Direct Seeding Southern Pines: Development of Techniques, Use, and Current Status

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Abstract

The "golden-age of lumbering" of the early 20th century left millions of acres of forest land in need of reforestation. Forests of the western Gulf Coast States of the South were especially decimated because of the development and use of steam-powered logging equipment. Faced with this reforestation need, scientists of the Southern Forest Experiment Station began an effort to develop direct seeding as a regeneration option. The key to successful direct seeding was found to be protecting seed from bird and rodent predation. Increasing the quantity and quality of pine seeds, controlling hardwood competition, and developing appropriate site preparation treatments were also important for successful direct seeding. The seeding technology resulted in successful restoration of millions of acres of southern pine forests. Direct seeding, however, is now infrequently used primarily because of the lack of large, open areas needing reforestation. This article includes an historical overview of direct seeding in the South as well as guidelines for current use of this reforestation technique.

The Need for Reforestation in the South

Much of the 90 million ac (36 million ha) of longleaf pine (*Pinus palustris* Mill.) throughout the coastal plain of the South were harvested by aggressive logging in the late 1800s and early 1900s. The longleaf forests of the West Gulf Coastal Plain were particularly devastated by the use of steam-powered logging equipment that was developed to harvest forests of the region (figure 1).

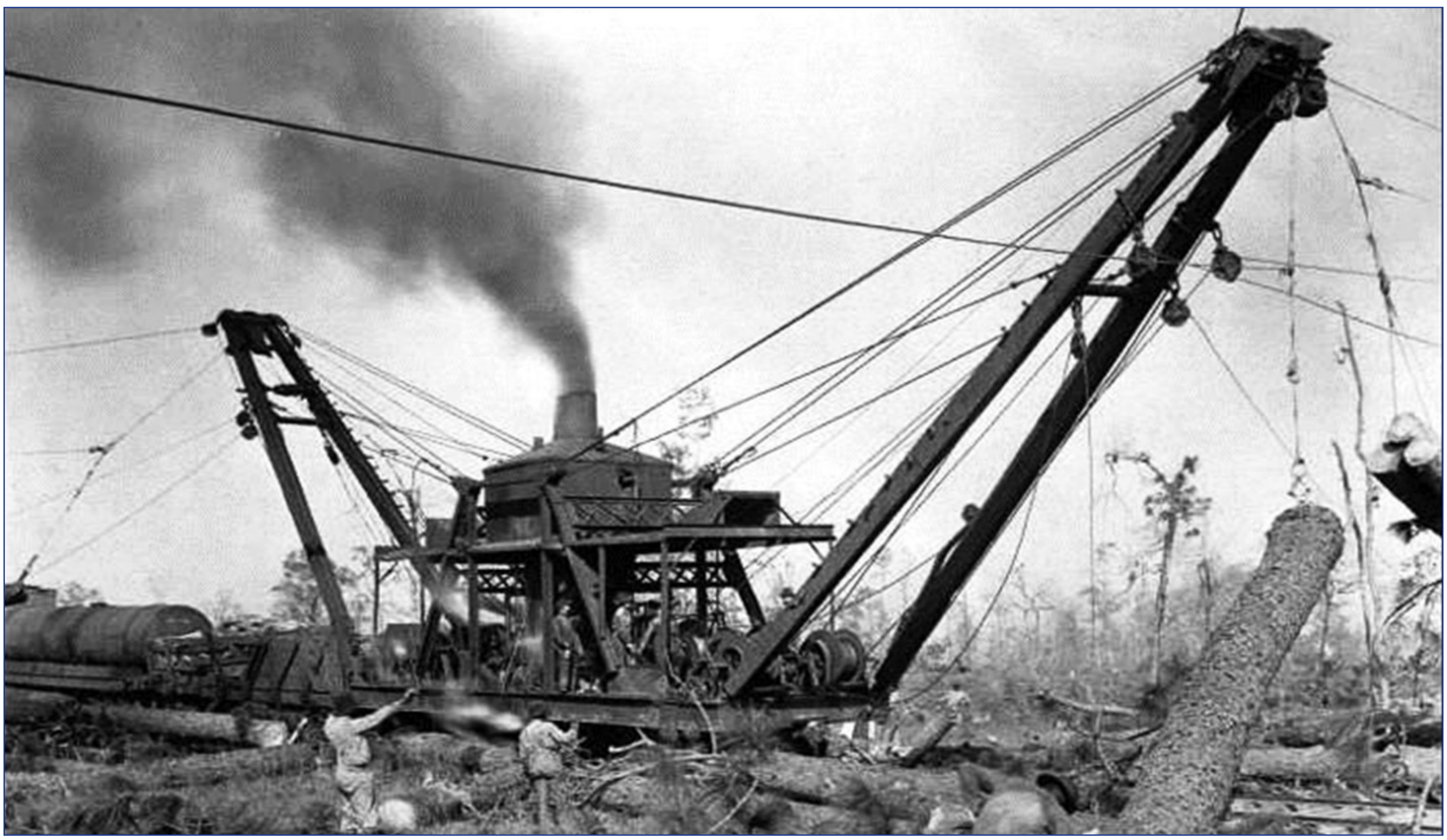

Figure 1. Steam-powered skidders manufactured by the Clyde Ironworks in Duluth, MN, greatly increased logging capability in the early 1900s. With one setting of the skidder, 40 ac (16 ha) of timber could by skidded to the railroad track for loading on train cars. (Photo from USDA Forest Service files circa 1930)

In the late 1940s and early 1950s, foresters in the South were faced with a huge reforestation problem—millions of acres of forest land clearcut in the early 1900s remained desolate and nonproductive. Much of this land was previously occupied with mature stands of longleaf pine, but the harvest was so complete that no seed sources remained to provide for natural regeneration. Planting of longleaf pine was then unreliable.

In 1954, it was estimated that about 13 million ac (5 million ha) were in need of reforestation across the South (Wakeley 1954). When the Southern Forest Experiment Station established the Alexandria Research Center in central Louisiana in 1946, the territory served by the research center covered more than 7 million ac (2.8 million ha) in western Louisiana and eastern Texas. Nearly 80 percent was commercial forest land and nearly one-half of this once supported magnificent stands of old-growth longleaf pine. More than 20 percent of the longleaf pine land was barren of pines, and another 50 percent was below its full potential because it was largely covered by grasses, scrub oaks, and other low-value hardwoods (Cassidy and Mann 1954) (figure 2).

It was estimated that if the treeless longleaf pine land in Louisiana and Texas was reforested by planting nursery-grown seedlings, the task would take 50 or more years at the rate feasible with the then-current nursery capability (Cassidy and Mann 1954). A significant need existed to develop additional technology to meet this huge reforestation need. Although expanding bareroot nursery production was an obvious goal, another option considered to speed the process was to develop direct seed capability.

Early Seeding Attempts

For generations, direct seeding had been considered a potential forest regeneration technique. Sowing of tree seeds on prepared

Figure 2. This area became part of the Palustris Experimental Forest and represented millions of acres of cutover forests across the South. (Photo from USDA Forest Service files 1950)

soils was often tried and was sometimes met with success. In 1920, the Great Southern Lumber Company of Bogalusa, LA, hand sowed slash pine (*Pinus elliottii* Engelm.) on furrows plowed by teams of mules (Barnett 2011) (figure 3). An 800-ac (314-ha) tract was successfully regenerated and is considered the first commercial direct seeding in the United States (figure 4). Great Southern Lumber Company's head ranger, F.O. (Red) Bateman, was responsible for the seeding operation. Other seeding trials, however, were not successful and Bateman later described direct seeding as generally unsuccessful because of seed losses from bird predation (Wakeley 1976).

Development of Bird and Rodent Repellents

The mission of the Alexandria Research Center was to develop improved methods of reforesting and managing forest land. Research in direct seeding began because it was seen as (1) fast and requiring minimal labor, (2) inexpensive, (3) a method to create dense stands that were particularly good for longleaf pine, and (4) an approach that could be expanded quickly to take advantage of bumper cone crops since storage of longleaf pine seeds was then problematical (Derr 1958).

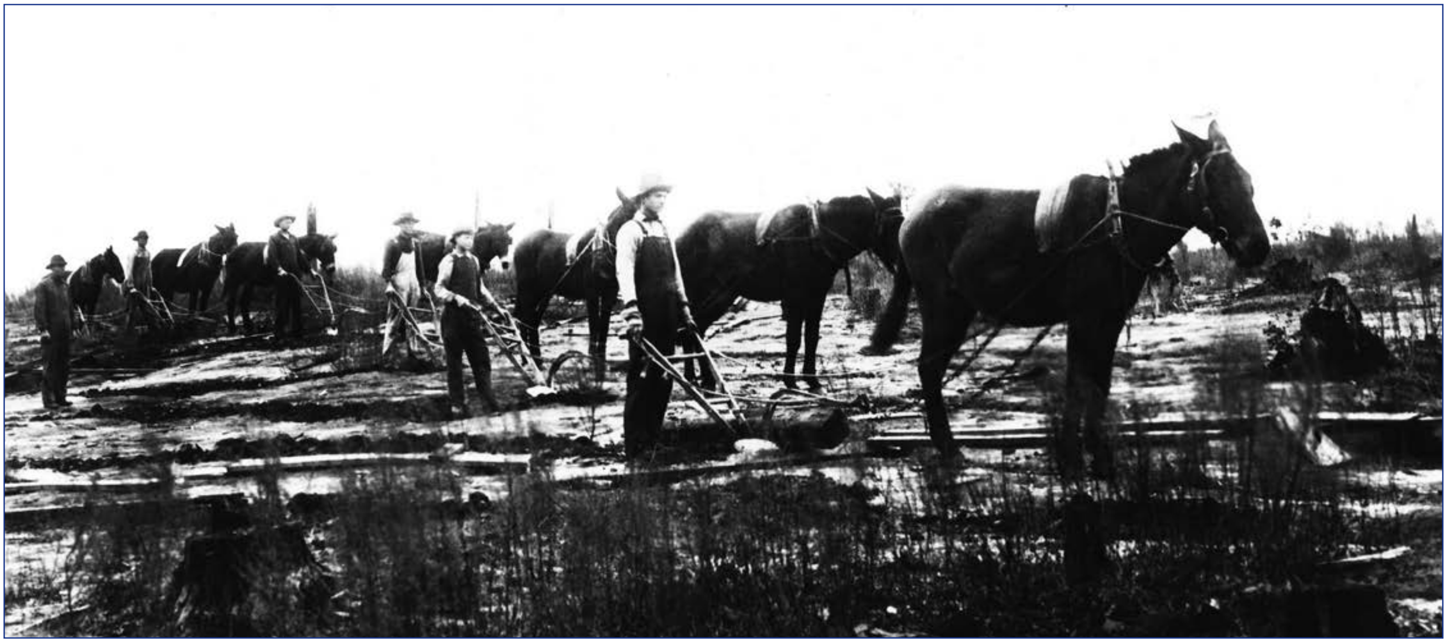

Figure 3. In 1920, the Great Southern Lumber Company reforestation efforts began with this direct seeding of slash pine on sites created by plowing furrows. (Photo from USDA Forest Service files circa 1924)

Figure 4. The 800-acre slash pine plantation 5 years after direct seeding into furrows plowed by mules. (Photo from USDA Forest Service files circa 1930)

Harold J. Derr and William F. Mann, Jr., led the direct seeding initiative. Derr was the scientist assigned to the project and Mann, the center leader, supervised and participated in the effort.

By 1954, about 3,000 ac (1,200 ha) in direct seeding experiments had been conducted using longleaf, slash, and loblolly (*Pinus taeda* L.) pines. No successful methods had been found, but the major causes of failure were identified (Cassidy and Mann 1954). Seed-eating birds were the greatest problem. The vast areas of cutover land provided ideal habitat for large flocks of eastern meadowlarks (*Sturnella magna*) (figure 5) and other birds frequenting field conditions (Burleigh 1938). Studies indicated that coating the seeds with a repellent treatment might be effective in reducing predation and a U.S. Fish and Wildlife Service scientist, Brook Meanley, was assigned to the Alexandria Research Center to intensify the search for effective chemicals.

Bird Repellents

The first chemical found to effectively reduce bird predation was Morkit®. This material was manufactured in Germany and was composed of anthraquinone, a chemical frequently used in cosmetics, and inert ingredients. When Morkit® was withdrawn from the market, anthraquinone alone became the primary candidate. Later, caged tests of Arasan Seed Disinfectant® (50 percent tetramethyl thiram disulphide) demonstrated that birds did not eat seeds treated with this chemical and also had some rodent-repellent qualities (Meanley and others 1957). Thiram 42-S®, a liquid suspension, later became the preferred formulation to use in direct seeding because it provided a durable, dust-free coating that was superior to previous formulations (Mann 1970). Thiram 42-S® is still in use today and is also an effective, registered fungicide formulation that is frequently used as a treatment to control seedborne microorganisms.

Rodent Repellents

Although early studies found birds were the primary predators of pine seeds, these tests were conducted with longleaf pine seeds sown in the fall on sites with a light grass rough (Derr 1958). Longleaf pine seeds lack dormancy and germinate soon after natural dispersal in the fall. When other, more dormant, pine species that require stratification were sown in the spring, they were subject to heavy rodent predation because losses from rodent populations increase during the fall and winter.

When Endrin-50W®, sold mainly as an insecticide, was incorporated into the repellent coating (figure 6), rodent predation decreased and seeding success was significantly increased. It was typically added to the repellent mixture at a rate of 1.0 lb (0.45 kg) (0.5 lb of active ingredient) per 100.0 lb (45 kg) of seeds (Mann 1958, Derr and Mann 1959). Endrin-50W® is a potent chlorinated hydrocarbon poison, however, and concern existed about its toxicity to the environment and animal life.

In the 1970s, public concern about the use of extremely toxic chemicals in agriculture caused Endrin-50W® to be withdrawn from the market by the manufacturer. At the same time, the use of direct seeding began to decline because large open sites where its use is best suited were generally not

Figure 5. The cutover forests provided ideal habitat for flocks of eastern meadowlarks, which ate huge quantities of seeds. (Photo from USDA Forest Service files 1958)

Figure 6. Longleaf pine seeds treated with repellent coatings consisting of Arasan 75®, latex, and aluminum flakes. (Photo from USDA Forest Service files 1960)

available. An effort was made, however, to find a chemical with rodent repellency that could replace Endrin-50W®. A number of possible replacement chemicals were evaluated, but none were environmentally safe or as effective (Campbell 1981a, Barnett 1995).

More recently, field tests have shown that oleoresin capsicum is a promising rodent repellent (Barnett 1998). Capsicum is obtained from dried cayenne peppers (*Capsicum frutescens*) and is standardized with olive oil. Its strength is measured in parts per million (ppm). The ppm are converted to Scoville Units (SV), the industry standard for measuring the heat of peppers (American Spice Trade Association 1960). One ppm is equivalent to 25 SV. Nolte and Barnett (2000) evaluated the efficacy of thiram-capsicum seed treatments (500,000 SV) on house mice (*Mus musculus*) and deer mice (*Peromyscus maniculatus*) fed longleaf pine seeds. Although positive results were obtained, it is unlikely that capsicum or any other chemical will be found to be as effective as Endrin-50W® in repelling rodents.

Repellent Application

An essential component of any repellent seed coating is a sticker to bind the repellent coatings to the seeds. After evaluating several chemicals, Dow Latex 512-R® was found effective when applied to pine seeds (Mann 1958). Repellent treatments were evaluated over time and modified to take advantage of improved formulations. The preferred formulation became a combination of thiram (standardized as a water suspension and marketed as Arasan 42S®), Dow Latex 512-R®, and Endrin-50W® (Derr and Mann 1971). The repellent mixture consisted of 1 gallon (3.8 liter) Arasan 42S®, 5 fl oz (150 ml) Dow Latex 512-R®, and 0.5 lb (0.23 kg) Endrin-50W®. This mixture usually treated about 50 lb (22.7 kg) of pine seeds, depending on species (figure 7). In addition, about 8 tablespoons (8 ml) of aluminum powder or flakes were typically added to the mixture to ensure the flow of seeds through sowing equipment (Derr and Mann 1971).

Figure 7. Tommy Melder mixing latex into an Arasan-42S® repellent formulation. (Photo from USDA Forest Service files 1961)

Application of Direct Seeding

Direct seeding was developed for use on forest lands that generally fall into one of two categories: open lands or those partially or wholly occupied by brush and low-quality hardwoods (Derr and Mann 1971). Seeding also was found to be useful in restocking stands destroyed by wildfires and wind storms. Most of the commercial pine land in the South was considered suitable for direct seedling (figure 8).

Figure 8. An industrial forester for T.L. James Company is evaluating a cutover site for its potential for direct seeding. (Photo from USDA Forest Service files 1963)

Although regenerating large areas of cutover longleaf pine forests was the driving force for developing direct seeding technology, it was also used to regenerate slash pine (Mann and Derr 1964), loblolly pine (Mann and Derr 1961), and other southern pine species (Derr and Mann 1971).

Sites and Site Preparation

Site preparation for direct seeding is important to expose mineral soil that seeds need for germination (figure 9) and to control competing vegetation that will interfere with the survival and growth of new stands. Fire is the simplest and least expensive site preparation method, and it is often sufficient on open sites. On sites with hardwood brush and trees, mechanical and chemical methods of control are typically required. Whatever means are chosen, fairly complete removal of competing hardwoods is needed, and the likelihood of sprout growth must be considered.

Figure 9. Longleaf pine seed germinating on mineral soil on a prepared site. (Photo from USDA Forest Service files circa 1959)

Timing and Rate of Distribution

Two distinct sowing seasons exist—spring and fall. Fall sowing is generally recommended for longleaf pine because these seeds germinate naturally in the fall. Seeds of other major southern pines that exhibit some level of seed dormancy—loblolly, slash, and shortleaf pine—are best sown in the spring after seed stratification.

Sowing rates vary considerably by species, quality of the seeds, method of sowing, and level of stand stocking desired by the landowner. General recommendations for broadcast seeding are to sow about 3.0 pounds (lb) (1.4 kg) of longleaf pine seeds per ac, 1.0 lb (0.45 kg) for slash and loblolly pines, and 0.5 lb (0.23 kg) for shortleaf pine (table 1). These seeding rates result in 12,000 to 20,000 viable seeds per ac and may result in as many as 2,000 to 5,000 seedlings per ac (per 0.4 ha). For sowing in rows or spots, rates should be less (table 1).

Ground Application

Sowing by hand is the oldest form of direct seeding; but, as seeding technology improved and areas to be seeded increased, mechanized ground equipment was developed. Hand-operated cyclone seeders are the simplest of such equipment. These seeders were efficient for small areas and production per day could be up to 15 ac (6 ha) (Derr and Mann 1971) (figure 10).

Sowing seeds in spots prepared by raking, hoeing, or kicking areas free of vegetation and litter were found to be effective methods for small acreages. At the recommended rate of 1,000 spots per ac (2,470 spots per ha), 2 to 4 ac (0.8 to 1.6 ha) could be seeded per day (Campbell 1982a).

Tractor-mounted seeders were frequently used and usually resulted in seeds sown in rows. Some tractor operators simply

Table 1. Average number of seeds per pound and suggested sowing rates per acre.

Species	Seeds per lb[1]	Weight of dry seeds per acre for seeding					
		Broadcast		Rows[2]		Spots[3]	
		Number	lb	Number	lb	Number	lb
Longleaf pine	4,700	15,000	3.24	2,900	0.63	4,350	0.94
Slash pine	14,500	14,000	1.11	2,900	0.23	4,350	0.35
Loblolly pine	18,400	12,000	0.75	2,150	0.14	3,650	0.23
Shortleaf pine	48,000	20,000	0.48	4,350	0.10	5,800	0.14

[1] Dry, untreated seed, with viability of 95 to 100 percent: averages from Wakeley (1954).

[2] Rows 10 ft (3 m) apart for all species. Spacing within rows: 1.5 ft (0.46 m) for longleaf and slash, 2.0 ft (0.6 m) for loblolly, and 1.0 ft (0.3 m) for shortleaf.

[3] Spots spaced 6 by 10 ft (1.8 by 3 m), 6 seeds per spot for longleaf and slash, 5 per spot for loblolly, and 8 per spot for shortleaf, with 1,000 spots per ac.
(Adapted from Campbell 1982b)

Figure 10. Harold J. Derr, research forester for the Southern Forest Experiment Station, Pineville, LA, sowing longleaf pine seeds with a cyclone seeder in 1954. (Photo from USDA Forest Service files)

dropped seeds on previously prepared sites, but many plowed a furrow or disked a narrow strip and metered out seeds (Derr and Mann 1971) (figure 11).

Aerial Application

About 75 percent of the total acreage seeded in the South has been from the air, either with small fixed-wing aircraft or helicopters (figure 12). Seedling effectiveness differs little between planes or helicopters. Both aerial application types require constant checking of equipment and precision flying for best results. Accurate seeding requires good ground control and proper calibration of seed release equipment (Derr and Mann 1971).

Figure 11. Thomas C. Croker demonstrating a row seeder that elevates a low ridge in a plowed furrow and drops seeds that will be pressed into the soil. (Photo from USDA Forest Service files circa 1962)

Figure 12. Aerial seeding being used with a fixed-wing plane, with seed distribution controlled by flag men on the ground. (Photo from USDA Forest Service files 1959)

Appraisals

Seed losses begin on the day of seeding and continue throughout the germination period. A successful seeding is one where losses are minimized so that adequate first-year stocking is achieved using the least amount of seeds. To determine seeding success, two or three evaluations are needed during the establishment period. These evaluations determine predation activity, initial stocking, and stocking at the end of the first year.

Estimating Predator Activity

Finding the cause of failures of seeding was a difficult task. Establishing observation stations, where repeated observations could be made, became essential for evaluating predator activity. An observation station consists of an identification stake and two nearby small cleared spots containing 25 treated seeds each. An additional screened spot with at least 10 seeds can be added to provide an estimate of field germination (Derr and Mann 1971) (figure 13).

The number of stations needed varies with the acreage of the seeding and cover conditions. For small areas, a minimum of 15 stations is needed to achieve meaningful data. On large areas, one station per 10 ac (per 4 ha) may be adequate, depending on site and ground cover conditions. Frequency of examination of stations may range from daily to weekly during the germination process.

When damage is observed, additional checking is needed to determine the nature of the losses and to evaluate seed treatments. Derr and Mann (1959) provide descriptive information related to the damage to seeds that are caused by different predators (figure 14) for identifying causes of seed losses.

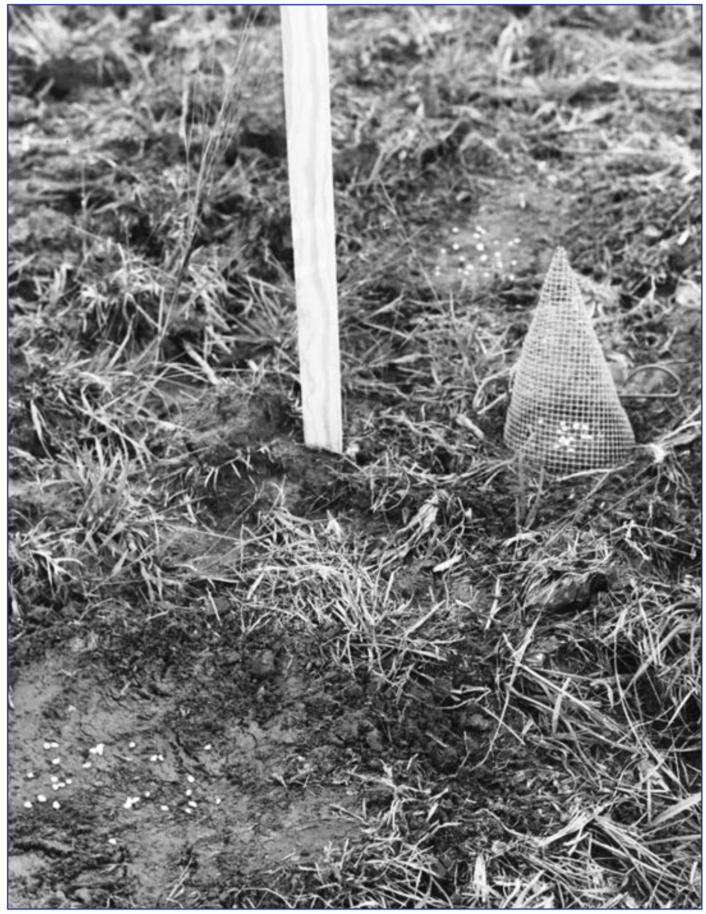

Figure 13. Observation station with center stake, two spots with 25 treated seeds each, and a screened spot with 10 seeds to evaluate germination potential. (Photo from USDA Forest Service files 1964)

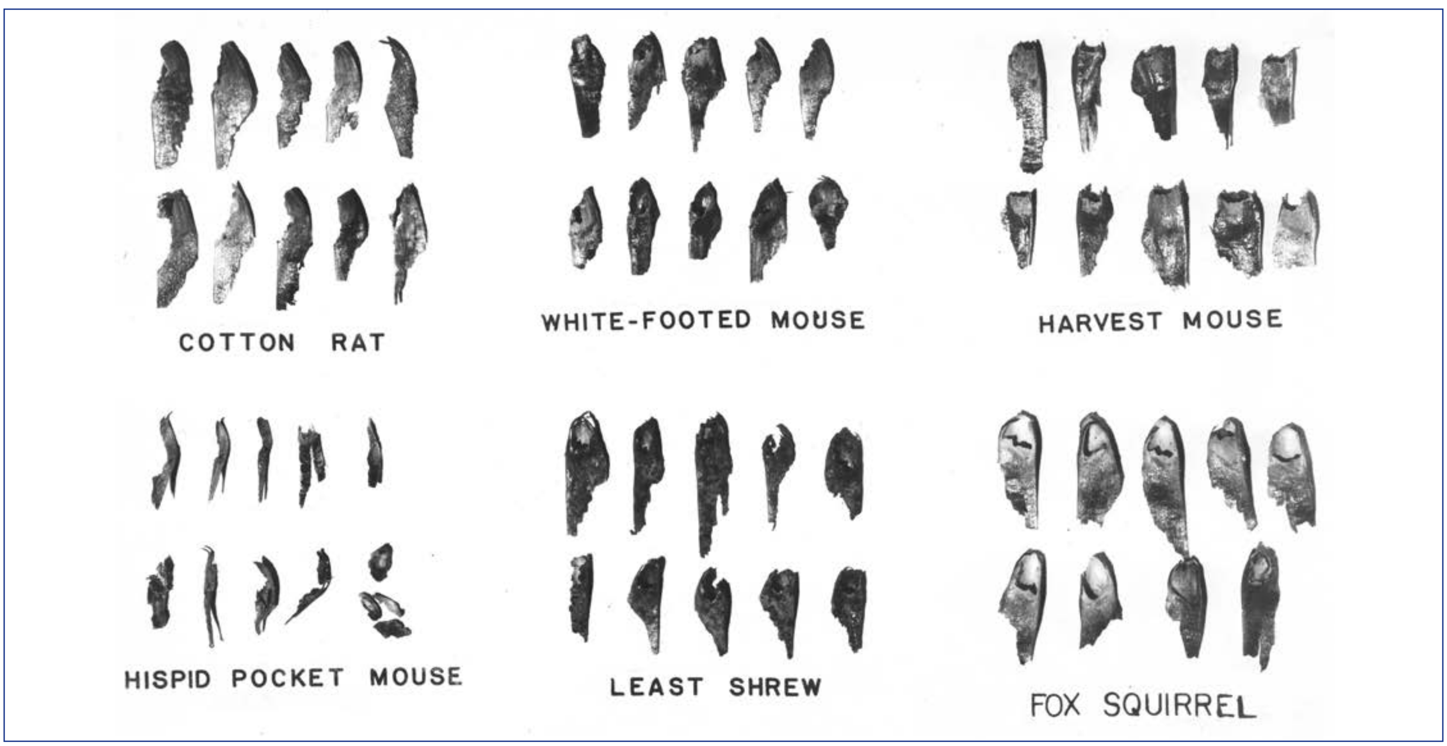

Figure 14. Characteristic damage to untreated longleaf seeds by seed predators in central Louisiana. These hull fragments were obtained from caged predators. (Photo by Brooke Meanley, U.S. Fish and Wildlife Service 1958)

Seedling Inventories

Survival of established seedlings during the first year is critical after direct seeding. To determine causes of early losses, two inventories are generally advised—one at the beginning of the summer when germination has completed, and the other at the end of the first growing season when mortality from summer drought is passed. The early inventory indicates the efficiency of the repellents. The second provides an estimate of overall seeding success.

Success of broadcast seeding can be determined by estimating the number and distribution of seedlings per acre. Estimates of both variables can be determined by installing sampling plots of a milacre (1/1,000 ac) in size. Circular milacre plots with a radius of 44.7 in (1 m) are ideal because they are quickly established and measured—a stiff wire or stick of the appropriate length is swept around a central point to establish plot boundaries and observe seedlings. Twenty-five plots is the minimum number for any seeded area. On large areas, one plot per ac (per 0.4 ha) has been used successfully (Ezell 2012).

Long-Term Protection and Management

After the first season, mortality from drought usually is not a major problem and substantial height growth begins for most southern pines. Protection from wildfire for the first few years is necessary for most southern pines. The exception is longleaf pine, which exhibits a fire-tolerant grass stage that may remain for several years (figure 15). Use of prescribed burning in the second or third year after seeding may be necessary to reduce vegetative competition and stimulate height growth of longleaf pine.

Direct seeding can result in overstocking of trees. Precommercial thinning may be needed when stocking at the end of the first year is 2,000 or more seedlings per ac (per 0.4 ha). Guidelines for timing and methods of thinning have been developed for loblolly and slash pine (Lohrey 1972, 1973). Stands basically should be precommercially thinned to about 400 to 800 seedlings per ac to improve growth and increase stand value.

Figure 15. Longleaf pine seedlings after a prescribed burn to reduce competing competition and brown-spot infected foliage. (Photo from USDA Forest Service files circa 1964)

Advantages and Disadvantages of Direct Seeding

Direct seeding can be an effective practice for regenerating southern pines. On many sites, seeding is more economical than planting nursery-grown seedlings or waiting for natural regeneration. The choice of seeding depends on the landowners' goals and economic situation, as well as the condition of the site and the capability of the land manager. Use of the direct seeding method has declined from its widespread use in the 1960s and 1970s, however. A number of reasons exist for this decline. These reasons and the merits of direct seeding are discussed in the following sections.

Advantages

The most notable advantage of direct seeding is lower initial cost compared with planting nursery stock. The cost of seeding is usually less than one-half that of planting for initial seedling establishment. Direct seeding is also beneficial for some species, notably longleaf pine, that are difficult to regenerate by planting bareroot nursery stock. Furthermore, direct seeding is a good alternative for regenerating low-quality sites.

Disadvantages

One of the most notable problems with seeding is poor control of tree spacing and stocking (number per acre). If environmental conditions are ideal after seeding, too many trees may survive and result in an overstocked situation that will require precommercial thinning. Pine stands with more than 2,000 stems per ac will result in reduced growth and financial return (Williams and others 2008). Understocking can also occur when establishment is not adequate to fully stock the area; this situation may be even more costly to the landowner.

Another disadvantage is that seeding usually does not take advantage of genetically improved seed sources because of higher costs and less availability. Large quantities of seeds are needed for broadcast seeding where tree percent (ratio of seeds sown to seedlings obtained) is significantly lower than for planting seedlings.

Seeding is best suited for use on large, open tracts of forest land. Such open areas are now seldom available for reforestation. Also, the loss of effective rodent repellent products from the market reduced the efficiency of seeding in areas were rodents are major seed predators. Although capsicum in combination with thiram does reduce rodent damage to seeds (Barnett 1998, Nolte and Barnett 2000), it is not as effective as the earlier thiram-endrin combination.

An additional problem limiting successful application of seeding is lack of availability of specialists with a high degree of technical skill, knowledge, and experience with seeding (Williston and others 1998).

Current Application of Direct Seeding Technology

Direct seeding was never meant to replace planting nursery-grown seedlings as a regeneration tool, but it was used over a 25-year period to reforest nearly 2 million ac (0.81 million ha) of forest land in the South (Campbell 1982b) (figure 16). After effective repellents were developed, supporting research

Figure 16. Men distributing longleaf pine seeds. Seeding with cyclone seeders is a viable regeneration option for land managers who have small tracts to reforest. (Photo from USDA Forest Service files 1959)

programs were established to provide necessary seed production capacity, to control competing hardwoods, and to clarify site preparation needs. These supporting programs were critical for implementing large-scale seeding operations (Mann and
Burkhalter 1961; Mann 1968, 1969). The greatest use for direct seeding has been in regenerating vast acreages of cutover forests. Many landowners, however, also saw it as an inexpensive tool for reforesting small tracts of land (Mann and Burns 1965, Campbell 1981b). Guidelines for such use are readily available (Duryea 1992, Williston and others 1998, Gwaze and others 2005, Ezell 2012).

Today, use of direct seeding is limited. Traditional forest regeneration by natural seeding or planting of genetically improved nursery stock is the prevalent means of reforesting highly productive sites. Nonetheless, direct seeding can still be an applicable technology. Some elements to be considered are summarized in the following sections.

Where Should Direct Seeding Be Used?

With the exception of excessively drought-prone areas, nearly any site that can be planted with seedlings can be direct seeded. The areas where seeding has the greatest current application are (1) large areas resulting from wildfire or other natural disasters, (2) remote or inaccessible areas, (3) low-productive sites where growth of trees would not make the cost of planting operations economically feasible, and (4) any area where a minimal investment is essential (Ezell 2012). The last category is important because many small private landowners cannot afford the cost of intensive site preparation and planting. It is better to direct seed these areas than to allow undesired species to become established.

What Species Are Best Suited for Direct Seeding?

Problems with the regeneration of longleaf pine were the primary reasons for the development of direct seeding, and seeding remains as an option for its regeneration. The development of container seedling production and planting, however, has made it a reliable method for reforestation of longleaf pine (Barnett and McGilvray 1997). Container seedlings are costly, but cost-share programs currently lower the expense to landowners.

Species selection will be affected by goals of ownership, but putting a species on sites where it grows best and with little danger of loss results in the most successful direct seeding (figure 17). Sand pine (*Pinus clausa* [Chapm. ex Engelm.]

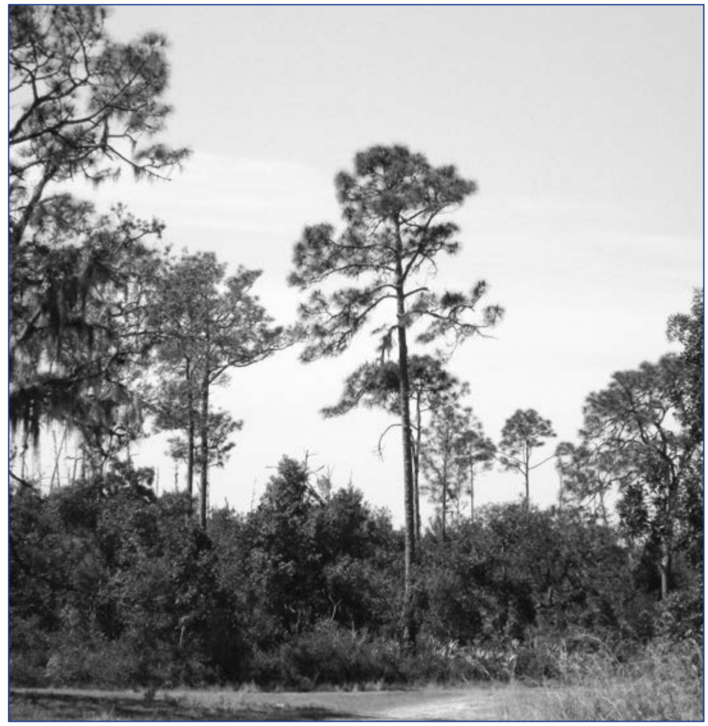

Figure 17. Sand pine growing on infertile sandhill sites in northwest Florida. This sand pine scrub ecosystem is common on these deep, sandy sites. (Photo from USDA Forest Service files circa 1965)

Vasey ex Sarg.) and shortleaf pine (*Pinus echinata* Mill.) are two southern pines that occur on infertile soils where seeding is a good alternative to planting (Outcalt 1985, 1990; Gwaze and others 2005).

Seed availability must be considered for any species. Also, seeds with viability of at least 85 percent and a minimum of 95 percent sound seeds will enhance seeding success.

What Are Weather Constraints to Direct Seeding?

Arid soils and periods of low rainfall may reduce the success of direct seeding. During the late 1950s and early 1960s when direct seeding techniques were developed, the South was in a rainfall cycle that favored seeding. Fall and winter Palmer Drought Severity Index (PDSI) values between 1956 and 1962 were positive, averaging 0.76, and those of the same period between 2006 and 2012 were negative, averaging -3.27, indicating significantly drier weather conditions during recent years (Barnett 2014). These data indicate that land managers planning to use direct seeding as a management tool should consider the severity of soil moisture regimes for the areas being considered for seeding. Localized PDSI data are readily available from the NOAA National Climate Data Center Web site at http://www.ncdc.noaa.gov/oa/climate/research/prelim/drought/palmer.html.

What Does Site Preparation Need To Accomplish?

Site preparation for direct seeding should expose mineral soil for prompt seed germination and accomplish some degree of vegetative competition control. The site preparation must result in enough competition control to get a stand established and begin tree height growth. Control can be achieved by use of prescribed fire, mechanical treatments, or, in some cases, by use of herbicides.

What Seed Treatments Are Needed?

Two types of seed treatments may be required for successful direct seeding. The first depends on seed dormancy that may require stratification to assure prompt germination after sowing. Commercial forest tree seed dealers have the knowledge and resources to provide appropriate seed stratification treatments.

The second seed treatment is to protect seeds from bird and rodent predation after sowing and throughout the germination process. Thiram 42-S® is the commonly used bird repellent and also provides some initial rodent repellency. If the area to be seeded is relatively small, however, rodent predation can be a serious problem, because animals can be drawn from surrounding areas. Capsicum in combination with Thiram 42-S® provides the best available seed protection; recommended rates for this repellent coating per 1 lb (0.45 kg) of seed are 76 ml of thiram (Gustafson 42-S®), 3 ml of latex, and 1 ml of capsicum (500,000 SV).

When Should Seeds Be Sown?

Seeds that lack dormancy, e.g., longleaf and sand pine, can be sown in the fall when soil moisture is fully recharged. Seeds of other major southern pines species should be stratified before sowing in the spring. Spring sowing should be done early, about mid-February, to ensure germination is complete before droughty soil conditions develop.

How Should Seeds Be Distributed?

Large areas (more than 50 ac [20 ha]) needing reforestation can be broadcast seeded by airplanes or helicopters. Tractor-drawn row-seeding equipment is another option. Small tracts of land can be inexpensively regenerated by use of hand- and spot-sowing techniques. With use of hand-cranked cyclone seeders, one person can sow about 15 ac (6 ha) per day. Spot seeding of about 1,000 spots per ac is another option for small areas.

How Is the Success of Direct Seeding Determined?

Installation of sample plots is needed to determine seeding success. For broadcast sowing, circular plots can be established as described previously. On these plots, the number of germinated seeds are counted and recorded. An inventory at the end of the growing season will provide data to determine success of the seeding operation. About 25 plots are the minimum needed for any small seeded area and one plot per acre may be sufficient for larger areas (Ezell 2012). Sampling row- and spot-seeded areas may require a different approach, but the milacre-plot method may be used with confidence. Derr and Mann (1971) give specifics for these techniques.

Where Are Sources of Technical Expertise?

A limitation in the application of direct seeding is lack of specialists with expertise in seeding. Before beginning a large-scale operation, advice from those who have used the technique is very helpful.

Conclusions

Early studies by scientists of the Southern Forest Experiment Station in Alexandria, LA, determined that direct seeding was a viable technique to help reforest millions of acres of cutover forest land in the region. The use of direct seeding was a major achievement that resulted in large areas of devastated forest land being put back into production.

Development of repellents to protect seeds from bird and rodent predation became the key to successful direct seeding (figure 18). Effective repellents for protecting seeds from bird predation are anthraquinone and thiram. Both chemicals are not toxic and are readily available. Protection from rodents is essential on some sites but the most effective rodent repellent, Endrin-50W® a toxic hydrocarbon, was withdrawn from the market in the 1970s. A chemical as effective as Endrin-50W®, but safe to use, has not been found. A combination of Thiram 42-S® and capsicum, however, does provide a lesser level of protection from rodents.

Decline in the use of direct seeding began in the 1970s when much of the large areas of cutover forests were regenerated with pines, when the rodent repellent Endrin-50W® was withdrawn from the market, and when problems of overstocking of stands requiring precommercial thinning became apparent. Direct seeding still has applicability to large areas needing

Figure 18. Direct seeded longleaf pine seedlings that have begun height growth. Direct seeding was used to effectively reforest hundreds of thousands of acres with longleaf pine. (Photo from USDA Forest Service files circa 1963)

reforestation after wildfire and other natural disasters and to species growing on infertile soils where the cost of planting nursery stock is hard to justify economically.

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