

Direct-Seeding
Longleaf Pine



Acknowledgment

This tribute is to foresters who pioneered in direct seeding before repellents had been developed, and whose contributions are too important to be forgotten. They cooperated unstintingly with the researchers, and their repeated pilot trials, conducted despite numerous failures, afforded the necessary opportunities to test ideas and observe results on a practical scale. Equally important, their confidence and encouragement did much to keep the research active when progress was slow. The persons and organizations named here deserve special recognition:

**Charles H. Lewis, Jr., Crosby Chemicals, Inc.,
DeRidder, Louisiana**

**Robert E. Mitchell, Hillyer-Deutsch-Edwards, Inc.,
Oakdale, Louisiana**

James E. Mixon and staff members of the Louisiana Forestry Commission, Baton Rouge, Louisiana

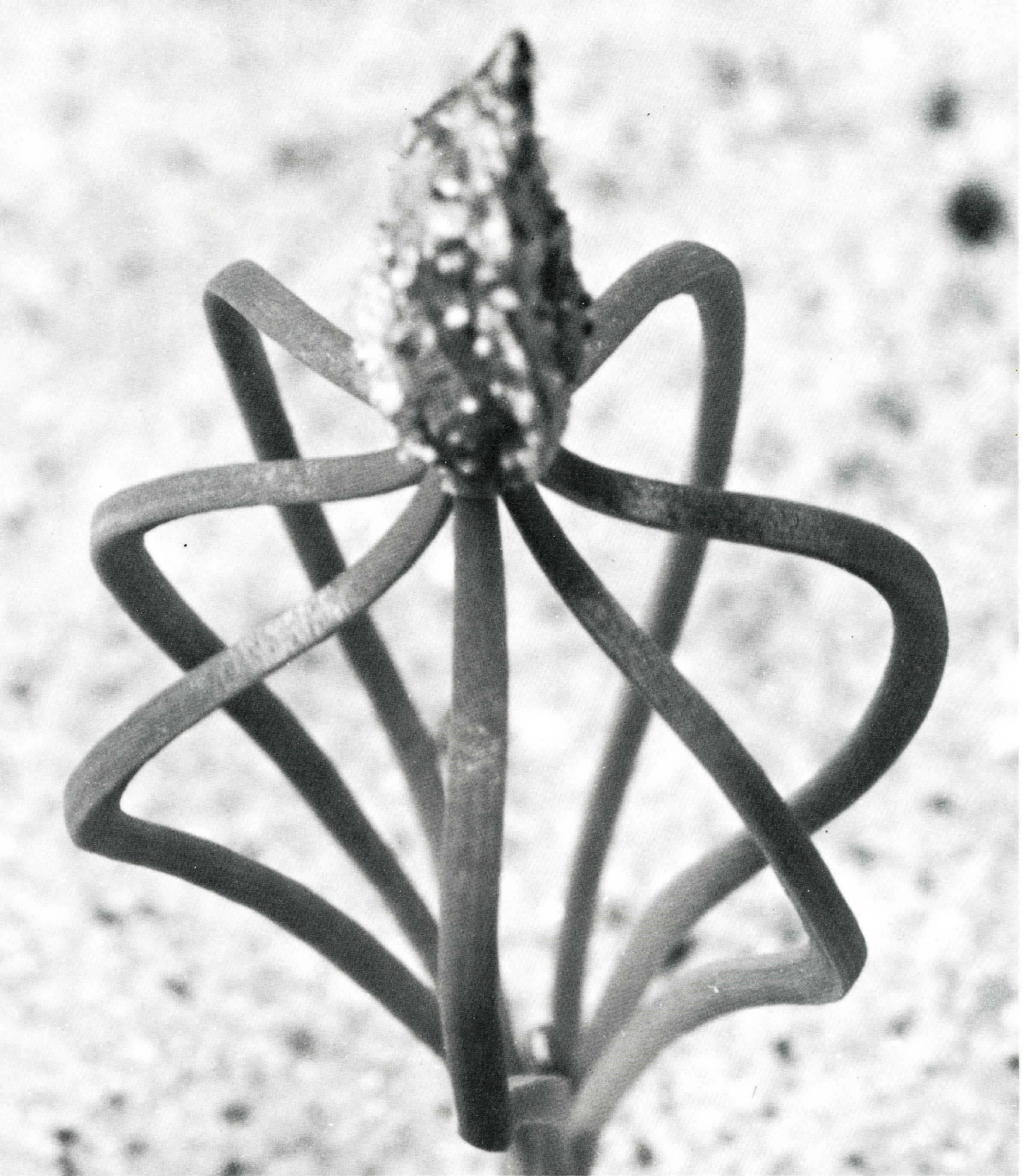
**William M. Palmer, Jr., Nebo Oil Company (now Bodcaw Company),
Good Pine, Louisiana**

**Hugh S. Redding and staff members of the Kisatchie National Forest,
Pineville, Louisiana**

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W. F. Mann, Jr.

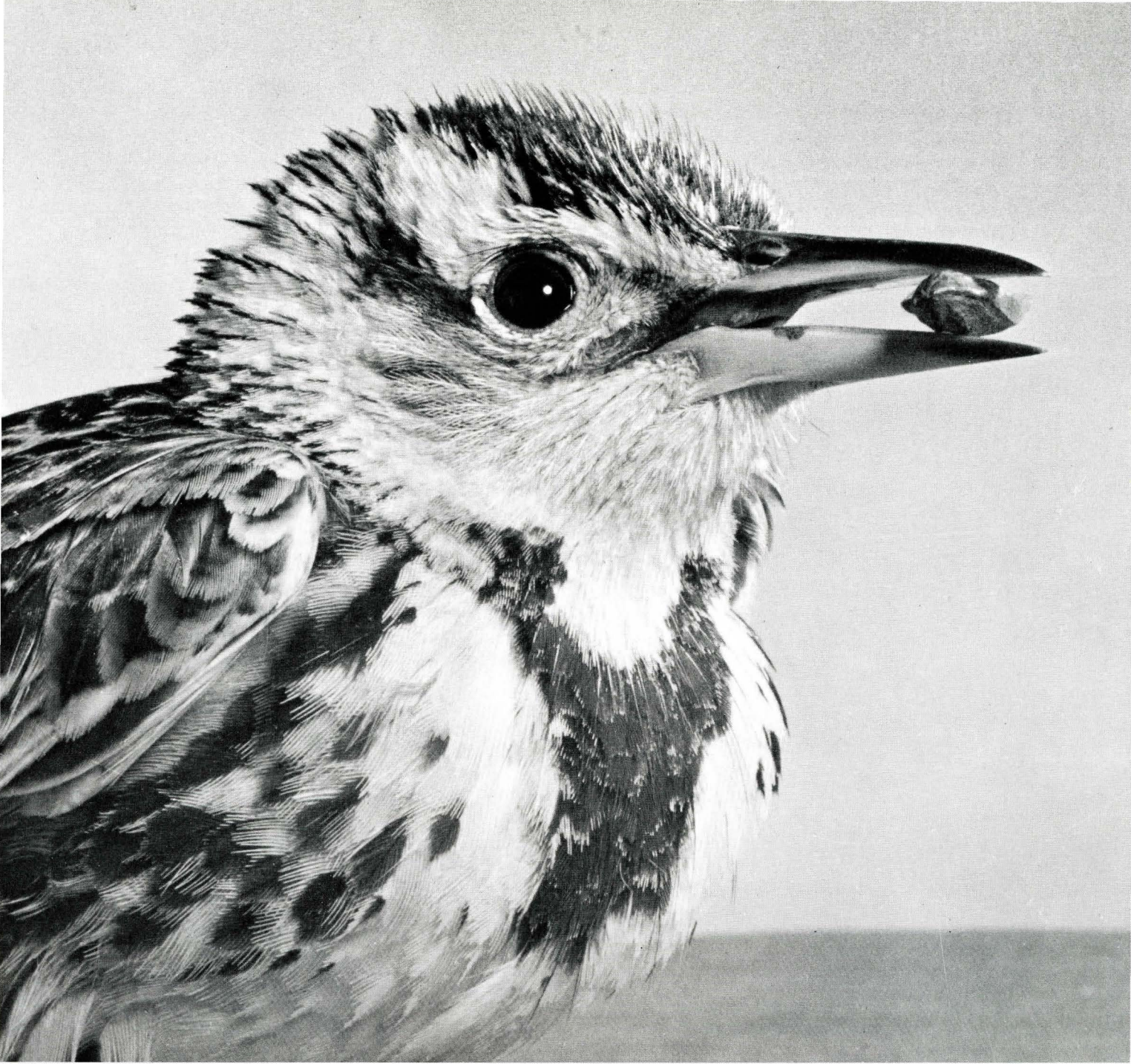
Southern Forest Experiment Station
Forest Service
U.S. Department of Agriculture



Longleaf pine seedling just before seedcoat is shed. This species is challenging to manage, and rewarding to grow.

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Birds were major seed predators before a repellent was developed.

This publication updates "Guidelines for direct-seeding longleaf pine," which was issued in 1959 as Occasional Paper 171 of the Southern Forest Experiment Station. Prescriptions for longleaf have been improved substantially since then. New techniques have resulted from additional research coupled with experience from practical operations. More than 200,000 acres have been sown on a wide array of sites across the South. These operations—many of which have been observed by the author—not only served as proving grounds for new developments, but established that the recommendations are broadly applicable throughout the native range of longleaf pine.

Research to develop reliable methods for direct-seeding longleaf was initiated by scientists of the Southern Forest Experiment Station in 1947. For 8 years, studies were conducted to determine seedbed requirements on various soils, optimum season of sowing, predators of seed and seedlings, and methods of distributing seed. Concurrently, research was concentrated on finding a coating to protect seeds from birds, rodents, and insects.

A bird repellent was discovered in 1954, and was followed in 1957 by a combination repellent effective against most of the major predators. Longleaf was the first of the southern pines to be sown operationally—beginning about 1955. Seeding has become the most prevalent method of regenerating this species, because planting nursery-grown seedlings is expensive and survival is often low.

The purpose of this paper is to cover all phases of a direct-seeding operation from initial planning to appraisal of results. Each major aspect is covered in a separate section, and with sufficient detail to guide a forester with no previous experience through his first operation. Recommendations for additional reading are listed at the end of the text.

Guidelines given here should not be applied to other species, which differ with respect to site preparation, season of sowing, seed treatments, and sowing rates. Similar papers for loblolly and slash pines were published separately in 1961 and 1964; the one for loblolly was updated in 1966 (Mann and Derr, 1964, 1966). Information on other species is also available (Mann 1966).

ADVANCE PLANNING

Site Appraisal

Sites to be regenerated should be inspected to determine if direct-seeding is practical on them and whether longleaf is a suitable species. Such inspections should be made 8 to 12 months in advance of the intended sowing date.

Longleaf is well adapted to a wide variety of soils in the Atlantic and Gulf Coastal Plains, and in the Appalachian foothills in Alabama and Georgia. Loblolly and slash pines also grow rapidly on many of the soils that are productive for longleaf. The choice of species on such sites will depend on the preference of the landowner.

Longleaf has several characteristics that must be considered carefully before it is selected over other species. Foremost is slow initiation of height growth, which is often delayed until the fourth or fifth year. This stemless period reduces growth and yields, and defers the time when returns can be obtained by thinning. Young longleaf are often attacked by the brown-spot needle blight, which retards growth and kills pines if left unchecked. Periodic prescribed burning is needed to control the disease until pines reach a height of about 3 feet, when they are no longer subject to severe infection. The incidence of infection varies from site to site, but usually several burns are necessary, and add to the expense of management. Occasionally pines escape infection and burning is unnecessary.

While longleaf is difficult to manage in early years, it is often selected for sites where the hazard from wildfire is high. Seedlings, even those only a year old, are highly resistant to damage by fire. Other advantages are freedom from disease and insects after juvenile years, and the high proportion of poles and piling obtained from well-stocked stands. Whatever the reason for selection, it is usually safe to regenerate longleaf on sites it occupied in virgin stands.

Some sites that originally had stands of longleaf are in the flatwoods region. Here hardpans and slowly permeable subsoils impede movement of water through the soil profile, resulting in excessive surface water during wet seasons. In dry weather, the sites can be as droughty as

sandy ridgetops, because moisture in the shallow horizon above the hardpan is quickly depleted. These soils may be difficult to regenerate by any method, and planting may be surer than seeding. In an extreme drought during the first year the entire seeding may be lost. At the other extreme, long inundation will cause serious loss of seed viability, though brief submergence may do no harm. While direct seeding on flatwoods sites has been moderately successful, the extra risks should be recognized.

Many former longleaf sites are dominated by scrub hardwoods. There are two common methods of destroying this competing overstory. First is complete removal by bulldozing, chopping, disk-ing, or chaining in advance of sowing. The technique selected should minimize sprouting, because slow-growing longleaf seedlings are quickly overtopped. The other method is to kill the hardwood overstory by tree injection in the first summer after sowing. Prompt release is necessary for maximum survival and growth.

Landowners are often tempted to try direct seeding where planting has been unsuccessful. Such sites should be avoided, especially in initial operations. The better course is to conduct early

trials on average or good sites and tackle the more difficult ones after experience is gained. There are few exceptions to this general rule. The most notable example is spoil banks left from strip mining, where steep, rocky slopes almost preclude planting. Such sites have been seeded with remarkable success in northern Alabama.

Several situations should be avoided in addition to those where seeds are apt to be submerged. First are steep, eroded sites where seeds are easily washed away. Longleaf seeds, even when coated with repellents, are readily moved by water. The other situation to avoid is broadcasting on coarse, sandy topsoils. These soils dry out within a few hours after a rain, and for satisfactory germination, seeds must be buried about $\frac{1}{4}$ to $\frac{1}{2}$ inch deep. A row-seeding machine, which in a single pass drops and covers the seed in a strip prepared by scalping or furrowing, is suitable for large tracts. On small tracts, seeds can be sown on spots and a hoe or firerake used to cover them with soil.

Once the decision has been made to direct-seed longleaf, it is necessary to consider means of protecting seed and seedlings.

Longleaf has been seeded successfully on steep, rocky spoil banks that are virtually impossible to plant.



Seed sown on the surface of deep, dry sand germinates poorly.



Protection

The repellent coating wards off most of the major predators but is ineffective against such others as town ants, short-tailed crickets, and squirrels, which may be numerous on localized areas. The hazards from predators that are not influenced by the repellent seed coating should be estimated when the site is appraised initially.

Town ants, found in portions of east Texas and Louisiana, destroy seed as well as seedlings. Consequently, colonies must be located and treated with mirex bait in advance of sowing (Echols 1966). Since this insect can defoliate even sapling-sized trees, areas should be rechecked annually for new infestations until the pines are at least 10 feet tall.

Short-tailed crickets carry seed to their burrows and destroy young seedlings in winter and early spring. They may be serious predators on a variety of sites but seem to prefer wet, heavy soils, where as many as 10,000 burrows per acre have been found. Damage declines sharply with the advent of warmer weather, which favors the regrowth of grasses and weeds. The repellent coating does not keep the crickets from carrying away seed, but it usually kills them after a period of time. As many as seven treated seeds have been found in a single burrow with a dead cricket, indicating that substantial damage may be inflicted before the insecticide in the coating is effective. Many heavily infested areas have nevertheless been sown successfully. Present



Burrows of the short-tailed cricket are indicated by small mounds of subsoil.

recommendations are to maintain high sowing rates where cricket burrows number 1,000 or more per acre.

Squirrels may eat considerable seed, especially in stands of hardwoods. Spot and furrow sowings seem especially vulnerable, probably because the seeds are easy to find. Laboratory trials clearly show that squirrels are not repelled or harmed by the repellent coating. The best protection devised so far is to reduce the population by hunting before sowing is started. Permission from local game authorities will be needed for shooting out of season. Killing hardwoods before seeding should alter the habitat and cause squir-

rels to leave the area. Another method of reducing losses is to sow as hardwood leaves are falling, so that seeds will be covered and hard to find. The usual procedure is to wait until 50 to 75 percent of the leaves are down, and then burn and sow. The remaining leaf drop will be enough to cover the seed without smothering the new seedlings.

Rabbits eat both seed and seedlings. The repellent coating ordinarily protects the seed fairly well, but cotyledon-stage seedlings are susceptible to heavy damage. The succulent seedlings are nipped off close to the groundline, with only a short stub to indicate that damage has taken place. Losses are greatest in the winter when other green vegetation is scarce, but they also occur in the spring. Assistance of State wildlife officials should be sought when populations are high enough to be a problem.



Rabbits clip off newly germinated seedlings near the groundline, often causing substantial losses.

Pocket gophers, often called salamanders, kill seedlings by eating the roots. Pines are seldom, if ever, damaged during their first year, but after that they are vulnerable until about 10 feet tall. Small trees may disappear completely as the gophers pull them into tunnels to feed on roots or consume them entirely. Larger ones turn brown and often lean over before the presence of gophers is recognized. They are easily uprooted by hand, as only short stubs of roots remain. Gophers prefer sandy, well-drained soils, where they may cause serious losses over areas of several hundred acres. Their presence is indi-

cated by mounds of soil about 8 inches high and 12 inches in diameter; the mounds are connected by tunnels a few inches below the soil surface. Grass may conceal the mounds, and the best time to check for them is after a burn for seedbed preparation or brown-spot control. Gophers should be controlled as soon as they are detected. An effective method is to place a handful of milo maize treated with strychnine in the tunnels at 1-chain intervals within the infested area (Wakeley 1954).

Grazing by hogs, cattle, and sheep has caused the failure of a number of longleaf seedlings. Hogs, which uproot trees as large as 10 feet tall, must be excluded completely before an area is sown. Cattle and sheep should be eliminated during the first year, because they kill young seedlings by trampling or by eating the needles along with grass. After the first year, light grazing by cattle, and perhaps sheep, can be tolerated. Forage utilization should not exceed 50 percent, and precautions should be taken to prevent concentrated grazing on small areas.

Seedbed preparation, hardwood control, and prescribed burning will attract livestock from several miles away. Consequently, areas previously grazed lightly may suddenly be overrun, especially small tracts where relatively few animals can result in overuse. It is necessary, then, to appraise the number of animals using nearby land, as well as those on the area to be regenerated.

Control of livestock under open range conditions may be difficult. Burning more acreage than will be sown, or burning nearby areas as a diversionary measure, often reduces the hazard from cattle and sheep. Temporary fencing, with untreated posts and several strands of barbed wire, suffices to exclude cattle for a few years. Where hogs are a problem, fences must be constructed with net and barbed wire, and with treated posts that will last at least 10 years. To keep per-acre costs of all types of fences down, large areas must be enclosed.

SEEDBED PREPARATION

The type of seedbed to prepare depends on soil, cover conditions, climatic factors, livestock hazards, and the value placed on fast initial growth. The method of sowing also should be considered, because in some situations it may

be desirable to prepare a seedbed and distribute seed in one operation. In this section, only pre-sowing bed treatments are discussed.

Open grassy areas have been sown most often. They require burning if the rough is heavy; otherwise the seeds, which are large and have a wing stub attached, are likely to lodge in the grass and fail to germinate. A light rough that results from burning a year in advance is usually preferable to a fresh burn, as it provides a better environment for germination. The light regrowth of grass accumulates dew and shields the seed from drying by wind and sun. In years with ample precipitation, seedling catch may be good on a fresh burn. But a light rough is superior when rainfall is scarce during the germination period.

There are some sites where moisture during the germination period is rarely a problem. On these, freshly burned seedbeds may have several major advantages. Autumn fires, as compared with earlier burns, result in slower buildup of brown spot, slightly faster height growth of seedlings, fewer rodents and rabbits, and later control of hardwood sprouts. Sowing on a fresh burn is sometimes necessary when seed unexpectedly becomes available or bad weather prevents spring burning. In these situations the fresh burn is a better choice than a heavy rough, except on rolling sites where rains may wash seed away.

On dry sites, disking improves first-year survival by reducing grasses that compete for soil moisture. It should be done in the summer or early fall, because the best kill of grasses is obtained when the weather is hot and dry. Burning

off the grass facilitates pulverization of the soil; the burn can be made immediately before disking or during the preceding winter. A heavy-duty offset disk, cutting about a 7½-foot swath, does a good job at a reasonable cost. It can be pulled by a crawler tractor used in fire suppression. To reduce costs, strips are disked about 8 feet apart. About 20 acres can be strip-disked daily for \$3.00 per acre. If seed is confined to the prepared strips part of this cost will be offset by a lower sowing rate.

A limited acreage has been sown with longleaf on sites so wet that elevated, disked beds were required. A bedding harrow with six to eight 28-inch disks, pulled by a heavy crawler tractor, will mound the soil about 6 inches high. Production averages about 20 acres daily at a cost of \$4.50 to \$5.00 per acre.

To minimize seed losses from silting, disked beds should be allowed to settle for a few months before being sown.

Two factors should be weighed carefully when deciding whether or not to disk. First, germination may be impaired on sites where the surface layers of disked soil dry out fast. Second, intensity of brown-spot infection will be increased. Brown spot is spread largely by rain splatter, and grasses help shield the pine foliage from spores. Consequently the potential gain in growth by reducing competition may be offset by a higher incidence of disease.

Seedbed preparation on sites with a stand of hardwoods is usually coordinated with control of the overstory. If hardwoods are destroyed by heavy machines, burning is often sufficient



Typical cutover site, with a light grass cover suitable for longleaf seeding.



Hardwoods are often destroyed with heavy machines, like this 5-ton disk.

unless disking is required to check sprouting. Burning off the accumulation of leaves is normally necessary when sowing beneath hardwoods. Mechanical preparation is not needed, for grass is sparse under a hardwood canopy.

Plowed furrows have proved unsatisfactory on most sites even though they control competing grasses better than disking does. Their main disadvantages are that seed is washed away on

sloping ground or submerged on flat, poorly drained sites; erosion is often severe; and insufficient grass develops to carry a suitable fire for brown-spot control when the seedlings are 2 or 3 years old. Furrowing has been effective in several small operations on flat, well-drained, sandy sites where flooding and washing were minor problems. Furrow seeding, a different technique than sowing in plowed furrows, will be discussed in the section on methods of sowing.

Dense stand of hardwoods with litter burned to expose mineral soil. Overstory must be deadened early in the first year after sowing.

(Photo by Louisiana Forestry Commission)



SEED PROCUREMENT

As soon as the area for seeding has been inspected, it is time to make detailed arrangements for seed procurement. It is important to plan early, because supplies are sometimes limited and alternative methods must be appraised. A landowner has several choices: he may collect and extract his own seed, collect cones and have the seed extracted by a commercial dealer, or buy cleaned seed. All three have merit, and the landowner's decision will depend on the supply of cones in his area, facilities available to him for processing cones, and cost of commercial seed.

Purchasing from a dealer is the usual method of obtaining seed. It avoids the uncertainties of cost and seed viability, and it is the easiest of the various alternatives. Prices have ranged from \$1.75 to \$3.00 per pound in recent years, depending on the abundance of seed, the quantity purchased, and how long it was held in storage.

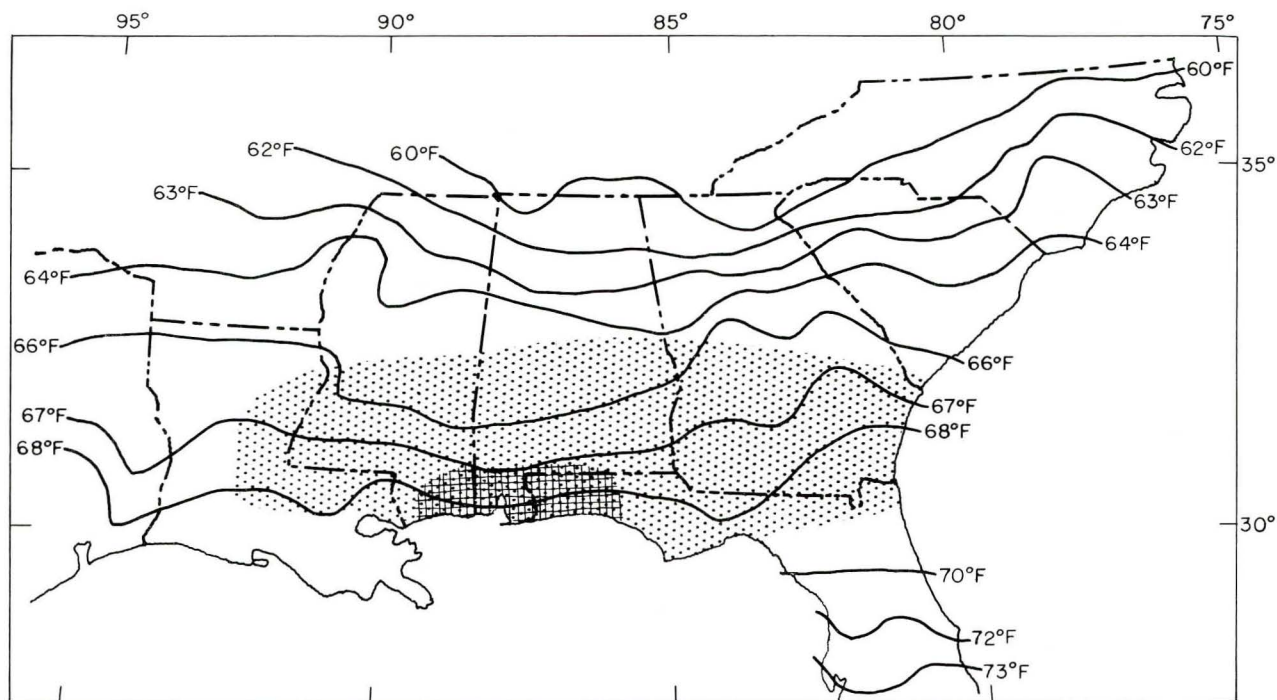
There are two important disadvantages to buying seed. First, the supplier can seldom give assurance that the seed is from trees with above-average form and growth rate, for he gets many of his cones from individuals who are apt to collect from limby trees that are easy to climb.

Second, it is often difficult to obtain seed from the zone that will give the best growth and yield in a particular area. For the major portion of the longleaf belt adjacent to the Gulf Coast, the optimum seed-collection zone (Wells 1969) is southeast Mississippi, southern Alabama, and northwest Florida (see map).

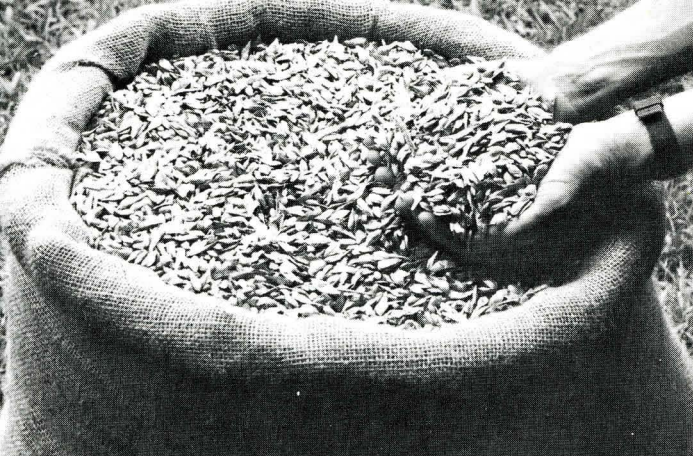
Minimum standards for viability, soundness, purity, and moisture content should be specified when seed is purchased. They should be verified by current tests in the USDA Forest Service's Eastern Tree Seed Laboratory (P. O. Box 1077, Macon, Georgia). The buyer should also know the geographic source of the seed and the year of collection.

Lots should be cleaned to at least 95 percent sound seed by number, a standard easy to attain with modern equipment. Excessive empties waste repellent. Impurities, which clog machines and cause poor distribution, should not exceed 2 percent by weight. A moisture content of 10 percent or less is advisable to insure a reasonable number of seeds per pound and to avoid the task of drying if the lot is to be stored.

For direct seeding, it is preferable to have at least 80 percent viability on a sound-seed basis. Lower viability may be accompanied by a drop



Optimum longleaf pine seed-collection area (hatched) for plantings to be made within stippled area. Isotherms of average annual temperature are shown.



Before seed is coated it should be cleaned of trash, which will clog hoppers and result in poor distribution.

in vigor, which may be a critical factor if weather is bad while the seed is germinating in the field. It is not known how much seed can deteriorate before it becomes risky to use. Unquestionably, however, high-quality seed is essential for consistent success, and increasing the sowing rate is not a good substitute.

Most landowners have the dealer coat the seed with repellents at an extra cost. This treatment will add about 8 percent to the weight. It is advisable to negotiate the cost of treatment separately rather than to pay one price for treated seed. When the dealer is to coat the seed, the purchaser should specify exactly what is desired—i.e., the amount of each ingredient, the manufacturer, and treating methods. It is not sufficient to order "repellent-treated seed."

Stored seed can be used if high viability is maintained (Barnett 1964, 1969). The former belief that fresh seed was essential originated from a number of failures in which badly deteriorated lots of stored seed were sown. Research has shown that longleaf seed can be kept for as long as 10 years with no serious loss of quality, and lots kept for several years have been successfully used in a number of commercial operations. When buying seed held in cold storage it is important to have a germination test conducted before the sale is finalized.

More and more landowners are collecting their own cones and having them processed in a commercial kiln. This method permits procurement of seed from preferable zones, and cones can be obtained from trees of above-average form and vigor. Costs of kilning cones and processing seed range from \$1.00 to \$1.25 per bushel of cones.

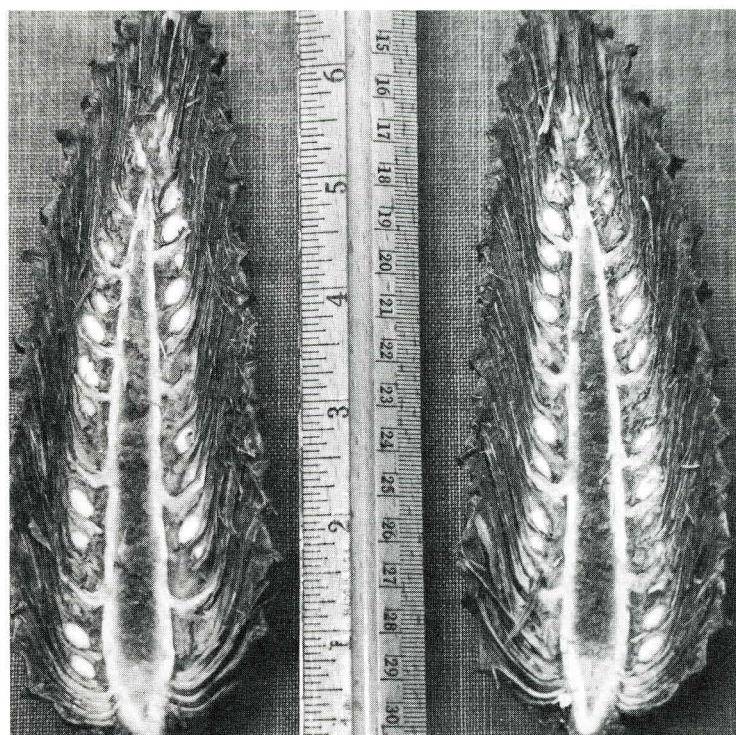
It is also feasible for landowners to process their own cones. Although specialized equipment

is required, capital investments can be recovered if 4,000 bushels are processed. A small, forced-draft kiln that can be constructed for \$2,000 will handle 1,000 bushels in a single season. Equipment for dewinging and cleaning costs an additional \$500. Improvised facilities are apt to be inefficient and harmful to the seed.

Collecting or buying cones may be an expensive way to obtain seed unless certain precautions are taken. Seed yield per bushel of cones varies widely, and low yields inflate costs substantially. Yields can be forecast several months before collecting by cutting sample cones longitudinally, counting the full seeds on the exposed surface, and determining the average yield per bushel of cones from the following tabulation (McLemore 1962):

Number of full seeds exposed	Estimated yield of full seeds—	
	Number per cone	Pounds per bushel
2	23	0.36
4	35	.56
6	47	.75
8	59	.94
10	71	1.14
12	83	1.32
14	96	1.53
16	108	1.73
18	120	1.92

Slicing cones longitudinally and counting the number of full seeds excised is the basis for predicting seed yields.



Fairly accurate estimates can be obtained by taking two cones from each of 20 trees. Seed yields in the tabulation were computed by assuming an average of 80 cones per bushel and 5,000 seeds per pound. Since the size of cones varies considerably, estimates can be improved by measuring the number of cones per bushel. This should be done only after cones have reached their full size.

Costs can be reduced substantially by collecting in bumper years and storing for use in lean years. Not only are cones cheapest when they are most abundant, but seed yields are greatest. In years of heavy crops, yields may average more than 1 pound of seed per bushel, as contrasted to $\frac{1}{2}$ or $\frac{3}{4}$ pound when cones are scarce.

Successful storage of seed depends on several factors. First, cones should be picked only after tests have shown them to be ripe. Earlier collection results in lower yields and seed that deteriorates relatively fast in storage. Second, cones should be processed within 30 days after collection and seed put into cold storage immediately. Seed from cones held more than a month loses germinability rapidly in storage even when otherwise handled properly. Finally, seed should be dried to 8 to 10 percent moisture content and held in sealed containers at a temperature between 0° and 34° F.

SEED TREATMENT

Pregermination Treatment

Longleaf seed germinates rapidly and completely when conditions are favorable. Therefore, it never requires cold stratification or other treatment to improve germination.

Repellents for Coating Seed

The components of the seed coating are a bird repellent, a chemical for controlling insects and rodents, a sticker, and an overcoating of powdered aluminum (Derr 1964).

Over the past 15 years, Morkit, sublimed anthraquinone, Arasan, and Arasan-75 have all been used successfully as bird repellents.¹ Because it is not irritating to the skin and mucous membranes, anthraquinone was suggested for hand sowing until recently. Arasan 42-S, a liquid thiram formulation, is now recommended for all species regardless of the method of sowing.

¹ Here and on following pages, mention of trade names is solely for information, and implies no approval of products to the exclusion of others that may also be suitable.

It provides a durable, dust-free coating that is superior to any previous formulation. Furthermore, it is easier and more foolproof to apply. The other components must still be added.

Knowledge of the repellents and how they act against predators is important for proper seed handling and appraisal of seed losses. It is also important in dealing with the public. Thiram, the active ingredient in Arasan 42-S, is manufactured by a number of companies. It is used extensively as a seed disinfectant and fungicide, and is applied to many seeds sold to home gardeners. Thiram has very low toxicity, but it is irritating to man. It repels most birds immediately; a few ingest one or two seeds before they reject it. Rabbits are also repelled. Mice and other small animals will eat seed treated with Arasan, although their preference for it may be low. Many insects and large mammals are unaffected.

Endrin is added to the seed coating as a deterrent to insects and rodents. The recommended dosage of endrin is 0.5 percent effective. It is highly poisonous and requires careful handling even with the small amount put in the repellent mixture. Studies in many portions of the South have invariably shown that rodents number from 10-15 per acre. Since half this number will destroy a seeding, endrin is almost always needed in the formulation. Moreover, endrin protects seed from many species of insects, which are often numerous. Rodents ingest three to eight seeds, depending on the size of the animal, and then will take no more. They are not killed—rather, a sublethal dose conditions them from eating additional treated seed. This is a desirable reaction because it precludes invasion of the area by new animals, as would occur if the coating were lethal to rodents. With the number of seeds normally ingested, birds are not harmed. Endrin should never be used alone because it will endanger birds that are repelled by the Arasan. The effect on insects varies—some are repelled, some die after contact with treated seed, and some destroy the seed without serious exposure to the chemical.

Whenever it is planned to use endrin in the formulation it is advisable to review seeding projects with the fish and wildlife and the health departments of the State in which the seeding is planned. The purpose of the review should be to determine possible adverse effects on nontar-

get organisms, streams, and water supplies, and to take positive steps to minimize any dangers.

Dow Latex 612 is used as a sticker to hold the repellents to the seedcoat. It has no effect on predators. The last ingredient of the coating is aluminum powder, which lubricates seeds for easy flow through machines and prevents clustering. Aluminum has no repellent properties.

Applying Repellents

Arasan 42-S contains 4 pounds of thiram per gallon. Two gallons will treat approximately 100 pounds of dry seed. When the latex sticker and endrin are added to Arasan 42-S, the total quantity needed to coat 100 pounds of seed is 2.2 to 2.4 gallons. The procedure described here has proved efficient for 5-gallon batches, though smaller amounts can be prepared similarly:

Place 2½ pounds of Stauffer's Endrin 50-W in a clean 5-gallon container, add 2½ gallons of Arasan 42-S, and stir with a paddle until the powder is thoroughly wet and free of dust. This is the most difficult step in the entire process. **CAUTION: Wear rubber gloves. Use a respirator or work out-of-doors where inhalation of endrin dust can be avoided. Dispose of empty containers so that animals and humans cannot come in contact with them.**

Beat with a paint mixer powered with an electric drill running at 1,200 r.p.m. until the mixture is smooth and free of lumps. This operation takes about 2 minutes.

Mix 25 fluid ounces (about 1½ pints) of undiluted Dow Latex 612 with another 2½ gallons of Arasan 42-S.

Blend the two mixtures together by pouring from can to can about 10 times.

The final mixture totals about 6 gallons. It is a stable suspension, but if prepared several days beforehand it should be stirred thoroughly before application.

About 1.2 gallons of the total repellent mixture are needed for 50 pounds of seed. The first batches should be examined carefully to determine if all seeds are fully coated. The best procedure is to start with a slight excess, then gradually cut back until a complete coating is obtained with no surplus. If too much is applied, dried seeds will stick together in large clumps.

The rolling-tumbling action of a small concrete mixer is very effective for applying the coating.

Fifty-pound batches of seed can be treated in a 3¼-cubic-foot mixer in approximately 3 minutes. A three-man crew can treat a ton of seed daily.

Coating is accomplished by placing a weighed amount of seed in the mixer, then adding the measured amount of the liquid repellent while the mixer is turning. After 2 minutes of tumbling, aluminum powder is added at the rate of 8 tablespoons per 50 pounds of seed, and the mixer is allowed to turn for another minute. Treated seed should be spread out 3 to 4 inches deep for drying. It should be raked periodically to hasten drying and reduce clustering. The seed is dry enough to pick up and put in sacks when the coating changes color from gray to white. In clear weather, the coating will dry thoroughly in 3 to 4 hours.

Lots of 2 to 5 pounds can be treated by mixing with a ladle in an open container such as a lard can. Approximately 3 fluid ounces of repellent mixture are required per pound of seed. An aluminum overcoating can be obtained by adding 1 teaspoon of the powder to the seed and stirring for another 30 seconds. Seed should then be spread out to dry.

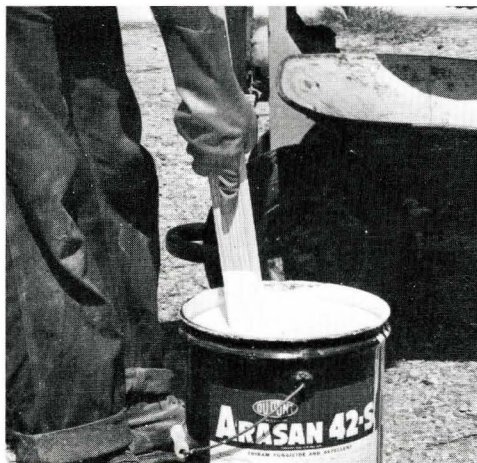
Whether it is applied by the landowner or a commercial dealer, the repellent coating should be checked for durability before sowing begins. The test is made by putting several hundred dry seeds in a small wire basket and running a full stream of cold water from a faucet over them for 2 minutes. If two-thirds of each seed remains coated, the repellents will weather satisfactorily in the field. If the loss is greater, application was improper and the seed should be washed to remove as much of the coating as possible, and then recoated.

Certain precautions are necessary when storing the sticker and the chemical repellents. The latex sticker is a suspension that is easily broken if stored in an uncoated metal container or subjected to temperatures below 32° F. or above 110° F. If the suspension is broken, the latex loses all adhesive properties and the repellents are quickly washed off in rains. Several serious failures have been traced to improper handling of latex. Arasan 42-S and Endrin 50-W should be stored in their original containers, which should be tightly closed. It is a good policy not to keep these chemicals for more than 1 year. Unused chemicals that have been mixed together should be discarded each season.

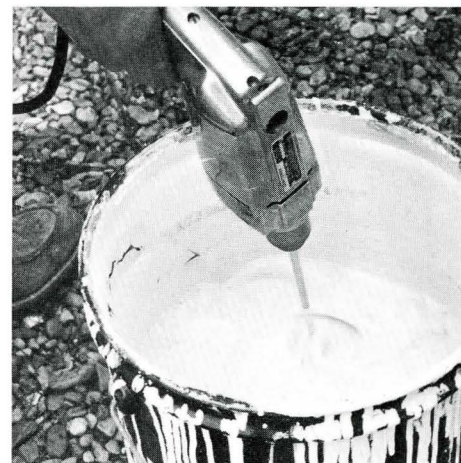
Directions for preparing repellent and applying it to seed:



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



Stir with wooden paddle.



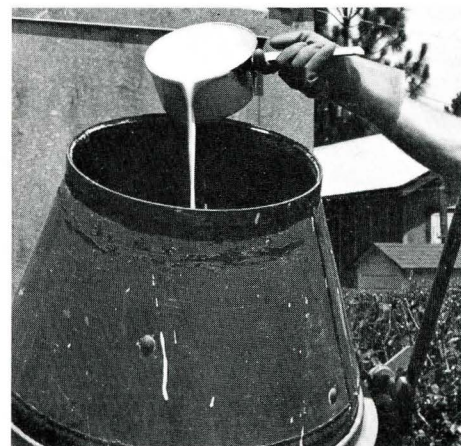
Beat with paint stirrer.



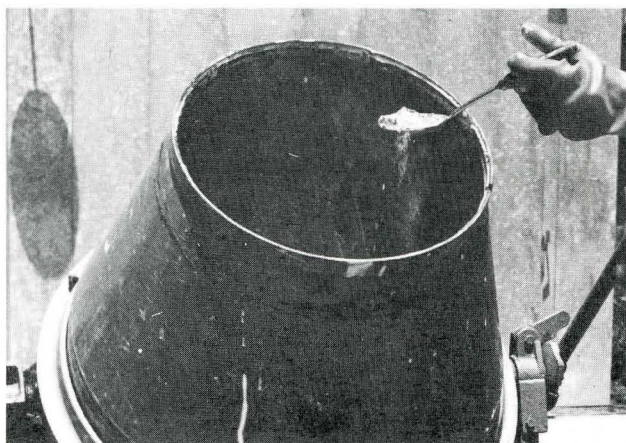
Add 25 fluid ounces of undiluted Dow Latex 612 to another 2½ gallons of Arasan 42-S.



Blend by pouring from can to can about 10 times.



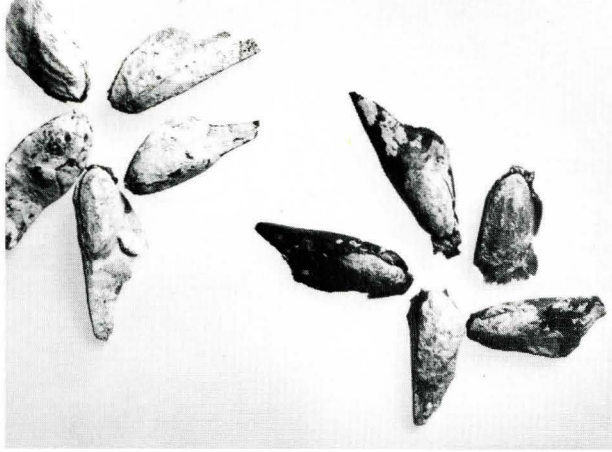
Pour finished repellent directly onto seed as mixer is turning. Tumble for about 2 minutes.



Add aluminum powder and tumble for another minute.



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



The coating on these seeds was checked by washing them under a full stream of water from a faucet for several minutes. Seeds on left retained repellents satisfactorily, while those on right lost too much.

Holding Repellent-Treated Seed

Operations should be carefully scheduled to minimize time between treating and sowing. Some delay is unavoidable, however, especially when seed must be shipped or bad weather interrupts sowing.

Seed treated with repellents can be stored for several weeks in a well-ventilated, unheated building or in a cold room at any temperature down to 0° F. Sacks should be placed so that air circulates around each one. If the seed must be kept until the following year, it should be dried to 10 percent moisture and stored at 0° to 25° F. The repellent coating will not lose its effectiveness even after 1 year of storage.

TIME OF SOWING

Fall sowing of longleaf pine has been recommended for a number of years, except in a few unusual situations. Recent research, however, indicates that late winter may be preferable on many sites. The decision about season must rest on careful appraisal of several factors.

Sites subject to frost heaving should be sown in the late winter. The damage occurs most often on heavy soils with sparse vegetative cover. On such soils repeated freezing and thawing is likely to lift small, fall-germinated seedlings out of the ground.

Clipping of newly germinated seedlings near the groundline is greater in fall than in spring sowing. Studies in central Louisiana have clearly shown that most clipping can be avoided by sowing in late winter. The damage is done primarily by rabbits when other green vegetation is scarce. Losses, which average about 25 per-

cent during the winter, have exceeded 75 percent in some situations. Consequently, February sowing should be preferred if clipping has been severe in the past or if the rabbit population is high.

Areas subject to early spring droughts should be sown in the fall, to give seedlings time to develop good root systems before dry weather sets in. When heavy clipping and early droughts are both probable, fall is the better choice for sowing.

The optimum time for fall sowing is as soon as soil moisture is adequate for prompt germination and maximum daytime temperatures drop below 85° F. Over much of the range of longleaf, the beginning of regular frontal storms is the best time. The storms are accompanied by rain, and summer temperatures begin to moderate. In the Gulf Coast region, this may occur from late October to early December, but usually conditions are satisfactory by the middle of November.

Sowing too far in advance of the optimum time is risky. Longleaf seed will not germinate when temperatures exceed 85° to 90° F., and it deteriorates rapidly in hot weather. Delay in sowing is also hazardous, as germination is very slow below 50° F. and seeds with radicles beginning to penetrate the soil are subject to uprooting and washing in heavy rains. Consequently, the timing is critical. The optimum period lasts for only a few weeks. The best procedure is to sow quickly when soil moisture and temperature are conducive to prompt, fast germination.

With spring sowing, temperature is the main consideration, since winter rains have usually recharged the soils. In the lower Coastal Plain, sowing should be done in early February. It is more desirable to sow too early than too late. Even if low temperatures occur, they will be of short duration, and preferable to high temperatures. Hot weather, which stops germination and spoils seed, must be avoided.

METHODS OF SOWING

Longleaf, like most other southern pines, has been sown by a number of hand and machine methods. The choice often depends on the size of the area, soil and cover conditions, the pattern of stocking desired, and the facilities available to the landowner.

Hand Sowing

Hand methods are useful primarily on small tracts. If the site is disked in strips, seed can be broadcast or placed in spots on the prepared ground. One man can cover about 15 acres when scattering seed, and 5 acres when spotting. Both methods conserve seed by confining it to the strips. Rubber gloves must be worn when handling treated seed.

Spotting has been successful on both open grassy sites and beneath hardwoods. Five or six seeds are dropped on a clear spot or a spot raked free of leaves. Seeds can be covered lightly with soil. To prevent blowback, leaves raked from spots should be scattered, rather than left in a pile on the edge of the spot. From 1,000 to 1,200 spots per acre are needed, depending on environmental conditions and stocking objectives.

Most tools for spotting have a device for barring mineral soil and a mechanism for metering a predetermined number of seeds on the prepared spot. They sell for \$15 to \$30. Each model has features that adapt it to special soil and cover conditions. For most small operations, a short-handled firerake and an apron for carrying seed are adequate.

A hand-operated cyclone grain seeder is well suited for tracts up to 200 acres in size. It is especially useful on irregularly shaped areas that are difficult to sow from the air, and on tracts where patches of established pines are to

be bypassed. Crews can be trained quickly to broadcast seed uniformly, and one man can cover 15 acres daily where brush and terrain are moderate.

Formerly a major disadvantage of the hand-operated seeder was exposure of personnel to the chemical dust from the repellent coating. With Arasan 42-S, however, the coating is essentially dust-free.

Tractor Seeding

Many tractor seeders have been developed over the past 10 years. Since they are numerous and diverse, only those that have been tried extensively will be described.

Power-driven cyclone grain seeders are sometimes mounted on a tractor. The swath width is generally about 40 feet, and a small tractor can cover from 30 to 40 acres daily. This broadcast method is efficient in dense brush where hand-operated seeders are impractical. It is dangerous on steep terrain.

Tractors have also been equipped to sow in rows on strips disked in the summer. Ordinarily twin grain hoppers are mounted on the rear of a tractor, and the metering plates are activated by a drive wheel that is in contact with the ground. Packing wheels are sometimes mounted to firm the soil in front of and behind the seed drop. Rubber-tired and crawler tractors have been used.

About 15 acres per man-day can be broadcast-sown with a hand-operated grain seeder.





A furrow seeder that operates behind a conventional fireplow. Adjustable hillers elevate a ridged bed in the center of the furrow to prevent washing and flooding of the seeds.

Tractor-drawn machines have been developed to prepare beds and sow in rows in a single operation. They form beds by plowing furrows, disking, or rotatilling narrow strips.

Furrow seeders are the most common (Croker 1964). They are of two types; one has a middle-buster plow pulled by a tractor, the other has a plow mounted on the front of a tractor.

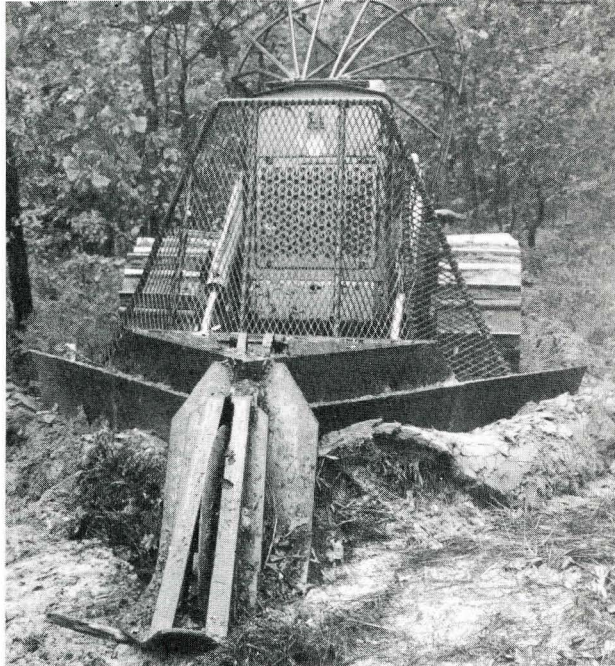
Those pulled by a tractor plow a shallow furrow and elevate a narrow mound in the center of the furrow with a set of hillers. Seeds are dropped from a hopper at predetermined intervals onto the mound and pressed firmly into the soil by a packing wheel. The slight elevation of the bed prevents seeds from being washed away or submerged for long periods; pressing the seed into the soil surface improves germination. The method is not suited to poorly drained soils, for the furrows flood in heavy rains. It is also impractical in dense stands of hardwoods.

In another model designed for deep, sandy soils where seed must be covered to obtain complete germination, the hillers are replaced by an agricultural sword. The sword opens a narrow slit for the seeds within the furrow, but up the slope and away from the bottom where water runs, and a packing wheel covers them with soil. This machine is limited to open, grassy areas, as the sword is easily bent or broken by tree roots.

Front-end furrow seeders also work best on sandy soils with good internal drainage. They are more rugged than the trailing type, however, and operate well in brushy hardwood stands. One model, used extensively on the Savannah River Project of the Atomic Energy Commission in South Carolina, sows directly in the center of a furrow. Seeds are dropped from a hopper into a very narrow trench cut about 1/2-inch deep. Subsequent rains wash sand over the seed, and this light covering facilitates germination. In dense brush the machine uproots and kills 50 to 70 percent of the hardwoods while sowing on an ideal bed. It is one of the most successful machines developed so far for sandy soils.

Another front-end furrow seeder has a cut-away V-plow that pushes a ridge of soil directly into the path of each tractor track. The weight of the tractor packs the loose soil, and seeds are sown on each ridge from hoppers mounted on the rear of the tractor. A hopper just behind the plow point can be operated to drop seed in the furrow as well.

Furrow seeders are capable of sowing from 15 to 20 acres per day. Their main advantage is low cost per acre, resulting from efficient distribution of seed and from the combination of bed preparation and sowing into one operation. Establishing trees in rows may also be an ad-



A front-end furrow seeder, with seed hopper immediately behind the point of the V-blade, operates effectively in dense brush.

vantage, provided that close in-row spacing is not objectionable. Disadvantages include: (1) high capital outlay for tractors and machines, (2) low average daily production of seeders, which cannot operate in severe weather, (3) the temptation to sow far beyond the optimum date to utilize machine fully and to meet production goals, (4) rough condition of the ground after seeding, (5) displacement of topsoil—a particular drawback on sites where fertility is low, and (6) limitation to sandy, level sites, and with some models to cleared or open sites.

Disk seeders that prepare flat beds were first developed to sow two rows simultaneously with the same tractor power required for a one-row furrow seeder. Later a single-row model was made

for maneuverability in hardwood stands. Two offset disk units, each about 1½-feet wide, are mounted about 4½-feet apart, edge to edge. A packing wheel and seed hopper and funnel are located behind each set of disks. Behind a light crawler tractor the dual unit can sow about 30 acres per day. This machine is adaptable to a broad array of soils. Sowing rates must be higher than with furrow seeders, because considerable seed is lost by silting even where disked soil has settled for several months. Moreover, disking in the cool, wet part of the year fails to control competing grasses satisfactorily. Otherwise, advantages and disadvantages are the same as with furrow seeders.

For wet soils that require thorough preparation by chopping and disking, a modified disk seeder has been developed. It elevates a narrow ridge that prevents flooding. The components are a pair of two-blade disks set in a hilling position, two packing wheels, and a seeder that is positioned to drop seed between the wheels. The units can be operated in pairs behind a light crawler tractor.

Aerial Seeding

Aircraft seeding is a widely used and proven method for reforesting large acreages rapidly and at minimum cost. It requires the least effort and capital outlay by the landowner; in most cases he is only required to furnish accurate maps of the area to be seeded, technical supervision, and personnel for ground control of the aircraft. Accurate work has been done consistently both with small fixed-wing airplanes and with helicopters.



A 2-row disk seeder that sows approximately 20 acres daily.

Aircraft of both types require special distributing equipment that must be calibrated accurately, especially for longleaf with its irregular-shaped wing stubs. In addition, accuracy requires uniform flying speed and altitude, and constant checking by the pilot for stoppage or malfunction of equipment. The landowner should establish, in advance, flagging positions that will insure straight flight lines. Many areas have been sown with flagmen pacing off the flight lines, but results are usually unsatisfactory.

Fixed-wing airplane.—The light monoplane is the only type of fixed-wing aircraft that has been used extensively. It is highly maneuverable and it can operate from short unimproved runways—often constructed on the area to be seeded. Depending on the size and shape of the areas, and on the distance from a landing strip, planes can seed from 150 to 200 acres per hour.

Most planes used in agricultural work can be adapted for pine seeding at a cost of about \$100. Modification is needed because the long,

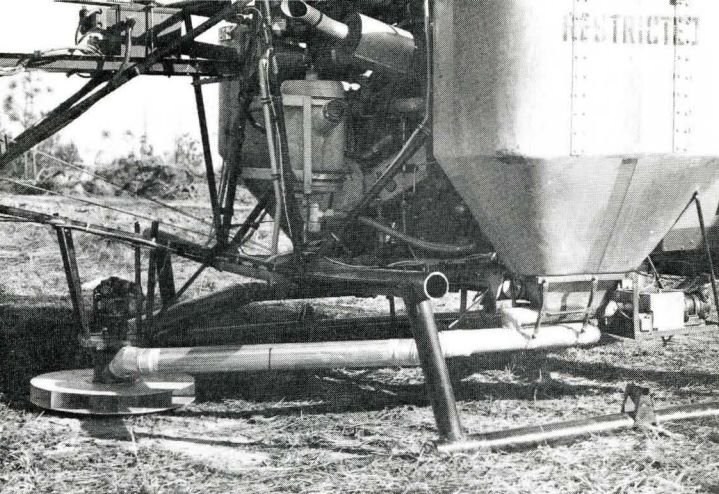
adjustable opening between the distributor and the hopper is too narrow for an even flow of seed. Plates set in the bottom of the hopper block off part of the aperture, permitting a wider setting.

Flight strips should not exceed 66 feet in width. At normal flying speeds and altitudes the distributor throws seed about 40 feet each side of the plane. Some overlapping of adjoining flights is necessary to prevent skips and to even out the distribution near the outer edges of the seed pattern.

Helicopter.—A light helicopter can operate from a small clearing on the area to be seeded. It thus has an advantage when a fixed-wing plane would have to travel a considerable distance to a landing strip. Otherwise the differences between the two types of aircraft are small and the choice often depends on the bid price. The helicopter's landing capability gives it a higher average production rate of 250 to 300 acres per hour, which reduces the cost of flagging and

A helicopter can sow 3,000 acres per day.





The revolving slinger on a helicopter distributes seed over a 99-foot swath.

other services provided by the landowner and permits a slightly higher contract price per acre.

A helicopter must be equipped with a power-driven centrifugal slinger for distributing the seed. It must also have a positive, motor-driven meter for dispensing seed from the hoppers into the slinger. The types in use will cover a 99-foot swath. When properly adjusted they distribute seed accurately.

RATE OF SOWING

Optimum sowing rates vary by method of sowing, soil condition, cover, site preparation, predator populations, stocking objectives, climate, and brown-spot hazard (Miller 1966). Most landowners have employed a single rate for each method of sowing. A few large landowners have initiated prescription sowing, adjusting rates in the light of experience with particular conditions. This practice will increase as landowners expand their operations and gain confidence in seeding techniques.

In the West Gulf region, recommended rates per acre for initial trials are 3 pounds for broadcast sowing, 2 pounds for disk seeding, and 1½ pounds for furrow seeding. The rates can be reduced about 35 percent on moist sites in the Southeast, where initial establishment and first-year survival are generally higher. These weights are for dry seed that has not been coated with repellents. They assume viability of at least 80 percent, and must be increased proportionately if germination is lower.

Well-cleaned longleaf seed averages about 4,500 per pound. In commercial operations initial establishment has averaged about 30 percent in Louisiana and Mississippi and 50 percent on good sites in Florida and Georgia. These tree

percentages are equivalent to 3,000 to 5,000 seedlings per acre from 3 pounds or 10,000 viable seed.

Offhand these levels may seem high, but only about one seedling in three starts height growth and reaches sapling size. First-summer mortality, especially in the westerly portion of the range, may reach 50 percent in dry years. Brown-spot infection and prescribed fires for disease control also reduce stocking; roughly half of the seedlings surviving the first year initiate height growth. The best insurance against understocking is to maintain sowing rates high enough to offset unusually large losses. Experience suggests that on good sites initial stocking in the spring following seeding should be at least 2,000 well-distributed seedlings per acre. On poor sites 3,000 seedlings are needed because first-summer mortality will be higher and losses to disease greater. With intensive site preparation, these stocking goals can be lowered by 25 percent.

To economize, some landowners have reduced sowing rates by as much as 50 percent. Reductions like this should be made only with the full understanding that they lessen the chances for success.

CALIBRATING SOWING EQUIPMENT

Faulty distribution of seed may result in irregular stocking and partial failure even though seedling establishment and survival are high. All of the machines described in the previous section can be adjusted to sow longleaf pine accurately and uniformly if the repellent coating is dry and the seed is free of trash. Screening seed through ½-inch hardware cloth immediately before placing it in the hopper will insure against clogging, which is the most common cause of poor distribution. Wet or sticky seed will not flow freely; hence the repellent coating must be dried thoroughly and kept dry in the field.

Sowing rates should be based on the weight of uncoated seed. The repellent coating will increase weight by 8 to 10 percent. Consequently, it is necessary to sow 3.3 pounds of coated seed to obtain a 3-pound rate. Because weight gains vary with the initial moisture content of seed and the method used to dry the repellent coating, it is desirable to determine the weight ratio of dry to treated seed for each job.

Tractor-drawn machines are calibrated by checking the number of seeds dropped on 100-foot segments of prepared beds. For example, a rate of 1½ pounds per gross acre on plowed furrows spaced 8 feet apart (center to center) requires 124 seeds on a 100-foot segment, provided that the lot contains 4,500 seeds per pound.

Machines for broadcast sowing—aircraft and cyclone seeders—are calibrated and checked by a system of area control. A predetermined quantity of seed is sown on an area of known size, and it is assumed that distribution is uniform over the entire area. An advantage of the method is that a constant check can be kept of the sowing rate as the job progresses, provided that the area in each flight strip is known. Seed-trap boxes, hoed spots, and other methods of appraising distribution have never been satisfactory in regulating rates, for it is seldom practical to inspect enough spots in the short time available for calibrating an airplane.

Fixed-wing airplanes can be calibrated as follows:

- Determine the weight of treated seed to be broadcast per acre.

- Select three tracts, each 20 to 40 acres in size and with regular boundaries, for calibration trials. Mark 1-chain flight strips on two ends of each tract to guide flagmen. A 66-foot swath gives excellent seed distribution with all types of airplanes now available.

- Carefully check to determine if hopper gate opens to the same width each time it is opened. Loose linkage has been a common cause of erratic distribution.

- If the pilot has experience with all species and rates, let him choose the size of hopper opening.

- Weigh seed for 20- or 40-acre trial. Add 20 pounds extra for a buffer. Screen all seed before it is put in the hopper.

- Sow the area, flying crosswind at a steady, normal speed. Flying parallel to the wind is satisfactory if the pilot can adjust his airspeed to maintain a fairly constant ground speed in both directions. Never calibrate when winds are gusty, shifting, or above 8 m.p.h.

- Weigh seed remaining in the hopper to determine if rate was accurate. Adjust gate

opening accordingly and sow another test area. Ordinarily the correct setting will be obtained in two or three trials.

After calibration, begin regular operations and steadily increase the area sown on each flight to about 100 acres. Because mistakes in the sowing rate are impossible to correct, seeding more than 100 acres per flight is an unnecessary risk. Costs of flying will not be increased appreciably by limiting the acreage per flight to a reasonable level.

Other broadcast machines are calibrated in the same manner. The effective swath is 99 feet for helicopters, 16 feet for hand seeders, and about 40 feet for tractor-mounted seeders. A trial area of ½ acre, or a single swath ¼-mile long, is adequate for hand machines. Five acres, the equivalent of a 40-foot swath 5,450 feet long, are needed for tractor-mounted seeders. A hopper opening of 1/3 inch, which is the approximate width of a coated longleaf pine seed, is a good starting point when calibrating cyclone seeders.

Minor adjustments in hopper openings often become necessary during the day, because moisture in the repellent coating varies with changes in relative humidity. If the coating becomes too wet the seed will not flow freely even if openings are increased, and the only recourse is to stop flying until the coating can be dried.

Most operations have been executed by flying crosswind, since a steady ground speed is necessary for uniform distribution. Crosswinds up to about 8 miles per hour have no appreciable effect on the swath width, but they shorten the distribution upwind and lengthen it downwind. Stronger crosswinds cause windrowing of the seed. Sowing should not be attempted when winds are gusty, for the course of the aircraft is likely to be irregular and differential drift of seed will give erratic distribution. If pre-established flight lines necessitate flying with a paralleling wind, the airspeed should be regulated to give a uniform ground speed. Variable or shifting winds cannot be tolerated regardless of the direction of flight.

The landowner should retain sole responsibility for specifying the amount of seed to be broadcast on each flight and for determining when the weather is unsuitable for sowing. Contracts for aerial services should state these facts clearly.



Seeding aerially in a heavy crosswind caused distinct windrowing of this longleaf stand.

A plane's altitude has limited effect on swath width. At heights of 80 to 125 feet, distribution is good if ridges are cleared by 60 feet. Below this level, strip width narrows excessively. Helicopters can operate as low as 10 to 20 feet, because the seed is thrown out by the slinger.

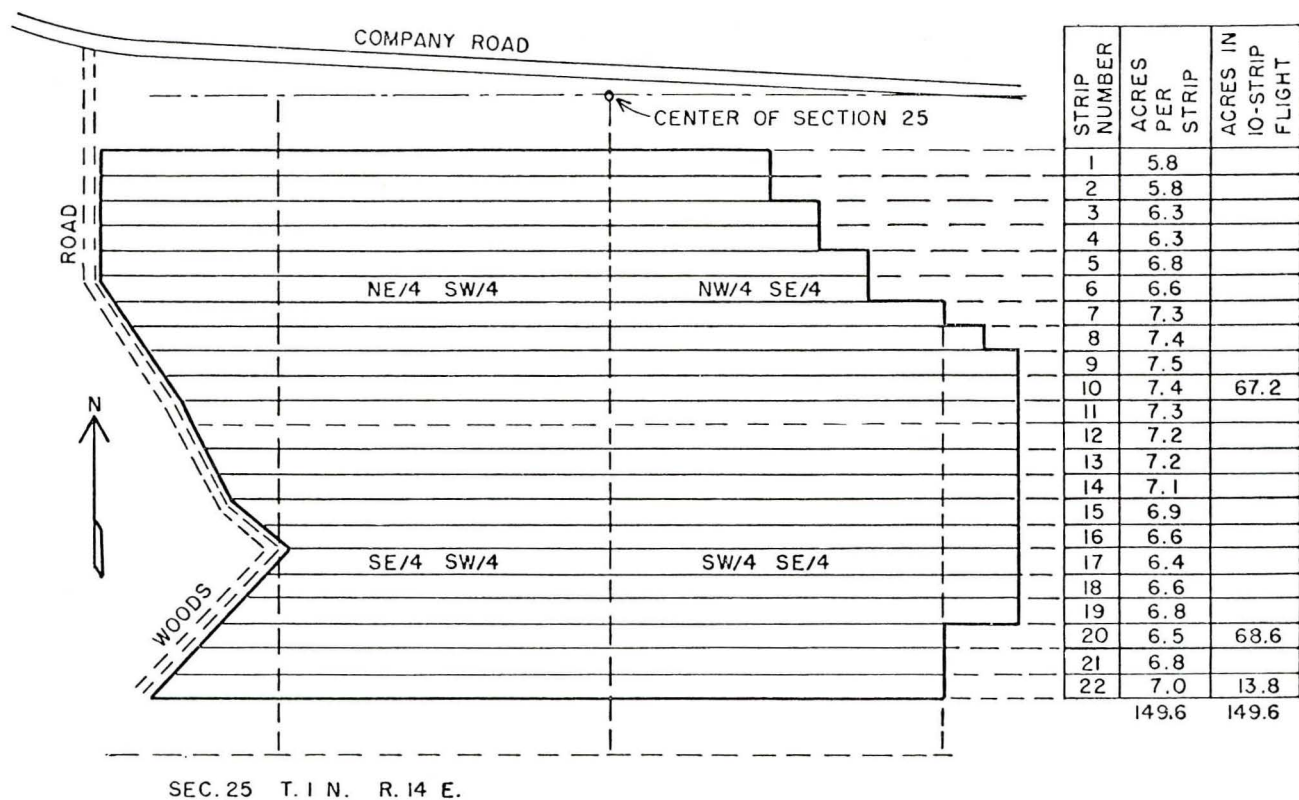
Flight strips are guided by flagmen on the ground. For accurate alignment the pilot needs to see at least two flags, other than the one directly below the ship, after completing each turn. Three flagmen are usually enough, although more may be needed if strips are long, terrain is rolling, or trees obstruct the pilot's vision. One flagman should be stationed at each end of the flight strip. Insofar as possible, flagmen should be on ridges and along roads or other openings. Flags, mounted on long bamboo poles, should be a distinctive color and should be moved back and forth as the aircraft approaches.

It is best to measure and mark flagging points on the ground in advance. Flagmen often get out of alignment if they are required to pace off distances between strips as the operation progresses.

A map showing flight lines and the acreage in each swath facilitates the entire operation (see drawing). With this information the acreage to

Placement of flagmen is important for good distribution; the pilot must see at least 2 flags at the start of each swath.





be sown during each flight and the amount of seed needed can be quickly determined, and the pilot can be told how many strips to fly before returning.

Despite precautions, hoppers will sometimes become clogged and the aircraft will return with an excessive amount of seed. The question, then, is where the stoppage occurred. Sometimes this information can be obtained from the flagmen. Otherwise, the best course may be to refly every second or every third strip, depending on the quantity of seed to be sown; altitude should be 200 to 300 feet. Reflying requires good communications with the flagmen.

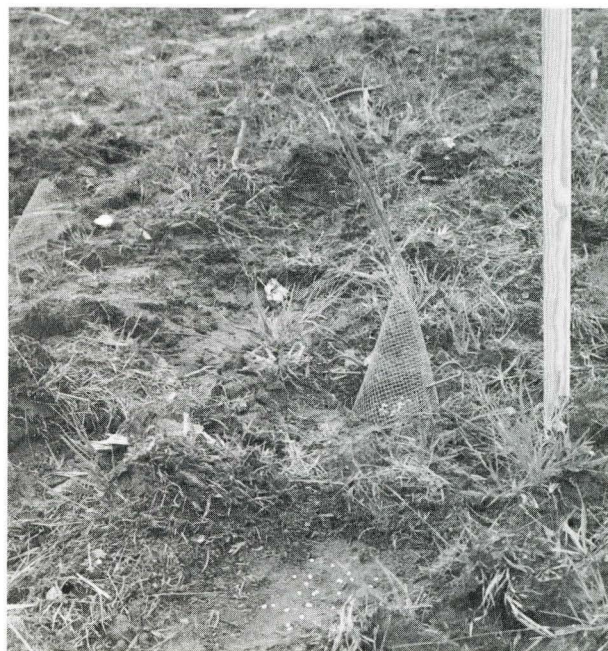
CHECKING DEPREDACTIONS

The landowner just starting a direct-seeding program should make frequent, systematic inspections during the germination period. It is the only way to determine if unusual losses are occurring and to establish why an operation fails. These examinations are not needed if several seedings in the same general area have been successful.

Seed is often difficult to find after it has been exposed to several rains. It is widely scattered,

and some of it is covered with soil and debris. A series of small observation stations, sown with extra seed, is the only practical way to follow the progress of germination and to appraise losses. A satisfactory station consists of an identification stake, 50 seeds sown within 18 inches of the stake, and one or two seeded spots screened to exclude birds and rodents. Screened

An efficient observation station, consisting of exposed and covered seed close to a numbered stake.



spots should be on level ground where the seeds cannot wash away. Window screening or 1/4-inch hardware cloth makes a satisfactory cover if pinned down firmly. If stations are well distributed over the seeded area they will indicate distribution of predators, extent of damage, and whether or not stocking is adequate. Twenty-five are sufficient for areas up to several hundred acres; 50 are needed for tracts of 1,000 acres or larger. One man can usually examine 50 in a day.

Stations should be checked weekly until most of the seeds have germinated. Progress of germination, number of intact seeds and seed hulls found, type of damage to seed and seedlings, insect activity, and condition of the repellent coating should be noted for each station. Germinating seeds should be marked with pins to detect losses that may occur during advanced stages of germination.

Some birds and insects, crayfish, and large mammals take longleaf seed whole, leaving no remnants for identification. Tracks or droppings may afford a clue to their identity. Many other predators leave characteristic hull and fragments behind. Some rodents carry seeds a few yards to protective cover; characteristically, they leave a neat pile of seed hulls where they have been feeding.

Some predators, among which rabbits and crickets are the chief suspects, clip new seedlings off near the groundline and carry away or eat the severed portion. All that remains is a short stub, 1/8 to 1/4 inch high, which is easily overlooked unless the seed or seedling is pinned soon after germination begins. Clipping is most prevalent in January and February, and the first seedlings to become established are the most vulnerable. As previously mentioned, seedlings germinating in the fall are damaged more than those started in the spring. If crickets are the cause, pieces of the cotyledons can be found in the upper food storage chamber of their burrows. Rabbits consume seedlings immediately after clipping them.

Harvester ants carry large numbers of seeds into their nests. Town ants take portions of germinating seed and sections of seedlings to their colonies. Several other species of ants cause minor damage by feeding on radicles or on endosperms after the seed cracks open in the early stages of germination.

Caterpillars, centipedes, and millipedes occasionally feed on seed and seedlings, but their combined damage is ordinarily less than 5 percent.

APPRAISAL OF STOCKING

Two systematic inventories should be made by those starting seeding operations. They should be independent of the observation plots used to determine seed and seedling losses. The first should be made as soon as germination is complete in February or April, depending on the season of sowing. Coupled with observations during the germination period, it will indicate the efficiency of repellents, severity of predation, and effect of weather on seedling establishment. A second inventory, preferably on the same sample plots used for the first, is needed at the end of the first growing season to appraise mortality and overall success. After experience is gained, the early inventory may be omitted.

The number of plots depends on the accuracy desired and the plot-to-plot variation (expressed as the coefficient of variation) in number of seedlings. Size of area seeded and size of sample plot influence the coefficient of variation. Experience indicates that, with plots 0.001-acre in size, a coefficient of variation of 100 percent may safely be assumed for areas up to several thousand acres. The formula for computing intensity of sampling with 67-percent reliability is:

$$\text{Sample plots needed} = \left\{ \frac{\text{coefficient of variation}}{\text{accuracy desired}} \right\}^2$$

If a landowner chooses to sample for ± 10 percent accuracy, the number of plots would be:

$$\left\{ \frac{100}{10} \right\}^2 = 100.$$

On a large area, 100 plots give an overall appraisal of stocking but no information on the location or prevalence of areas that are inadequately stocked. If, for example, it is desired to know whether stocking is sufficient on each 40-acre tract on a 1,000-acre area, each forty must be inventoried with 100 sample plots. The usual procedure is merely to sample the entire area, and wait until the trees are 3 or 4 years old to visually detect portions that need supplemental planting or seeding.

When seeding rates, methods of sowing, or sites vary within an area, it is desirable to inventory homogeneous subblocks separately.

For broadcast sowing, circular milacre (0.001 acre) plots equally spaced over the area are satisfactory. Average plot stocking multiplied by 1,000 provides an estimate of seedlings per acre. Distribution is expressed as the proportion of sample plots with one or more seedlings. These two statistics are closely related: adequate distribution is rarely obtained with less than 750 seedlings per acre. Both values are useful, however, and counting the seedlings takes little extra time once the plot has been located. A high average number of seedlings per acre and low sample plot stocking indicate uneven sowing or varying seedling establishment. Proportion of stocked milacres is the statistic most valuable for evaluating results—50 to 55 percent is commonly taken as the minimum for a successful operation.

Estimates on broadcast-sown disked strips require a modified technique. Two milacres—one on a disked strip and one on an undisked balk—are used at each sample location. The edge-to-edge distance between disked strips at each location is measured to determine the proportion of the area that is disked. To calculate overall stocking, average stocking on disked and undisked milacres is weighted by the area represented by each.

Where sowing is confined to rows, as on plowed furrows or on disked strips, inventories are made differently from those on broadcast areas. Sample plots, located over the entire area, consist of a 13.2-foot segment of a row or strip. Each plot is divided into two 6.6-foot subplots, and the number of seedlings on each is recorded separately. Distances from the center of the sample strip to the center of each adjoining strip are measured at each location to adjust average stocking to a gross acre. Seedlings per gross acre are estimated by multiplying the average stocking for 13.2-foot plots by

$$\frac{3,300}{\text{average distance between row or strip centers}}$$

Thus, if average stocking per 13.2-foot plot is five and row centers are 10 feet apart:

$$5 \times \frac{3,300}{10} = 1,650 \text{ seedlings per acre.}$$

The constant, 3,300, is derived by dividing 43,560 (square feet per acre) by 13.2. If the size of the sample plot is changed, a new constant must be calculated.

Stocking percent based on 1,000 perfectly spaced seedlings per acre is obtained by multiplying the percent of subplots stocked (6.6-foot segments of strip) by

$$\frac{6.6}{\text{average distance between strip centers}}$$

With this method, full stocking is less than 100 percent when the average distance between strip centers exceed 6.6 feet. Maximum stocking obtainable with strips on 10-foot centers is:

$$100 \times \frac{6.6}{10.0} = 66 \text{ percent.}$$

The effect of strip spacing on subsequent tree distribution should be carefully weighed when planning a seeding operation.

In seed-spot operations the simplest method of inventory is to determine the proportion of spots with at least one seedling. As more than one seedling per spot is excess stocking, it is unimportant to calculate the stand per acre. If the spots cannot be found readily, stocking can be estimated from mechanically spaced milacre plots.

COSTS

Costs, time requirements, and production estimates have been summarized in earlier sections for some phases of the seeding operation. Given here are approximate costs for situations that are most common in the South. Obviously, they will vary by the price of seed, acreage to be sown, expenses for equipment, and even efficiency of landowners. Generally, costs will average about 25 percent less in large than in small operations.

Seed prices, one of the main items of expense, are highly variable. In the past 5 years they have ranged from \$1.50 to \$3.00 for large lots. An average of \$2.75 per pound is used in the following estimates. Addition of \$0.30 per pound for repellent treatment brings the total seed cost to \$3.05 per pound.

A small landowner who hand-sows only a few acres can usually do the work cheaper than industrial landowners. He may have to pay higher prices for seed, but will save on outlays for

travel, supervision, Social Security, insurance, and the like.

Data given here are for tracts of 300 to 1,000 acres. Labor rates are \$1.60 per hour plus \$0.50 per hour for insurance, Social Security, and transportation. No allowance is included for supervision or overhead. All costs are on a per-acre basis.

Aerial broadcast sowing of 3 pounds per acre on open sites that were burned for seedbed preparation:

Burning	\$0.35
Seed	9.15
Aerial sowing	.80
Flagging of aircraft	.25
Total	\$10.55

Furrow-seeding open or brushy tracts with 1½ pounds per acre at a rate of 12 acres per day. Costs of hardwood control not included:

Burning	\$1.00
Seed	4.58
Furrowing and sowing	3.25
Total	\$8.83

Aerial sowing of 3 pounds per acre on tracts disked in strips:

Burning	\$0.35
Disking	2.50
Seed	9.15
Aerial sowing	.80
Flagging of aircraft	.25
Total	\$13.05

Hand-sowing 1.6 pounds per acre on disked strips:

Burning	\$0.35
Disking	2.50
Seed	4.88
Distributing seed (15 acres per man-day)	1.67
Total	\$9.40

Spot sowing, with six seeds on each of 1,000 spots per acre:

Seed	\$4.06
Distributing seed (2½ acres per man-day)	6.40
Total	\$10.46

STAND PROTECTION AND MANAGEMENT

Longleaf pine requires more care in early years than any of the other southern pines. But the method of regeneration—whether by natural or artificial techniques—has no influence on the intensity of management that is needed.

Mortality from drought is low after the first year. The big problem is to manage and protect the seedlings so that a well-stocked stand starts height growth quickly.

The seeded area should be inspected at regular intervals for hogs. It is not sufficient to rely solely on a fence, because these animals can penetrate the best of barriers. While looking for hogs the forester can make other observations. Overgrazing by livestock can result in losses from trampling and reduce grass fuels enough to complicate burning for disease control. Re-invasion by town ants and pocket gophers can also be detected and steps taken before serious losses occur.

Cotton rats, not mentioned previously, are believed to inhabit only areas with a heavy grass rough. Burning and other site-preparation treatments cause them to leave when their cover is destroyed. They sometimes become a problem when a new rough forms, but by this time the seedlings may be ready for a brown-spot burn that will again destroy the cover. In rare cases assistance of State game officials may be needed for controlling this pest.

Prescribed burns are usually needed to control brown spot sufficiently for trees to start height growth. Burning solely because the grass growth is heavy is unnecessary. Vigorous seedlings can withstand the competition of dense grass even when they are being enveloped. Scheduling of burns is largely dependent on the severity of brown-spot infection. Predetermined schedules are impractical, as infection varies by geographic location and from year to year.

Brown spot typically develops gradually enough so that it can be kept under observation in regular inspections. Stands seldom have much infection at the end of the first year, but by the second or third year a burn is usually required.

The severity of infection should be appraised as late as possible in the winter. Fall ratings may be misleading, because the disease builds up rapidly from November through January. The best procedure is to conduct a brown-spot survey



Six-year-old longleaf stand in active height growth after two burns for brown-spot control.

on well-distributed milacre plots. Only the best seedling on each sample plot is used to estimate the proportion of needle tissue that is dead. If the overall average is 20 to 30 percent, the stand should be burned in the current season.

A second burn may be needed in 2 or 3 years, especially on poor sites where growth is slow. However, the decision should be made on the

basis of another disease survey. Infected seedlings that will initiate height growth without fire should be rated as having zero infection (Crocker 1967).

Burns should be made late in the dormant season—in January, or early February. Fast headfires, set on cold days with steady winds, have been used for initial burning with good re-



A row-seeded stand just emerging from the grass stage at age 3½ years.

sults. They are cheaper than backfires, raise ground surface temperatures less, and do a better job of destroying the pathogen. They can be made when fuel moisture is too high for backfires. Large areas can be treated rapidly when burning conditions are stable. Headfires are not advisable on areas when the seedling stand is composed of two age classes—a situation found when reinforcement seeding is done in understocked natural stands.

If a second burn is needed when a portion of the stand is in active height growth, backfires are recommended to avoid killing the most vigorous seedlings. Two objectives should be kept in mind when backfiring for brown-spot control. One is to keep surface temperatures low—best accomplished by firing against a steady wind on cold days. The other is to secure a complete burn. Patchy burning can result in a rapid reinfection by brown spot.

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Caution!

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals, and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U. S. Department of Agriculture, consult your county agricultural agent or State Extension specialist to be sure the intended use is still registered.



Use Pesticides Safely
FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE