks are used to prepare the bed. One model, used extensively on open, grassy sites, has two 2-foot sections of an agricultural disk arranged in tandem to create a flat bed just ahead of the seeder (fig. 33). This machine requires less power than a plow—two units can be pulled by a light crawler tractor—and it can function on poorly drained soils where furrows might accumulate water. The dual unit can cover 30 acres per day.

Another disk seeder has been developed specifically for low, poorly drained sites that are cleared and disked initially in the summer before seeding. Its disk blades elevate a narrow bed, 3 to 4 inches high, which prevents seed submergence and improves initial growth on sites where water tables are high. The same principle is employed in a larger unit designed for grass-covered flatwoods sites. The elevated bed it creates is about 6 inches high and 6 feet wide.

Disk seeders have two main drawbacks. First, they leave rough beds on which considerable seed is lost by silting. Second, disking in cool, wet weather fails to control grass adequately.

Disk and furrow seeders alike are equipped with modified agricultural seed-dispensing devices that work satisfactorily under optimum conditions but are inaccurate on rough ground or where there are numerous roots in the plow zone. A recently developed device that is accurate under normal forest conditions employs a vacuum system to move seeds from a hopper and drop them at precise intervals (*83*). Plans and specifications are available from the San


FS-519007

Figure 31.—This row seeder elevates a low ridge in the center of a plowed furrow and drops seed onto it at regular intervals.

Dimas Equipment Development Center, USDA Forest Service, 444 E. Bonita Avenue, San Dimas, Calif. 91773.

Aerial Seeding

An estimated 75 percent of the total acreage seeded has been sown from the air, either with small fixed-wing craft or helicopters. On operations exceeding 500 acres, aerial seeding is comparable in cost to most ground methods of broadcasting seed. It is also fast, permitting completion of work while conditions are suitable for germination. Frequently, it is the only practical means of sowing inaccessible terrain or debris-covered areas. Properly calibrated and controlled, aerial seeding is the most accurate broadcasting method, giving complete cov-

FS-519008

Figure 32.—A front-end row seeder designed for sandy sites and capable of operating in brush.

erage regardless of terrain, brush, or debris.

Pine seeding offers off-season employment for pilots whose main income is from agricultural work or maintenance of utility rights-of-way. The flying techniques are essentially the same, but seeding requires a very low application rate per acre, and terrain or tree cover usually makes control of flight lines difficult.

In seed distribution there is not much difference between planes and helicopters. Power-driven seed meters and a centrifugal slinger must be used on a helicopter (fig. 34), while planes can operate with gravity flow of seed into a venturi-type distributor (fig. 35). The power-driven equipment can be calibrated more accurately and gives good distribution across the flight strip, but the simpler equipment on fixed-wing craft is adequate when properly

FS-519009

Figure 33.—Disks on this seeder prepare a flat bed.

used. Both types require constant checking and precision flying for best results.

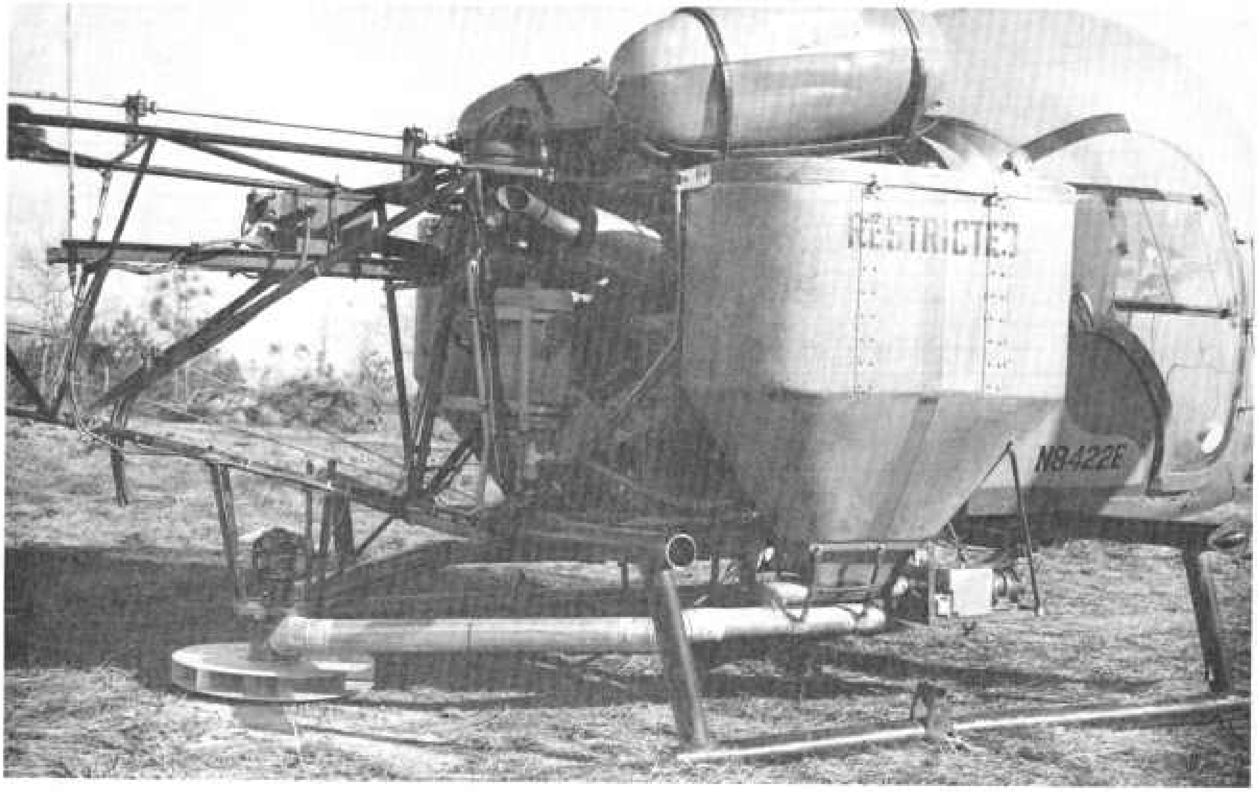
The main distinction between the two types of aircraft is in width of the flight strip. Helicopters will seed a strip 1.5 chains wide (99 feet), while planes should be limited to 1 chain. Both types will distribute seed farther than these distances, but some overlapping of strips is needed to insure uniform coverage.

Helicopter charges are more per acre but the sowing rate is about 300 acres per hour, as compared to 180 for a plane. The difference is mostly in time required for loading; helicopters can land on or near the site, while planes usually operate from a landing strip several miles away. Since faster operations lessen overhead costs and outlays for ground crews, total expense is about the same for both types of craft.

The following discussion is written in terms of the helicopter, whose use in agriculture is increasing rapidly. With minor modifications, however, the information is applicable to airplanes.

Aerial seeding has evolved as a cooperative venture between the contractor and his customer. Usually the flying service charges a per-acre fee and furnishes the aircraft, pilot, and one or two additional men to assist in loading seed and calibrating equipment. The landowner supplies the seed, overall supervision, and personnel for ground control. He also does any mapping required for control of flight lines. The role of each party should, of course, be agreed on in advance.

Accurate aerial seeding requires good ground control, which is often difficult on rolling terrain or where there is a high canopy of hardwoods. Preparation for it is needed in most cases; requisites include a large-scale map of the area to be seeded, location of the flagmen's positions for each flight line, and marking tract boundaries with a plowline where they are not distinct from the air. In addition, most flying services insist on a preliminary reconnaissance flight to check location and boundaries. A helpful technique is to delineate each flight strip on the map (fig. 36). Flight strips should be numbered on the map and in the field to facilitate systematic positioning of flagmen where the

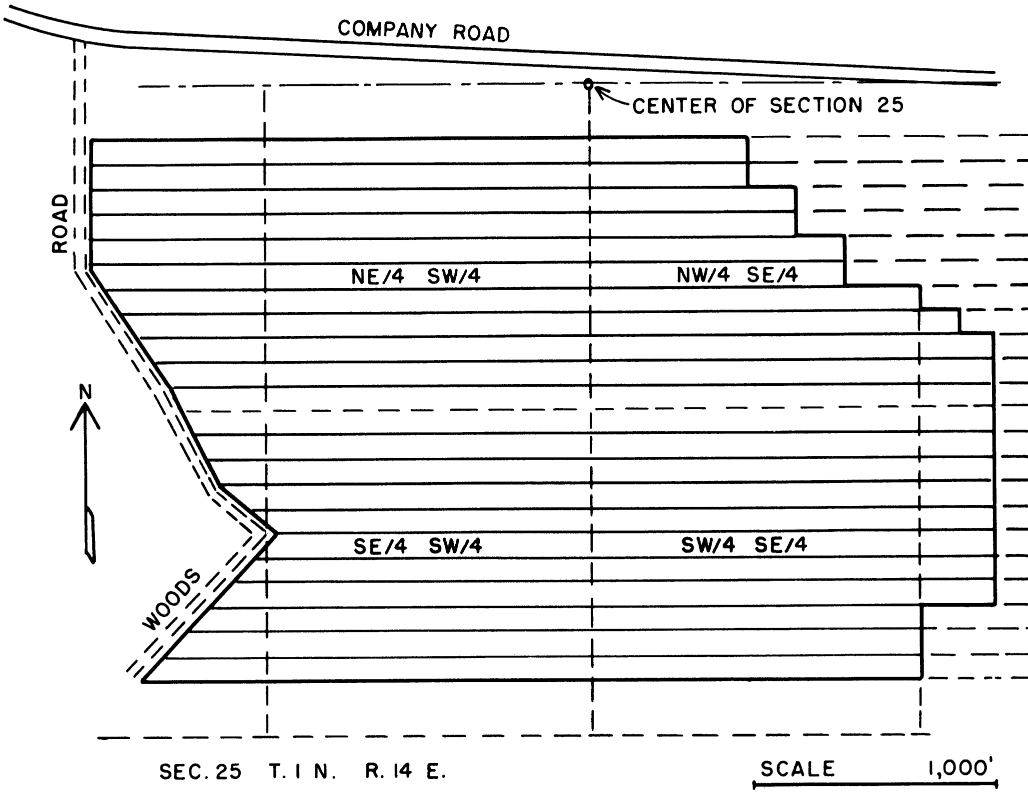


FS-519010

Figure 34.—The power-driven slinger on a helicopter distributes seed over a 99-foot swath.

FS-519011

Figure 35.—Up to 1,500 acres per day can be sown from a light airplane. Seed flows by gravity into a distributor that spreads a 66-foot swath.



STRIP NUMBER	ACRES PER STRIP	ACRES IN 10-STRIP FLIGHT
1	5.8	
2	5.8	
3	6.3	
4	6.3	
5	6.8	
6	6.6	
7	7.3	
8	7.4	
9	7.5	
10	7.4	67.2
11	7.3	
12	7.2	
13	7.2	
14	7.1	
15	6.9	
16	6.6	
17	6.4	
18	6.6	
19	6.8	
20	6.5	68.6
21	6.8	
22	7.0	13.8
	149.6	149.6

Figure 36.—A large-scale map, showing tract boundaries and estimated acreages in each flight strip, is essential for accuracy.

pilot will be able to see them. Numbering is particularly helpful when mechanical trouble or adverse weather interrupts seeding. The acreage and seed requirements for each mapped strip can also be calculated in advance, thus improving control of seeding rate.

On most tracts, at least three flagmen are needed—one on each flight strip terminal and a third in the center. More may be required on long strips, on rolling terrain, or where large trees restrict the view from the aircraft's operating altitude of about 150 feet. After finishing a strip and turning, the pilot needs at least two flags in view to align a new strip; the nearest flagman ordinarily cannot be used, since he will either be moving to the new strip or not easily seen from the turning craft (fig. 37). Correct alignment of flags is essential for accuracy and usually is not difficult when positions are located by measurement in advance. If flagmen are expected to estimate strip widths by pacing, huge errors in flight alignment may result.

Adequate coverage of the area and control of the sowing rate are responsibilities of the pilot. He calibrates the metering equipment, determines flying altitude and speed, and instructs flagmen on procedures for correct alignment of flight lines. For pilots experienced in aerial seeding, calibration is a routine procedure normally done in cooperation with the project supervisor just before seeding starts. For others, a detailed description of this important step is given in the next section.

Windspeed and wind direction must be considered carefully. Both can distort the seedfall pattern beyond the capability of the pilot to control it. Calm air is best, though rare during the seeding seasons. On most jobs, therefore, some work must be done in the wind. Steady winds up to 10 or 12 m.p.h. do not seriously affect the seedfall pattern, but if winds are stronger, or if they are gusty, seed distribution becomes erratic. Since some pilots are inclined to continue work in high winds, the landowner should retain the option of suspending operations whenever good seed distribution cannot be attained.

FS-519012

Figure 37.—Flagmen must be placed so that the pilot can align his course on two flags at the start of each flight line.

When there is a choice, flying crosswind is preferable to flying parallel, as it permits more accurate control of groundspeed in both directions. A crosswind blows seed downwind and has a tendency to windrow it, i.e., to cause bands of alternating high and low densities, as windspeeds increase. Flying can be done with a paralleling wind if it is steady and the pilot feels he can adjust his airspeed to maintain a constant groundspeed in both directions. On operations where ground-control points are established in advance, planned flight lines should be at right angles to the direction of the prevailing wind. The lines usually are not changed for a paralleling wind unless terrain requires it or the pilot insists.

With experienced and responsible contractors, strict performance standards are seldom required. However, there are opportunities in aerial seeding for the irresponsible contractor, simply because the timberland owner, unlike the farmer, cannot see results of the work for several years. Performance standards should specify the allowable error in rate of sowing, time limits set for doing the work, and the percent of random milacre (1/1,000 acre) plots acceptable without seed. It is not realistic to specify a minimum average number of seeds per plot, for this implies that observers can find all seeds that fall on a sampled plot.

Calibrating Seeding Equipment

Proper calibration—adjustment of the seed release mechanism to the desired sowing rate—is important in all operations; precision calibration is essential in some. For example, a helicopter flying at the usual speed of 60 m.p.h. can release up to 36 pounds of seed per minute. A row seeder, at the other extreme, may not use this amount in 2 days. For best results, the rate of seedflow should be rechecked frequently during the seeding operation and readjusted as necessary. Repellent-treated seeds of the six pines vary considerably in flow characteristics; none are outstanding, and satisfactory flow of partially dewinged longleaf seed is difficult to obtain with any equipment.

Seeds of all species should be screened to remove clusters and foreign objects, which can cause much delay and inaccuracy, especially in aerial work. A simple wooden frame supporting 1/4-inch-mesh hardware cloth is adequate for all species except longleaf, which requires 1/2-inch mesh.

The weight of treated seed required per acre must be determined before calibration. It can be obtained in two ways: (1) weigh several representative bags of treated seed for which the untreated weight is known. Calculate the difference in percent and apply this correction factor to the weight of untreated seed desired per acre, or (2) divide the total weight of treated seed allocated to an area by the area's net acreage. Since treated seed fluctuates in weight, especially when stratified, the amount required per acre should be determined just before seeding starts.

Many unsuccessful attempts have been made to calibrate aircraft equipment with seedtraps or other means of estimating the number of seeds distributed per acre. Sample variation has been high, and it has seldom been feasible to examine enough samples to insure accurate adjustment. As a workable alternative, the following step-by-step calibration procedure has been developed from experience with many operational seedings. It is written for the helicopter but with slight modification is applicable to fixed-wing aircraft.

1. Select a likely meter opening and adjust the meter on each hopper to this setting.

2. Place 20 pounds of seed in each hopper. Load it in 5-pound increments, level, and mark the hopper wall so that the amount remaining can be estimated at any time during the operation.

3. Loosen the seed tubes from the slinger, place a net bag over each, and make a 30-second trial with the engine running. Waste air from the cooling fan is normally used to move seed through the tubes from hoppers to slinger. If the system depends on ram air (created by movement of the craft in flight), short tubes should be available to permit gravity flow of seed from the hoppers into the bags.

4. Weigh seed released from each hopper separately to determine if meters are operating at the same rate. Then calculate the rate per acre from the total weight of seed released. Acreage covered in any given time depends on flying speed. At 60 m.p.h. it is $\frac{40 \text{ chains} \times 1.5 \text{ chains}}{10} = 6$ acres in 30 seconds. For other operating speeds, simply substitute the distance covered (in chains) per 1/2 minute of operation. If the sowing rate per acre is high or low, adjust meter openings and repeat trials until the desired rate is attained.

5. If helicopter equipment is operating properly, the rate set in ground tests is usually accurate. However, rate should be checked on an area basis under actual operating conditions. This can be done by seeding a selected area of known dimensions and determining the weight of seed expended; or it can be accomplished by starting the operation on flight strips of known length, so that the acreage covered with a load of seed can be computed. Usually, minor meter adjustments are needed. As the job progresses, it is advisable to maintain a constant check on the seeding rate by recording the weight of seed carried and acreage covered in each helicopter load. Adjustments are also required occasionally to compensate for changes in humidity or temperature, or for conditions that affect the ability of the pilot to maintain the planned ground speed.

Distributors on fixed-wing aircraft are calibrated similarly, but the static ground check is not precise and is usually omitted if there is any information or experience to suggest an approximate setting for the hopper gate. Rate of seedflow into the distributor is affected by airspeed, vibration, and other features of the aircraft. Also, the hopper gates vary in size and shape. Equipment for agricultural work must be modified for best results in pine seeding. Usually, metal plates are inserted to provide short, wide apertures in place of long, narrow ones. Calibration is checked on the basis of area sown per load, in the same manner as described for a helicopter except that the swath is only 1 chain wide. Interruptions in seedflow, due either to presence of foreign material or bridging of the seed above the openings, is more common in fixed-wing craft than in helicopters, and less easily detected in flight. Therefore, it is essential to record the weight of seed in each load and the area covered.

Frequently, aerial seeding is done on irregularly shaped tracts or on areas containing stream bottoms and islands of pine reproduction where seedflow is normally cut off. In these situations, continuous monitoring of sowing rate is difficult, and it is then doubly important to have a measured calibration area.

Seed stoppages and mechanical breakdowns occur with both types of aircraft. When not detected promptly, they cause areas of unknown size to be seeded too lightly or not at all. To refly such areas at the full sowing rate is wasteful of seed, and if done at a reduced rate requires recalibration of the equipment. A compromise procedure frequently used is to refly alternate strips at the full rate but at higher altitude. This procedure does not insure full and uniform coverage, but it does provide stocking on areas that are difficult to identify precisely.

Ground-operated machines for broadcasting seed are also calibrated and checked by a system of area control. The quantity of seed released over an area of known size is determined, and meters are adjusted until the desired rate is reached. Hand-operated cyclone seeders sowing a ¼-chain (16½-feet) swath cover 1 acre each ½ mile; tractor-mounted units have twice the capacity, covering 4 acres per mile of operation.

Row-seeding machines are calibrated by checking, on a hard surface, the number of seeds dropped per chain of travel. This value can be used to compute average spacing within the row and the number of seeds per acre for a given interval between rows. Drop plates on row seeders are usually modified to release one or sometimes two seeds at a time. Adjustments in the rate of sowing are made by changing sizes among sprocket wheels that drive the rotating plate.

PROTECTING SEED AND SEEDLINGS

A single prescription has not been devised that will protect seed and seedlings completely and under all conditions. In most operations not much more than the repellent coating is needed to assure success. But large losses occur occasionally and hazards not forestalled by the repellents may be encountered. Some hazards can be avoided prior to sowing; others may not appear until seeds are on the ground or have completed germination. Careful, systematic examinations should be made during germination and in the first year, for losses can often be reduced if timely action is taken. Such examinations are particularly important for localities where there is little direct-seeding experience. They should be included in the initial plan.

A method of establishing observation stations for systematic appraisal of predator activity is described in a later section. Here, emphasis is on recognition of damage by animals, disease, and weather. Detailed knowledge of hazards will permit sowing rates to be adjusted to localities.

Birds

Despite the general effectiveness of the repellent, local losses to birds may occur—as when the repellent coating is deteriorated by heavy rains or repeated exposure to freezing temperatures. Also, there is one common bird—the crow—that has demonstrated indifference to repellents, though its damage has not been observed frequently and is considered minor. Sometimes migratory flocks of blackbirds or other species may destroy the seed on small areas. An understanding of bird attack is important in appraising damage to direct seeding.

Birds consume longleaf seeds either by swallowing them whole or by shattering the seedcoat and removing the endosperm. Meadowlarks, quail, mourning doves, and wild turkeys normally take longleaf seeds whole. Fortunately, repellent treatment is highly effective against these species. Birds that shatter longleaf seeds include common blackbirds and associates, juncos, and sparrows. The repellents are effective against this group also, but when damage occurs it is likely to be caused by these species. Seeds of the other pines are small enough to be swallowed whole by most birds.

Fragments of shattered seedcoats are good evidence of bird attack. Generally damage is concentrated in small areas. Remains of longleaf seeds look as if they had been struck repeatedly by a sharp object; seedcoats of other species are usually broken into small pieces but sometimes are simply split in half. Meadowlarks often break off the wing stub of longleaf before they eat the seed. Rodents also shatter seedcoats, but theirs is a tearing or cutting action that can usually be distinguished on close inspection. Small ants occasionally cut the seedcoat; the fragments resemble those left by birds, but uneaten portions of the endosperm frequently remain to identify the damage as insect-caused.

When seeds are eaten whole, bird activity is difficult to detect. Indirect signs such as tracks or droppings are often obscure, and if present do not establish conclusively that feeding occurred. Direct observation of birds is helpful but difficult, as some species feed during the early morning or late evening and others, moving in large flocks, may visit an area sporadically. Whole seeds are also removed by other animals, and an observer must guard against blaming birds (and the repellent) when other predators may be responsible. Observation stations, with seeds concentrated in a small area, are invaluable for detecting seed losses and identifying predators.

There is no effective control of bird attack except patrolling, which is practical only on small areas. The best defense is to insure that all seeds are properly coated with repellent.

Small Mammals

Small seed-eating mammals common in southern forests include white-footed mice, harvest mice, cotton rats, and squirrels. In some areas, hispid pocket mice, pine voles, and golden mice may also be prevalent (*36, 77, 91, 97*). The least shrew, which is widely distributed and sometimes numerous in local areas, is included through its role as a seed and seedling predator is not fully documented. This is a secretive animal, seldom seen, difficult to trap, and hard to evaluate in captivity.

Small mammals are far less numerous on southern pine sites than in the West. All species combined rarely number more than 10 individuals per acre, but such a population is enough to destroy a seeding if repellents are not used. A single mouse can eat 50 to 100 untreated seeds daily (fig. 38).

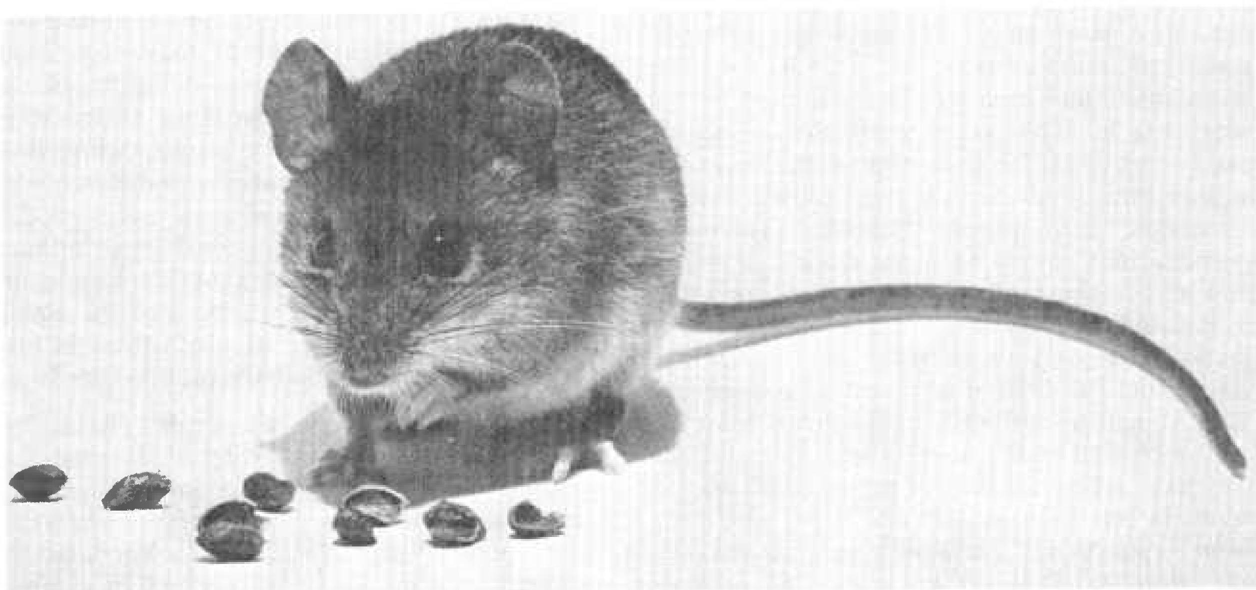


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Figure 38.—Unless the repellent coating contains endrin, mice will destroy much of the seed.

Most mice are deterred by the repellents when populations are normal and alternative foods are adequate. Numerous cage tests have shown that rodents stop eating treated seed after sampling four or five. In hulling the seed, they apparently ingest enough endrin to cause aversion, and thereafter they reject treated seed even when it is the only food offered. Mice cause some damage in all seedings, but usually the loss is serious only when the repellent coating is depleted, when the seeded area is small, or when small quantities of seed are used, as in spot sowing.

Mice sometimes shatter and split seeds, but often they merely bite off one end of the seedcoat and remove the endosperm (*97*); such empty hulls therefore distinguish depredations of mice from those of birds. Toothmarks and clean cuts on the seedcoat fragments are other evidence. Mice will, however, often remove seed to a secluded location before eating it. If seed is disappearing from observation stations and mice are suspected, traps may be set.

Control of mice by poisoning has not been tested widely on southern pine sites, but it is doubtful if this approach would have much value in direct seeding. On areas up to 40 acres, studies of removal by trapping have shown rapid reinvasion (*36*).

Squirrels are not repelled or deterred by the repellent recommended here, or by any other chemical that has been tested and can be used operationally on seed. Where numerous, they may destroy seedings completely, especially of longleaf pine. They are not a problem on extensive open areas; the most likely situation for squirrel damage is where seeding is done under large hardwoods or on small clearings surrounded by hardwoods. They usually destroy seed in place. They are adept at robbing seedspots, which are useful therefore in preliminary evaluation of a site to determine if a squirrel problem exists.

Squirrel damage to longleaf seeds is distinctive: The fox squirrel removes one broad side of the seedcoat; the eastern grey squirrel cuts off the rounded end (fig. 39). Coats of smaller seeds hulled by squirrels may resemble those left by the white-footed mouse (*97*), and thus identification of squirrel feeding may be difficult if other rodents are present. Elevated stations baited with other preferred foods such as peanuts or pecans may be necessary to confirm squirrel activity. The only effective control is trapping or hunting—of course, in cooperation with game authorities. Since the range of each animal is relatively large, hunting is usually the better method. It should be done before seeding starts, and should be followed by frequent checking during germination.

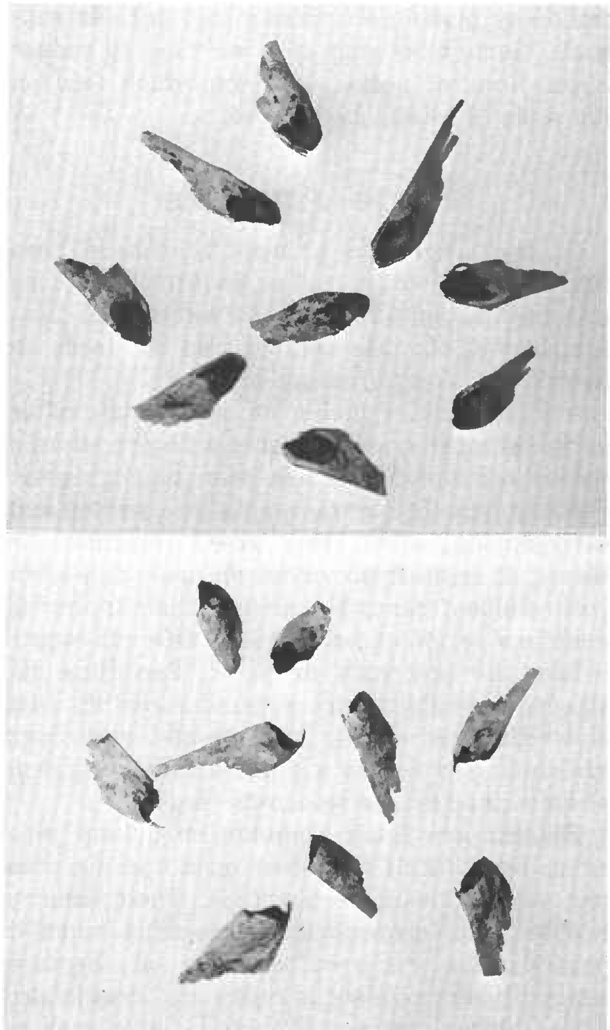

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Figure 39.—Repellent-coated longleaf seed hulls left by fox squirrels (above) and eastern grey squirrels (below). Repellents do not protect against these animals.

Cotton rats may kill young seedlings, especially of longleaf, by girdling them at the groundline. They ordinarily are not a nuisance where site preparation has been adequate. If their cover cannot be burned, the rats can be controlled by placing strychnine bait in their runways. Such baits may also be used to reduce infestations of pocket gophers, which feed on the roots of established seedlings.

Large Animals

Of the large wild animals that have been observed feeding on seed or seedlings, only the cottontail rabbit appears to do widespread damage. It does not take treated seed but feeds on cotyledons of germinating seedlings.

Loss to rabbits during or immediately after germination frequently averages 25 percent of a stand; occasionally it has been much higher. Feeding usually occurs during late winter and early spring, when other green vegetation is scarce. It is most prevalent on areas fall-sown with longleaf pine. Frequently the clipping is done in a period of 1 to 3 weeks. Often it occurs before the seedcoats drop off. Seedlings destroyed by rabbits are severed smoothly just above the groundline; the stem and cotyledons are then removed to a point about one-eighth of an inch below the seedcoats (fig. 40).

Rabbits are fairly common on upland pine sites, yet difficult to detect on a specific area unless they are numerous (*24*). Their damage can be very inconspicuous, especially when it occurs after the seedcoats are off, because nearly the entire plant is removed. There is also little indirect evidence of their activity, such as tracks or droppings, even when many seedlings are removed from a small area. A series of staked seedlings at representative locations offers the best means for appraising losses. These seedlings must be inspected frequently, because prompt action is necessary to prevent serious losses. Removal by hunting or trapping is the recommended control. Night hunting is especially effective. Permits for it and for off-season hunting must be obtained from State game authorities.

Raccoons, skunks, and opossums have damaged longleaf seedings in limited areas, but if their populations are normal, these animals seldom destroy enough seed to justify control. When there are large unexplained losses from observation stations, a local concentration of one or more of these species should be suspected. Hunting and trapping are the only practical controls.

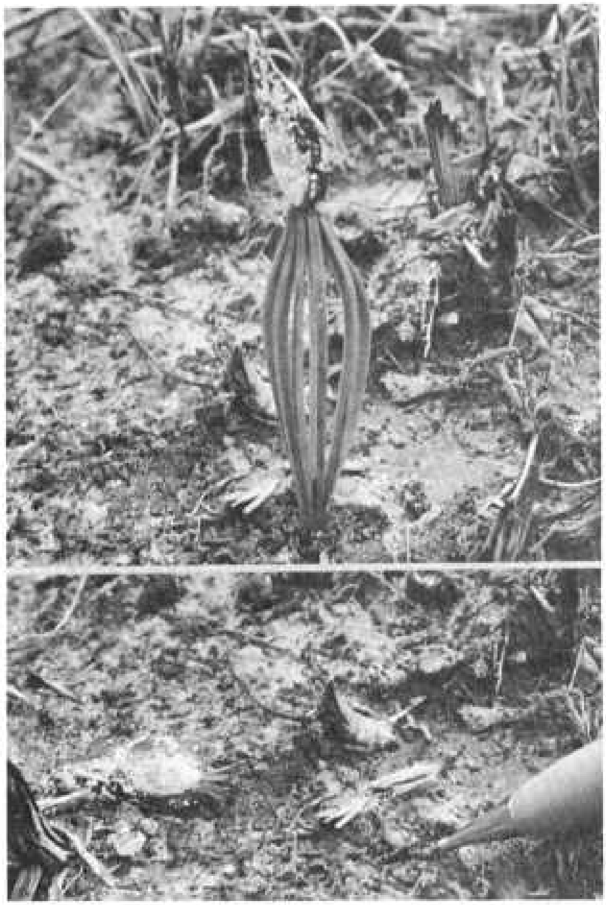

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Figure 40.—Clipping by rabbits usually occurs shortly before seedlings shed their seedcoats (above); all that remains is a short stub of stem and the untouched seedcoat containing cotyledon fragments (below).

Livestock

Entire seeded stands have been lost through error in judging the intensity of use and damage by domestic animals. These losses begin during germination and accumulate over the first year or two.

Most young stands can tolerate moderate grazing by cattle. Generally, moderate grazing is defined as the intensity at which approximately one-half of the annual production of forage is utilized. On open areas, this is achieved with 30 to 40 head of cattle per section of land (*26*). Sites occupied by hardwoods have lower carrying capacities, and the distribution of grazing on them is likely to be spotty. After hardwoods are treated, cattle concentrate under the deadened trees, where the seedlings are also apt to be concentrated (fig. 41). Management of grazing on hardwood-dominated sites is not simple; often the best course is to exclude animals for the initial 2 or 3 years.

Prepared seedbeds of any kind attract cattle, usually early in the first season when seedlings are most susceptible to trampling. On areas open to unrestricted grazing, temporary fencing may be needed. Intensity of seedbed treatment, number of cattle in the vicinity, and opportunities for diversionary burns are factors helpful in deciding if fencing is desirable.

Range hogs must be excluded from longleaf pine regeneration, and they are destructive, directly or indirectly, to other species as well. Hogs eat treated seed but seldom in large quantities. They feed heavily on longleaf seedlings and often cause serious damage by uprooting or burying other seedlings in their normal foraging for food, especially on disked or furrowed sites. Total exclusion of hogs, sheep, and goats by fencing or other means is strongly suggested by experiences with seedings of all species.

Insects

Several insect pests may be troublesome. Though it is doubtful if any have been primarily responsible for a seeding failure, they reduce yields and create undesirable variations in tree distribution.

For convenience, insect predators can be classified into two broad groups: those that move seed or seedlings to their nest sites and those that destroy them in place. Short-tailed crickets and harvester ants move ungerminated seed into underground chambers; the crickets occasionally take germinating seed as well. The Texas leaf-cutting ant (town ant) cuts emerging radicles and cotyledons from germinating seed, moving them to underground chambers

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Figure 41.—Cattle are attracted to areas where hardwoods have been deadened, and concentrated grazing endangers seedling stands.

and leaving the expended seed behind. Predators that destroy seed or seedlings in place include minor species of ants and several miscellaneous pests.

Short-tailed crickets are widely distributed in Louisiana; extent of their occurrence elsewhere is not known. They are especially prevalent on poorly drained sites. Heavy populations may be damaging to a direct seeding; concentrations of 10,000 per acre have been reported, but densities of 2,000 to 5,000 per acre are more common.

Small mounds of soil on the surface are signs of their presence (fig. 42). Excavation below a mound reveals a single tunnel leading to a food storage chamber 1 to 2 inches below the surface. The adults are usually found singly at the bottom of a 12- to 18-inch gallery running downward from the food storage chamber. Crickets may forage and raise fresh mounds in a single night, then remain inactive for long periods. Their mounds are inconspicuous when washed down by rain; heavy infestations are apparent only during periods of activity. When foraging, a cricket will move seed and occasionally germinating seedlings into the food chamber, along with bits of green vegetation (*86*). Feeding on treated seed usually kills crickets, but before dying an individual may move several seeds into its burrow.

Harvester ants of four species are found within the southern pine region. The Florida harvester ant occurs in sandy soils from south Mississippi eastward to the Atlantic coast. The

FS-519019

Figure 42.—The short-toiled cricket lives in an underground burrow marked by a small mound of excavated soil.

other three, the western, red, and Comanche harvester ants, live in similar soils in north Louisiana and Texas. They are large, fast-moving ants that have underground nests in which they store seeds of many species, including pines. A typical surface mound is illustrated in figure 43. Densities of two to five nests per acre are common on some sites. The ants sometimes remove treated seeds; their potential for damage has not been fully evaluated.

Several insects or other pests destroy seed or seedlings in place. None can be classified as generally serious, though each is capable of causing heavy damage in small areas. Following is a list of those that have been identified:

Small red and black ants: Enter germinating seed and eat the endosperm.

Small fungus-growing ant (Trachymyrmex): Suspected of cutting cotyledons of newly germinated seedlings.

Slugs, snails: Feed on emerging radicle of treated or untreated seed, cutting it flush with the seedcoat. Occasionally mine lower one-third of endosperm.

Millipedes: Feed on untreated seed; there have been few instances of damage to treated seed. Portions of a cotyledon are taken occasionally.

Cutworms: Sever cotyledon-stage seedlings at the groundline, leaving them in place or partially consuming them.

White-fringed beetles: Destroy first-year seedlings by feeding on the roots. Found under sod on abandoned fields.

White grubs: Destroy or stunt first-year seedlings by feeding on the roots. These, too, are most prevalent on old fields.

With present knowledge, direct control of insect predators is practical, and essential, only for the Texas leaf-cutting ant. This pest must

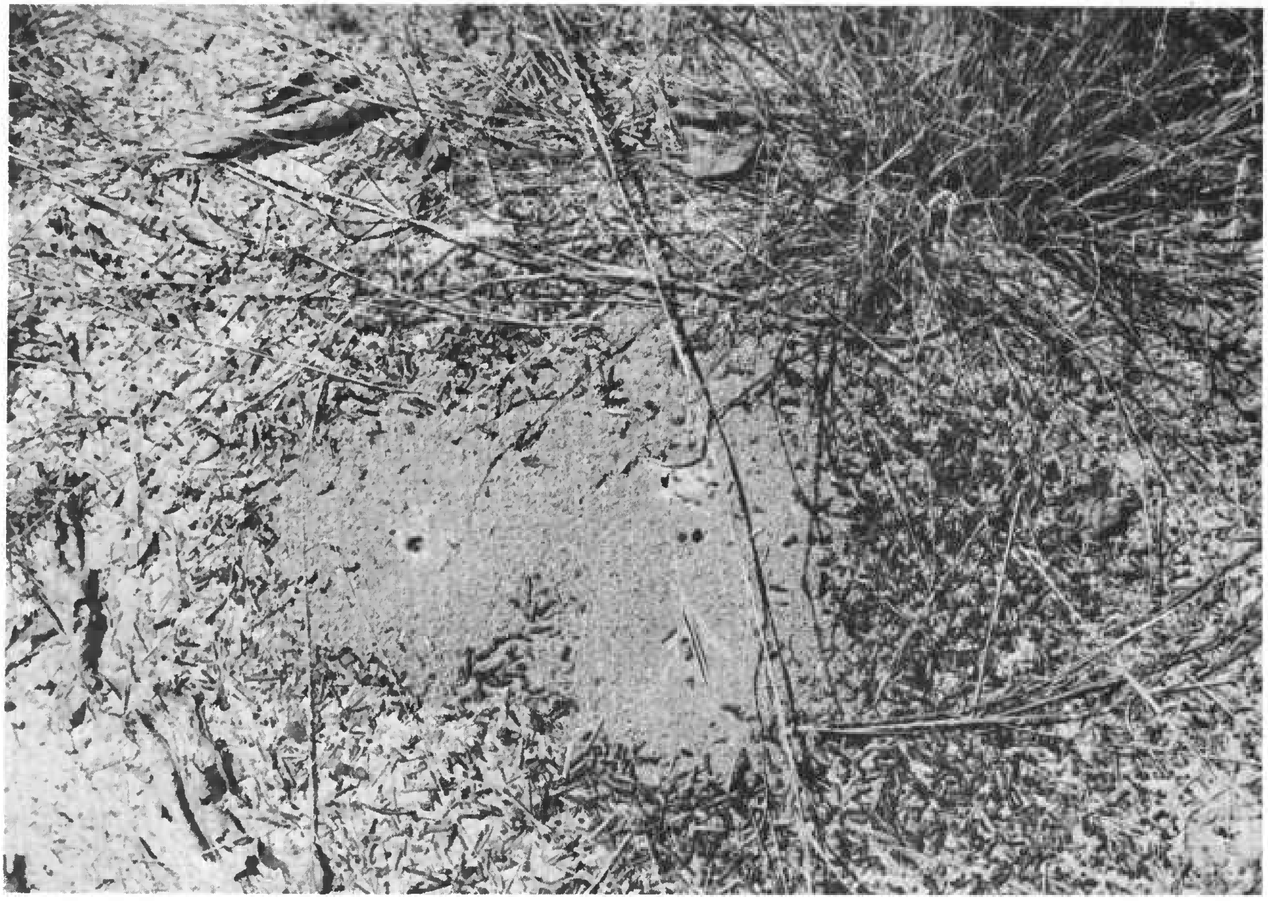

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Figure 43.—The nest of the harvester ant can usually be identified by a ring of charred debris around the entrance hole.

be eliminated well in advance of sowing, for it can destroy all germinating seeds and seedlings within range of its nest. An ant colony can be eliminated with a single application of a special mirex bait (*27*), or by fumigation with methyl bromide. When populations of other insects—particularly crickets and harvester ants—are heavy, the most practical course is to increase sowing rates 10 to 20 percent.

Disease

Damping-off, caused by any one of several fungi, is the only disease of concern in direct seeding. It is primarily a nursery disease, and there have been few instances of extensive damage to field-sown seedlings—a fortunate situation, since control is difficult and uncertain even in intensely managed nursery beds. The disease appears during germination or soon after. The stems of infected seedlings wilt and shrivel near the groundline; the affected part of the stem turns dark. Longleaf seedlings flatten out on the ground, seedlings of other species topple over.

In preemergence damping-off, the embryo or radicle is destroyed before the seedling appears. The thiram used in the repellent coating is basically a fungicide, and probably controls some of the organisms causing damping-off. Such an effect is suggested by field comparisons in which coated seeds have consistently germinated better than untreated seeds on protected spots where predation by animals and insects was minimized.

Weather

Drought, seed movement and silting by heavy rain, and frost heaving are the main effects of adverse weather. They are in some respects inherent risks, though loss from drought and water can be lessened by proper site and seedbed preparations.

Moving surface water from high-intensity rains may displace germinating seedlings before the radicles are firmly anchored in the soil. Losses are most likely on steep terrain burned just before seeding. If burning can be scheduled 6 to 8 months ahead of sowing, the light regrowth of vegetation usually reduces water movement enough to prevent serious loss. The large, buoyant seeds of longleaf pine are most easily dislodged by moving water. But a light 1-year-rough is a good seedbed for this species.

Frost heaving has been reported as causing excessive seedling losses on some soils, particularly those that are bare or poorly drained, or have a high proportion of clay in the surface layer. Repeated freezing and thawing of the soil lifts the seedlings and exposes the roots. Most losses have been to longleaf pines sown in the fall, and for this species the only preventive is to retain some cover on the site or to sow in spring. On some sites damage may also occur in the first winter after spring germination, and here sowing rates should be high enough so that stocking will be adequate even if there is some loss.

APPRAISALS

Seed losses begin on the day of sowing and continue throughout the germination period. Then attrition of seedlings starts. A successful seeding is one in which losses are minimized, so that adequate first-year stocking is achieved with the least amount of seed. For consistent success, a landowner must have reliable estimates of controllable losses, of stand density, and of losses from uncontrollable factors such as drought.

Two or three estimates are normally made during the establishment period. They are: (1) predator activity before and during germination, (2) initial stocking, and (3) stocking at the end of the first year. The second evaluation is often omitted in routine seeding when initial yields are not required to evaluate sowing rates or site treatments. A stocking survey may also be needed at the end of the second year or later if heavy losses from cattle, rabbits, or dry weather are suspected.

Direct seeding often has been done without adequate appraisals. Some well-stocked stands have been "discovered" several years after a cursory initial examination caused them to be written off as failures. Worse, perhaps, are situations in which seeded areas are carried on the record as stocked when, in fact, the stands are inadequate. In these cases, opportunities for reseeding are lost and expensive site preparation must often be done again.

Estimating Predator Activity Before & During Germination

Observation stations, where repeated examinations can be made, are essential for detecting predator activity in initial seeding trials. Because the seeds are exposed and concentrated, predation on these plots may be greater than elsewhere. Nevertheless, the stations provide the best reference points for determining whether important predators are at work. Occasionally, they must be supplemented by other means when unusual losses are found. After several successful sowings the stations usually can be discontinued.

An effective observation station consists of an identification stake and two small cleared spots containing 25 exposed seeds each and located at least 3 feet from the stake in opposite directions (fig. 44). An additional screened spot with 10 seeds is usually added nearby to provide an estimate of maximum field germination. All spots should be sown with treated seed from the same lot used on the general area. Small seeds, as of loblolly or shortleaf pine, are easily lost from view if moved by water or covered by soil and debris. Some of the difficulty can be overcome by placing them on small concave disks of window screen laid in contact with the soil. Also, the number of seeds per spot can be increased substantially. Increasing the number precludes accurate counting but still permits gross estimates of predator activity.

Concentration of the seed in small spots allows rapid examination, thus permitting placement and examination of an adequate number of stations. It also increases the likelihood that predators will leave evidence of their visit. Simultaneous destruction of both spots at a station indicates a higher level of predator activity than single-spot attacks.

The number of stations varies with size of the seeding and with the number of distinct cover conditions. Fifty well-dispersed stations are usually adequate for areas of 100 to 1,000 acres in size. More are needed on larger areas or one where there are wide differences in site or cover conditions. For small areas the number can be scaled down, but 15 is about the minimum.

The frequency at which the stations are examined may range from daily to weekly. The inter-

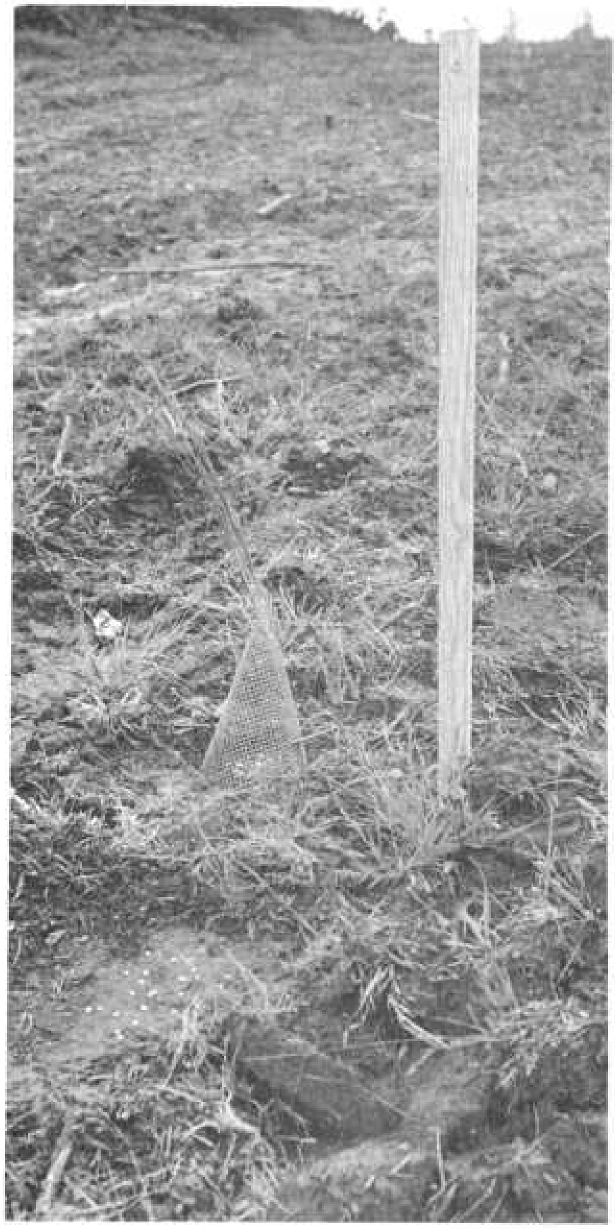

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Figure 44.—A typical observation station, consisting of screened and exposed seeds placed near an identification stake.

val need not be fixed, but examinations more than a week apart tend to defeat their purpose. The usual procedure is to start on a weekly schedule, then shorten the intervals when a significant amount of damage is detected or germination begins. Only in rare situations are daily observations needed; an example would be while rabbits are being controlled on areas where their damage to seedlings has been detected.

A simple record form is helpful in maintaining continuity of observations for each station. The number of seeds destroyed or missing between examinations should be recorded, and notes should be made on evidence left by the predator. Other information to be documented includes apparent condition of the repellent coating, number of undamaged seeds still visible, progress of germination, and insect activity. Germinated seedlings should be marked with pins, because seedlings are often destroyed with very little evidence remaining. Spots losing seeds early in the observation period should be reseeded to maintain their usefulness for detecting additional damage.

Some losses can be expected on any series of observation stations, but it is difficult to say how much damage must occur to indicate serious predation. Usually a minor loss of seed occurs during the initial 2 weeks. The loss may include all of the 25 seed samples from some spots. Seed fragments or damaged spots usually indicate rodent activity. This activity normally stops after the initial attack, indicating that a local animal has been conditioned by the repellent against further feeding.

Initial losses are of minor concern unless they occur on a majority of the stations and unless they continue. Then, the possibilities of a high rodent population or damage by migratory birds should be investigated. Heavy and sudden losses occurring late in the germination period usually signify migratory birds, or if germinating seedlings are removed, rabbits. Both agents should be checked by direct observation at times of the day when they are most likely to be feeding. Rabbits, of course, are seldom active during daylight.

Data from the observation stations should not be regarded as providing a true sample of conditions on the seeded area. This is not the purpose of the stations. True samples, i.e., random plots of a prescribed size on which sown seeds are observed in place, require considerable effort. Observation stations simply provide a quick means of detecting damage. When damage does occur, further checking of the seeded area is required to evaluate it properly. Supplemental methods are sometimes needed in initial seeding trials to identify a predator or measure the extent of its damage. They include trapping with live or snap traps, night observation with a light, or staking of established seedlings.

Seedling Inventories

The first year is critical for all southern pines. New seedlings are highly vulnerable to drought before their root systems are well formed. Mortality varies greatly by climate, soil type, and cover conditions. Climate is the most important single factor. On flatwoods sites in the Southeast, summer rainfall is usually well distributed and mortality normally averages less than 5 percent. In the West Gulf region, where summer droughts of 4 to 8 weeks' duration are common, mortality may reach 70 percent in dry years, even on well-prepared seedbeds.

At least two seedling inventories are advised —one at the beginning of summer when germination is completed, the other at the end of the first growing season when danger of mortality from drought is past. The early inventory indicates the efficiency of repellents in new localities. The second usually estimates overall success, for loss after the first year is normally low. The difference between the first and second inventories represents first-year mortality, a highly useful statistic in adapting future operations to local conditions. Occasionally losses are heavy between the first and second years, and then a third inventory may be desirable.

Seeding success can be judged by number of seedlings per acre and by distribution of these seedlings; the two values are closely related. Tree percent, the ratio of seedlings to seed, is often calculated too. It should be about 25 in early summer (that is, one seedling for four seeds) ; if it is substantially lower there is good chance that something unusual has occurred.

Stocking, a measure of seedling distribution, is normally expressed as the percent of milacre (1/1,000-acre) sample plots having one or more pines. Land managers judge success most frequently by the stocking present after the first growing season. In broadcast sowing, distribution approaches 100 percent when seedlings number 5,000 to 6,000 per acre. It may drop to about 50 percent with 1,000 seedlings per acre. When densities are between 1,500 and 3,500 seedlings per acre the usual range of stocking is between 60 and 80 percent (fig. 45). A commonly accepted minimum criterion for success is 55 percent.

Both number of seedlings per acre and stocking can be determined for the same set of sample plots. Little extra time is required to count all seedlings on a milacre once the plot has been established. The two values allow better interpretation of results than does stocking alone. For example, low stocking but a high number of seedlings per acre suggests either non-uniform sowing or uneven germination or survival.

Circular milacre plots are convenient for sampling broadcast seedings, as only a sweep of the plot radius (44.7 inches) is necessary to delineate the plot boundary. Plots are usually on a systematic grid, with distance between plots and between lines of plots dependent on the number taken. Plot centers must be established without bias, plot areas must be carefully searched for seedlings, and borderline seedlings must be accurately classified as on or off the plots. The mean number per plot multiplied by 1,000 provides an estimate of number per acre. Stocking, based on 1,000 perfectly distributed

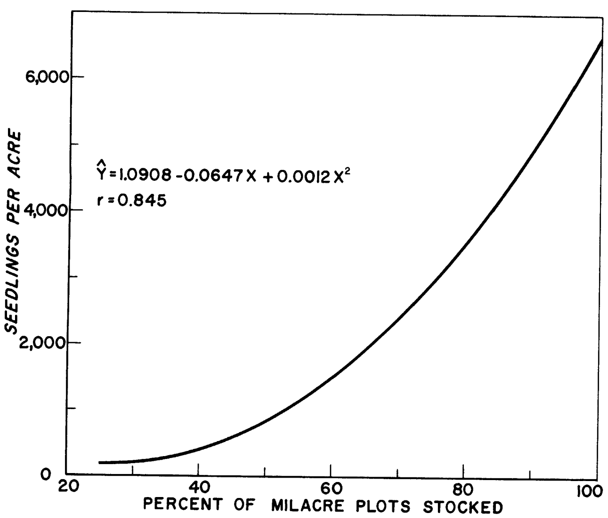

Figure 45.—Relationship between number and stocking of seedlings obtained from broadcast sowing. Data are from 209 research and operational seedings.

seedlings per acre, is expressed as the percentage of sample plots with at least one seedling. When stocking alone is desired, the field procedure is the same except that searching on a plot is discontinued after the first seedling is found.

The number of sample plots required depends on desired accuracy and the expected plot-to-plot variation (expressed as coefficient of variation). Experience has shown that the coefficient of variation for average number of seedlings per plot is close to 100 percent on milacres sampling broadcast seedings. This means that there is a 1:1 ratio between the mean and its standard deviation. For example, a stand with a mean value of four seedlings per milacre would have two out of three sample plots falling in the range of 4 ± 4, or from zero to eight seedlings per plot.

The intensity of sampling for 67-percent reliability is calculated as $\left(\frac{\text{coefficient of variation}}{\text{desired accuracy}}\right)^2 =$ number of sample plots. Thus, if an accuracy of ± 10 percent is required and a coefficient of variation of 100 percent is assumed, the number of sample plots needed would be $\left(\frac{100}{10}\right)^2$ or 100. Generally, 100 plots are adequate for sampling seedling numbers on areas up to several thousand acres. If separate estimates are wanted for subunits, approximately 100 sample plots will be required for each. In practice, subunits are usually sampled with a smaller number of plots; the resulting error of estimate is larger, but the combined total for all subunits gives a sufficiently accurate estimate of the whole seeding. Such sampling allows rough identification of subunits that may require supplemental seeding. These subunits are then sampled more intensively before a final determination is made.

A modification in sampling procedure is desirable for areas that are disked in strips and sown broadcast. Seedlings on the undisked portions contribute to the stand, but may differ in number and distribution from seedlings on disked portions. Both populations can be determined simultaneously by examining a pair of sample plots at each location—one on the disked strip and one on the untreated balk. Stocking and average number of seedlings per acre on each type of seedbed are computed separately, then weighted by the proportion of area in each category for the estimate of overall stocking. If unknown, the percent of the area disked can be estimated by measuring edge-to-edge distances between strips at each plot location.

On tracts seeded in rows or strips, rather than broadcast, the sample plot becomes a linear segment of the row. The procedure is to establish, on regular transect lines, a plot consisting of two adjacent 6.6-foot segments. A location marking the common boundary of the two subplots is selected in an unbiased manner. The total number of seedlings on each subplot is recorded. Finally, the distances from the center of the sampled strip or row to the center of each adjoining one are measured at each location. The estimate of seedlings per gross acre is computed by multiplying the mean stocking per sample location (both 6.6-foot subplots) by $\frac{3,300}{\text{average distance between centers}}$. For example, if the mean stocking per 13.2-foot sample plot is 12 and the strip or row centers average 16.5 feet apart, stand density is $\frac{12 \times 3,300}{16.5} = 2,400$ seedlings per gross acre. The constant, 3,300, is derived by dividing the number of square feet per acre (43,560) by the total length of the sample segment (13.2 feet). Sampling with a plot length other than 13.2 feet simply requires computing an appropriate constant.

Stocking percent is derived by multiplying the percent of subplots (6.6-foot segments) stocked with one or more seedlings by $\frac{6.6}{\text{average distance between centers}}$. Obviously, any strip or row spacing over 6.6 feet reduces the maximum stocking that can be attained. If the average interval between centers is 13.2 feet, full sample-plot stocking will be 100 $\left(\frac{6.6}{13.2}\right)$ or 50 percent.

Stocking of spot-sown tracts is normally estimated as the proportion of spots with at least one seedling. The total yield of seedlings may also be tallied to evaluate sowing rates, though more than one seedling per spot is excess (*13*). Occasionally, seeded spots are difficult to relocate after germination is complete. In these cases, sampling methods described for broadcast-sown areas must be used.

LITERATURE CITED

(1) Anonymous.
1960. A wide spectrum repellent for rodents and wildlife. DuPont Agr. Newsletter 28(3):9.

(2) Abbott, H. G.
1961. Direct seeding of conifers. Northeast. Logger 10(4):20-21, 32-33, 37.

(3) Abbott, H. G., and Hilton, R. L.
1965. Seeding white pine under poor quality hardwoods. **In** Direct seeding in the Northeast—1964. A symposium, pp. 34-37. Univ. Mass.

(4) Asher, W. C.
1964. A formula for estimating slash pine seed yields. J. Forest. 62:37-39.

(5) Baldwin, H. I.
1965. Summary of direct seeding in New Hampshire 1924–62. **In** Direct seeding in the Northeast—1964. A symposium, pp. 59–64. Univ. Mass.

(6) Barnett, J. P.
1964. Stored longleaf seed successfully direct seeded. USDA Forest Serv. Tree Planters' Notes 65, pp. 3–5.

(7) Barnett, J. P., and McLemore, B. F.
1966. Repellent-coated pine seed can be stored. Forest Farmer 25(9):14.

(8) Barrett, J. P.
1963. Slash pine gum flow unaffected by seed origin. Forests and People 13(2):18–19.

(9) Beers, W. L., Jr.
1959. Sowing criteria by sites. **In** Direct seeding in the South. A symposium, pp. 129–135. Duke Univ.

(10) Boyer, W. D.
1964. Longleaf seed losses to animals on burned seedbeds. USDA Forest Serv. Res. Note SO-6, 3 pp. South. Forest Exp. Sta., New Orleans, La.

(11) Bramlett, D. L., and Hutchinson, J. G.
1964. Estimating sound seed per cone in shortleaf pine. USDA Forest Serv. Res. Note SE-18, 2 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

(12) Burns, R. M.
1961. Seed sowing tool. USDA Forest Serv. Tree Planters' Notes 45, pp. 3–4.

(13) Campbell, T. E.
1964. Development of slash pine on seeded spots. J. Forest. 62:821–822.

(14) Cassady, J. T., Hopkins, W., and Whitaker, L. B.
1955. Cattle grazing damage to pine seedlings. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 141, 14 pp.

(15) Cobb, H. C.
1959. Seed collection and processing. **In** Direct seeding in the South. A symposium, pp. 40–46. Duke Univ.

(16) Cooper, E. N.
1959. The industrial need for direct seeding. **In** Direct seeding in the South. A symposium, pp. 7–12. Duke Univ.

(17) Cooper, E. N.
1961. Tussock seeding and mound planting. USDA Forest Serv. Tree Planters' Notes 46, pp. 5–7.

(18) Cotrufo, C.
1962. Pretreatment of eastern white pine seed. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 176, 2 pp.

(19) Croker, T. C., Jr.
1960. The H-C furrow seeder. USDA Forest Serv. Tree Planters' Notes 43, pp. 15-16.

(20) Derr, H. J.
1960. Preventing sticker failures in direct seeding. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 128.

(21) Derr, H J.
1963. Better repellent for direct seeding. USDA Forest Serv. Tree Planters' Notes 61, pp. 26–30.

(22) Derr, H. J.
1964. New repellent formulation for direct seeding. J. Forest. 62:265.

(23) Derr, H. J., and Enghardt, H.
1960. Is geographic seed source of slash pine important? South. Lumberman 201(2513): 95–96.

(24) Derr, H. J., and Mann, W. F., Jr.
1959. Guidelines for direct-seeding longleaf pine USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 171, 22 pp.

(25) Dickson, R. E., Hosner, J. F., and Kahler, L.
1961. Polyethylene bag storage versus stratification in sand as a pregermination treatment for white and loblolly pine. USDA Forest Serv. Tree Planters' Notes 48, pp. 15–16.

(26) Duvall, V. L., and Whitaker, L. B.
1963. Supplemental feeding increases beef production on bluestem-longleaf pine ranges. La. State Univ. Bull. 564, 18 pp.

(27) Echols, H. W.
1966. Texas leaf-cutting ant controlled with pelleted mirex bait. J. Econ. Entomol. 59:628–631.

(28) Farrar, R. M., Jr.
1959. Seeded and planted pines grow at similar rates. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 122.

(29) Fenton, R. H., and Sucoff, E. I.
1965. Effects of storage treatments on the ripening and viability of Virginia pine seed. USDA Forest Serv. Res. Note NE–31, 6 pp. Northeast. Forest Exp. Sta., Upper Darby, Penn.

(30) Forrest, W. G.
1964. The effect of pretreatment on germination of slash pine seed. Forest. Comm. New South Wales Res. Note 14, 11 pp.

(31) Graber, R. E.
1965. Germination of eastern white pine seed as influenced by stratification. USDA Forest Serv. Res. Pap. NE–36, 9 pp. Northeast. Forest Exp. Sta., Upper Darby, Penn.

(32) Harrington, T. A.
1958. Virginia pine seeded in Tennessee. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 114.

(33) Harrington, T. A.
1960. Direct seeding white pine. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 125.

(34) Hatchell, G. E.
1961. A look at 9-year-old seeded loblolly pine. Forests and People 11(3):25, 44–45.

(35) Hatchell, G. E.
1964. Immediate release needed for maximum growth of seeded loblolly pine. USDA Forest Serv. Tree Planters' Notes 66, pp. 19–22.

(36) Hatchell, G. E.
1964. Small-mammal species and populations in the loblolly-shortleaf pine forest type of Louisiana. USDA Forest Serv. Res. Pap. SO–10, 12 pp. South. Forest Exp. Sta., New Orleans, La.

(37) Hatchell, G. E.
1966. Loblolly pine direct seeding in the lower Piedmont of Georgia. Ga. Forest Res. Counc. Res. Pap. 40, 4 pp.

(38) Hill, J. H.
1959. Site preparation for direct seeding in the Piedmont and mountain areas of the South. **In** Direct seeding in the South. A symposium, pp. 107-108. Duke Univ.

(39) Hodges, J. D., and Scheer, R. L.
1962. Soil cover aids germination of pine seed on sandy sites. USDA Forest Serv. Tree Planters' Notes 54, pp. 1–3.

(40) Hosner, J. F., Dickson, R. E., and Kahler, L.
1959. Storing loblolly pine seed in polyethylene bags as a substitute for stratification. J. Forest. 57:495–496.

(41) Jarrett, T. W.
1964. Depth of planting affects germination of white pine seed. J. Forest. 62:502.

(42) Jarvis, W. T., and Beers, W. L.
1965. Reclamation of a wasteland in Central Gulf Coastal Florida. J. Forest. 63:3–7.

(43) Jones, E. P., Jr.
1963. A test of direct seeding depths for slash and longleaf pine. USDA Forest Serv. Res. Note SE–5, 2 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

(44) Jones, L.
1962. Recommendations for successful storage of tree seed. USDA Forest Serv. Tree Planters' Notes 55, pp. 9–20.

(45) Jones, L.
1963. Germination of repellent-treated southern pine seed before and after storage. USDA Forest Serv. Res. Note SE–15, 4 pp. Southeast. Forest Exp. Sta., Asheville, N. C.

(46) Jones, L.
1966. Storing pine seed: What are best moisture and temperature conditions? Ga. Forest Res. Counc. Res. Pap. 42, 8 pp.

(47) Koenig, R. L.
1962. Comparison of early development of planted and direct seeded slash pine. Union Bag-Camp. Pap. Corp. Woodland Res. Notes 13, 4 pp.

(48) Lehto, T. V.
1960. Stratifying pine seeds in plastic bags. Amer. Nurseryman 111 (7):15.

(49) Lewis, C. H.
1959. The economic advantage of seeding over planting on large ownerships in Louisiana. **In** Direct seeding in the South. A symposium, pp. 171-178. Duke Univ.

(50) Little, S., and Somes, H. A.
1964. Root systems of direct-seeded and variously planted loblolly, shortleaf, and pitch pines. USDA Forest Serv. Res. Pap. NE–26, 13 pp. Northeast. Forest Exp. Sta., Upper Darby, Penn.

(51) McLemore, B. F.
1959. Cone maturity affects germination of longleaf pine seed. J. Forest. 57:648–650.

(52) McLemore, B. F.
1961. Prolonged storage of longleaf cones weakens seed. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 132.

(53) McLemore, B. F.
1961. Small, fast-drying cone kiln. USDA Forest Serv. Tree Planters' Notes 47, pp. 9–12.

(54) McLemore, B. F.
1961. Storage of longleaf pine seed. USDA Forest Serv. Tree Planters' Notes 47, pp. 15–19.

(55) McLemore, B. F.
1962. Predicting seed yields of southern pine cones. J. Forest. 60:639–641.

(56) McLemore, B. F., and Barnett, J. P.
1966. Storing repellent-coated southern pine seed. J. Forest. 64:619–621

(57) McLemore, B. F., and Czabator, F. J.
1961. Length of stratification and germination of loblolly pine seed. J. Forest. 59:267–269.

(58) McLintock, T. F.
1942. Stratification as a means of improving results of direct seeding of pines. J. Forest. 40:724-728.

(59) McQuilkin, W. E.
1959. Establishing white pine on open land. **In** What's known about managing eastern white pine, pp. 31–44. USDA Forest Serv. Northeast. Forest Exp. Sta., Sta. Pap. 121.

(60) McReynolds, R. D.
1960. Mortality of newly germinated southern pine seedlings following inundation. USDA Forest Serv. Tree Planters' Notes 43, pp. 23–25.

(61) Maki, T. E.
1968. Drainage and soil moisture control in forest production. **In** Ecology of southern forests, pp. 139–153. La. State Univ. 17th Annu. Forest. Symp. Proc. 1968. La. State Univ. Press.

(62) Maki, T. E., and Mann, W. F., Jr.
1951. Some effects of sheep grazing on longleaf pine. J. Forest. 49:278–281.

(63) Malac, B. F.
1960. More on stratification of pine seed in polyethylene bags. USDA Forest Serv. Tree Planters' Notes 42, pp. 7–9.

(64) Mann, W. F., Jr.
1952. Stratified pine seed for direct seeding. USDA Forest Serv. Tree Planters' Notes 11, p. 3.

(65) Mann, W. F., Jr.
1959. Preparing seed for direct seeding. **In** Direct seeding in the South. A symposium, pp. 52–61. Duke Univ.

(66) Mann, W. F., Jr.
1962. Tools for direct seeding. Forest Farmer 21(5):13–16.

(67) Mann, W. F., Jr.
1965. Progress in direct-seeding the southern pines. **In** Direct seeding in the Northeast—1964. A symposium, pp. 9–13. Univ. Mass.

(68) Mann, W. F., Jr., and Burkhalter, H. D.
1961. The South's largest successful direct seeding. J. Forest. 59: 83–87.

(69) Mann, W. F., Jr., and Burns, E. B.
1965. Direct seeding for the small landowner. Forest Farmer 25(3): 7, 14.

(70) Mann, W. F., Jr., and Derr, H. J.
1955. Not for the birds. USDA Forest Serv. Tree Planters' Notes 20, pp. 3–6.

(71) Mann, W. F., Jr., and Derr, H. J.
1961. Guidelines for direct-seeding loblolly pine. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 188, 23 pp.

(72) Mann, W. F., Jr., and Derr, H. J.
1964. Guides for direct-seeding slash pine. USDA Forest Serv. Res. Pap. SO–12, 27 pp. South. Forest Exp. Sta., New Orleans, La.

(73) Mann, W. F., Jr., Derr, H. J., and Meanley, B.
1956. A bird repellent for direct seeding of longleaf pine. J. Forest. 54: 190–191.

(74) Maple, W. R.
1961. Treated shortleaf pine seed can be stored. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 136.

(75) Maxwell, K. F., Cech, F. C., and Driver, C. H.
1960. Covering southern pine seed. Forest Farmer 20(2): 9, 12.

(76) Meade, F. M.
1963. Storage of repellent-treated pine seeds. Ark. Farm Res. 12(6):5.

(77) Mignery, A. L., and Yeatman, H. C.
1960. Mice hinder pine seeding on Cumberland Plateau. USDA Forest Serv. South. Forest Exp. Sta. South. Forest. Notes 129.

(78) Miller, S. R.
1957. Germination of slash pine seed following submergence in water. Union Bag-Camp Pap. Corp. Woodland Res. Notes 3, 2 pp.

(79) Miller, S. R.
1966. Prescription direct seeding as an operational program. Proc., Direct seeding workshops, Alexandria, La., and Tallahassee, Fla., pp. 99–109. USDA Forest Serv., Atlanta, Ga.

(80) Phares, R. E., and Liming, F. G.
1960. Comparative development of seeded and planted shortleaf pine on a forest site in the Missouri Ozarks. J. Forest. 58:957–959.

(81) Phares, R. E., and Liming, F. G.
1961. Development of shortleaf pine seedlings in seeded spots. J. Forest. 59:515–516.

(82) Phares, R. E., and Liming, F. G.
1961. Shortleaf pine direct-seeding success affected by month of seeding, release method, and weather. J. Forest. 59:804–807.

(83) Richardson, B. Y.
1965. New tools for direct seeding. South. Lumberman 211(2632):150–151.

(84) Roe, E. I.
1948. Viability of white pine seed after 10 years of storage. J. Forest. 46:900–902.

(85) Royall, W. C., Jr., and Ferguson, E. R.
1962. Controlling bird and mammal damage in direct seeding loblolly pine in east Texas. J. Forest. 60:37–39.

(86) Russell, T. E.
1958. Cricket hazard. Forest Farmer 17(12):12–13, 15.

(87) Russell, T. E.
1964. From oak-hickory tie orchards to profitable white pine—by direct seeding. USDA Forest Serv. Tree Planters' Notes 67, pp. 19–21.

(88) Russell, T. E., and Rhame, T. E.
1961. The advantages of disking for slash seeding. Forests and People 11(1):12–13.

(89) Scheer, R. L., and Woods, F. W.
1959. Intensity of preplanting site preparation required for Florida's sandhills. USDA Forest Serv. South. Forest Exp. Sta. Occas. Pap. 168, 12 pp.

(90) Seidel, K. W.
1963. Germination of treated shortleaf pine seed. USDA Forest Serv. Res. Pap. CS-5, 12 pp. Cent. States Forest Exp. Sta., Columbus, Ohio.

(91) Shadowen, H. E.
1963. A live-trap study of small mammals in Louisiana. J. Mammalogy 44:103–108.

(92) Shipman, R. D.
1963. Seeding depth—its influence on establishment of direct-seeded pine in the South Carolina sandhills. J. Forest. 61:907–912.

(93) Snyder, E. B., Wakeley, P. C., and Wells, O. O.
1967. Slash pine provenance tests. J. Forest. 65:414–420.

(94) Sower, D. W., Jr.
1964. Suggested guidelines for direct seeding Virginia pine in West Virginia. North. Logger 12(8):12–13, 36–39.

(95) Sowers, D. W., Jr.
1965. Direct seeding experiments with Virginia pine in West Virginia. **In** Direct seeding in the Northeast—1964. A symposium, pp. 68–71. Univ. Mass.

(96) Squillace, A. E.
1966. Geographic variation in slash pine. Forest Sci. Monogr. 10, 56 pp.

(97) Stephenson, G. K., Goodrum, P. D., and Packard, R. L.
1963. Small rodents as consumers of pine seed in east Texas uplands. J. Forest. 61:523–526.

(98) Sucoff, E. I., and Church, T. W., Jr.
1960. Seed production and dissemination by Virginia pine. J. Forest. 58: 885-888.

(99) USDA Forest Service.
1965. Silvics of forest trees of the United States. USDA Agr. Handbook 271, 762 pp.

(100) VanHaverbeke, D. F., and Barber, J. C.
1964. Seed crop estimation in a loblolly pine seed production area. Ga. Forest Res. Counc. Res. Pap. 21, 5 pp.

(101) Wakeley, P. C.
1954. Planting the southern pines. USDA Agr. Monogr. 18, 233 pp.

(102) Webb, C. D., and Hunt, D. L.
1965. Seed crop estimation in a slash pine seed production area. Ga. Forest Res. Counc. Res. Pap. 28, 5 pp.

(103) Wells, O. O.
1969. Results of the Southwide Pine Seed Source Study through 1968-69. Tenth South. Forest Tree Impr. Conf. Proc. 1969: (in press).

(104) Wells, O. O., and Wakeley, P. C.
1966. Geographic variation in survival, growth, and fusiform-rust infection of planted loblolly pine. Forest Sci. Monogr. 11, 40 pp.

(105) Wenger, K. F.
1953. How to estimate the number of cones in standing loblolly pine trees. USDA Forest Serv. Southeast. Forest Exp. Sta. Res. Notes 44, 2 pp.

(106) Zobel, B. J.
1959. Seed sources for direct seeding. In Direct seeding in the South. A symposium, pp. 27–31. Duke Univ.

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