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Guidelines for Producing Quality Longleaf Pine Seeds

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Cover: Dewinged longleaf pine seeds.

Photo by Eric Vallery, USDA Forest Service, Southern Research Station, Pineville, LA.

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Preface

The guidelines that follow represent current knowledge and research studies on how to collect, process, treat, and store longleaf pine seeds for nursery use. Experience has shown that results from small research studies may be difficult to apply on an operational scale because longleaf pine seeds are unusually sensitive to injury. However, these guidelines provide the best information available on handling cones and seeds of this species. Seed dealers and orchard and nursery managers will need to adapt these principles and procedures to their own operations.

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James P. Barnett and John M. McGilvray

Abstract

Longleaf pine (*Pinus palustris* Mill.) seeds are sensitive to damage during collection, processing, treatment, and storage. High-quality seeds are essential for successfully producing nursery crops that meet management goals and perform well in the field. Uniformity in the production of pine seedlings primarily depends on prompt and uniform seed germination, early seedling establishment, and a variety of cultural practices that are applied as the seedlings develop. The best collecting, handling, and processing methods maximize performance attributes and reduce the need for extensive nursery cultural practices to compensate for poor seed quality. Guidelines are presented that will help seed dealers, orchard managers, and nursery personnel produce high-quality longleaf pine seeds and improve the efficiency of nursery production.

Keywords: Container and bareroot nursery production, *Pinus palustris*, seed germination, seed orchard management, seed physiology, seed quality.

Introduction

Interest in restoring longleaf pine (*Pinus palustris* Mill.) to many sites in the South has increased dramatically over the last decade (fig. 1). One of the limitations in producing the quantities of seedlings needed for this reforestation effort is the lack of sufficient quantities of high-quality seeds. Although the quantity of seeds collected and seedlings produced has increased markedly, the quantity and quality of longleaf pine seeds remain insufficient to meet demand across the range of the species. Producing consistently high-quality seedlings requires prompt and uniform seed germination and early seedling establishment (fig. 2). Most nursery managers should be able to maintain 85-percent or higher germination and 90-percent or higher survival after the emergence of seedlings. Otherwise, oversowing will be necessary, and the subsequent waste of seeds will jeopardize efforts to produce high-quality crops economically and consistently.

With seeds of loblolly (*P. taeda* L.) and slash (*P. elliottii* Engelm.) pines relatively easy to collect, process, and maintain, why are nursery managers unable to produce similar quantities of quality longleaf pine seeds? The answers to this question can be found by examining the uniqueness of the species.

Figure 1—A recently regenerated longleaf pine stand showing vigorous early growth.

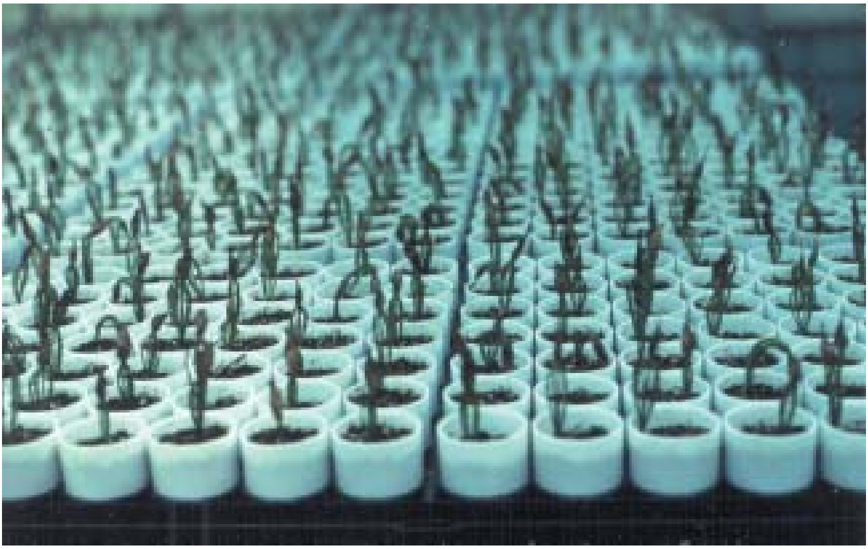

Figure 2—Prompt and uniform seed germination is the key to efficient production of container longleaf pine seedlings.

First, seed production of longleaf pine is extremely variable from year to year and from place to place. Although some open-grown trees will bear cones every year, crops are usually sporadic. A 21-year period in south Mississippi produced seed crops that were heavy for 2 years, medium for 7 years, light for 5 years, and failures for 7 years (Maki 1952). Boyer (1987) observed that the frequency of acceptable crops ranged from zero for a 19-year period to three for a 4-year period. The frequency of good crops appeared to be lower near the Gulf Coast than farther inland. Poor cone crops can result from lack of flowering or from insect damage to cones, particularly when crops are light (Allen and Coyne 1956, Barnett and Haugen 1995). Review of the physiology of cone and seed production indicates that reducing numbers of trees per acre is the most effective method of improving seed productivity (Barnett and Haugen 1995).

Second, the relationship between cone and seed maturity in longleaf is unique among the southern pine species. Longleaf seeds do not mature (germinate well) until the cones are mature enough to be opened operationally (Barnett 1996a). Therefore, to ensure that seeds have high viability, you must delay cone collection until the seeds are fully mature.

Third, unlike slash and loblolly pine, longleaf pine has an extremely short period of seed dormancy, often germinating immediately after separating from the cones. Therefore, proper handling before storage is critical. Because longleaf seeds are large and fragile with permanently attached wings, have thin, easily cracked seedcoats, and are unusually moist when extracted from cones, they are the most difficult of the southern pines to successfully collect, process, store, and treat without adversely affecting quality (fig. 3) (Barnett and Pesacreta 1993, Wakeley 1954).

Results from recent tests, combined with other documented findings and recommendations that will help you produce high-quality longleaf pine seeds, are reported in this paper.

Selecting Seedlots

About 450 acres of first-generation longleaf pine seed orchards have been established in the South (Dennington and Farrar 1983), with the primary emphasis of breeding for fast initial height growth and resistance to brown-spot needle blight (*Mycosphaerella dearnessii* Barr). Because these orchards can

Figure 3—Reasons for longleaf pine seed vulnerability to damage—large size, thin seedcoats, and wings that must be reduced to stubs.

only supply limited quantities of genetically improved longleaf pine seeds, reforestation must depend on collections from healthy, vigorous stands. Although the most conservative approach is to select seedlots from local sources, using nonlocal seed involves minimal risk if you follow the guidelines below.

Geographic variations in longleaf pine, although not as obvious as in loblolly and slash pine, are important to commercial growers (Lantz and Kraus 1987). For example, seedlings from central Florida sources have poor survival when planted north of peninsular Florida. Schmidtling (1999) found no ecotypic differentiation in the species—with few genetic differences between stands from deep sand sites and stands from heavier soils—and no important differences between eastern and western sources. The natural range of longleaf pine (fig. 4) consists of five primary collection or planting isotherms or both (formerly called zones) based on average minimum temperature (Schmidtling 2001). Seed can thrive if planted in an isotherm from which it was collected. Growth will be hastened by planting seed from one isotherm warmer and slowed by planting from one isotherm colder. Seed should not be moved more

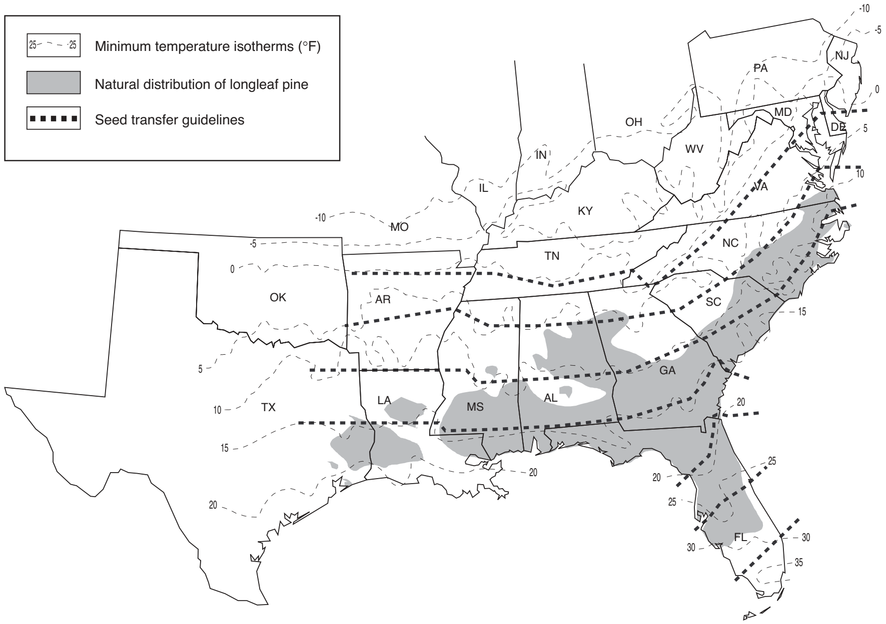

Figure 4—Longleaf distribution with seed transfer guidelines (Schmidtling 2001).

than one isotherm. Certification of seed sources by crop improvement associations in all Southern States provides valuable third-party verification of seed source.

Collecting and Processing Cones

The ability to predict cone and seed yields is important in scheduling and allocating resources for cone collection. Barnett (1999) published guidelines for predicting the number of cones per tree and converting to bushels, estimating numbers of seeds per cone, and converting numbers of seeds per bushel to pounds of seed per bushel. Once these data are available, scaling up of information for crop prediction is straightforward.

Collecting Cones

Careful control of cone collection is the first step in producing high-quality longleaf pine seeds (fig. 5). The most common source of early losses in seed quality is from cones collected before the seeds are fully mature. The

Figure 5—Collecting longleaf pine cones in a seed orchard with a cone shaker.

recommended timing of southern pine cone collections has not changed since Wakeley (1954) showed that a cone is mature enough for seed extraction when its specific gravity drops below 0.89. Two factors make specific gravity the best predictor of seed maturity: first, that water content decreases as cones mature; and second, that cone-specific gravity (the weight of freshly picked cones divided by their volume) is an indirect measure of moisture content. A graduated cylinder technique is a simple alternative for determining cone-specific gravity (Barnett 1979a). Fill a cylinder to a convenient level and record that level. Carefully place the cone in the cylinder and, if floating, record the new level (if the cone sinks, the specific gravity is 1.0 or more). The difference between the two recorded levels is cone weight. With a wire or small object, submerge the cone and record the third water level; the difference between this third level and the initial level is cone volume. Because longleaf cones are often too large to fit a standard-sized, graduated cylinder, Karrfalt (in press) devised a second alternative that uses a 3-inch PVC pipe (fig. 6). A third, nearly foolproof alternative is to float cones in oil that has a specific gravity of 0.88. There is little room for error in the oil flotation technique, but newer oil formulations make finding an appropriate specific gravity oil difficult.

Recent data confirm that collection should be delayed until cones are fully mature (fig. 7) because viability of longleaf seed from immature cones may decrease during cone storage if seeds have not reached some undetermined stage of ripeness (Barnett and Pesacreta 1993).

Additional tests were conducted to determine potential sources of major seed-quality losses. During two collection periods, specific gravity was measured for cones harvested from several clones in the Stuart Seed Orchard at Pollock, LA. Average specific gravity (table 1) was 0.86 for collection 1 (October 5 to 6) and 0.81 for collection 2 (October 20). Even with an average of 0.86, specific gravity was much higher for many individuals in collection 1, supporting Wakeley's (1954) recommendation that cone collection not begin until specific gravity for 19 of 20 cones is <0.89. If the data in table 1 are representative of all longleaf pines, average specific gravity must be about 0.81 before Wakeley's criteria are met.

The Louisiana data also support the previous conclusions that seed yields increase as specific gravity decreases (fig. 8). Seed germination was also markedly affected by cone maturity, with collection 1 germination averaging 49 percent compared to 69 percent for collection 2.

Figure 6—A method for quickly determining specific gravity of longleaf cones (Karrfalt, in press) involving a 3-inch PVC pipe plugged at one end: (A) install a 1/4- to 1/2-inch drain near the top of the PVC pipe and pour water into the PVC pipe until it begins to flow through the drain; (B) to determine cone weight, place a 100-mL graduated cylinder beneath the drain, place the cone in the PVC pipe, and record the amount of water that flows into the graduated cylinder; (C) to determine cone volume, submerge the cone and record the amount of additional water that flows into the graduated cylinder.

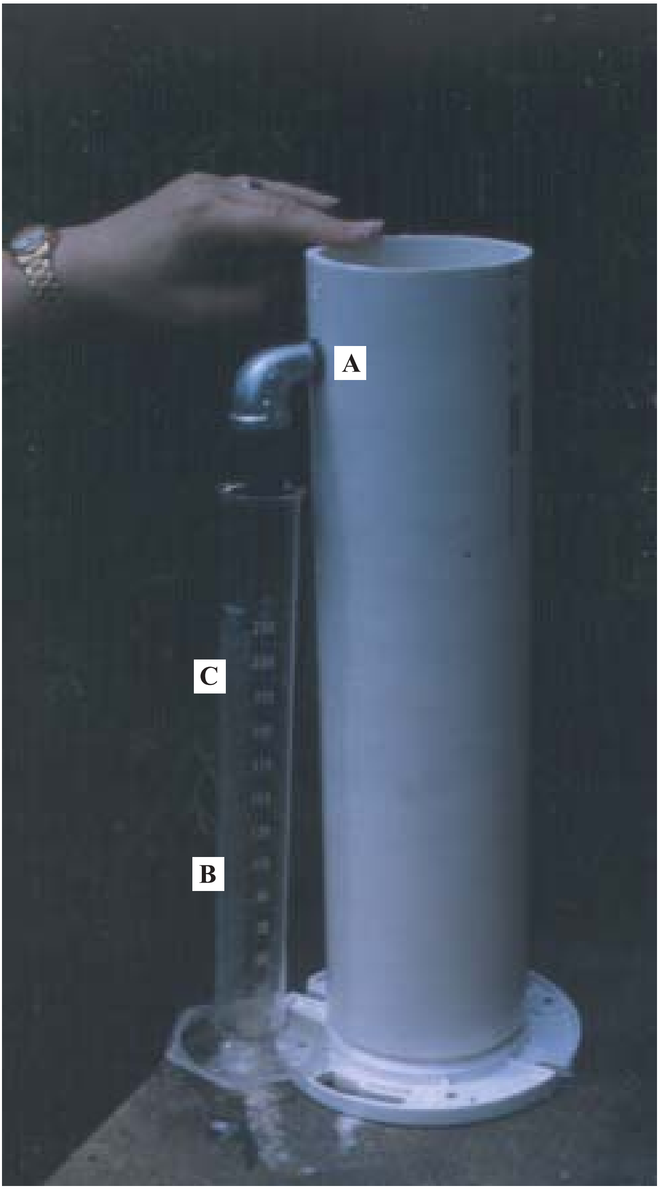

Figure 7—Fully mature longleaf pine cones.

Table 1—Longleaf pine cone-specific gravity, seed yields, and germination for two collection periods (October 5 to 6 and October 20)

	Cone-specific gravity[a]				
Collection period	Average	Above 0.89	Above 0.87	Seed yields	Germination
		- - - - - - *Percent* - - - - - -		*Lbs/bu*	*Percent*
1	0.86	27	44	0.49	49
2	.81	4	7	.73	69

[a] Specific gravity values represent an average of 20 replications of 10 cones each per collection period.

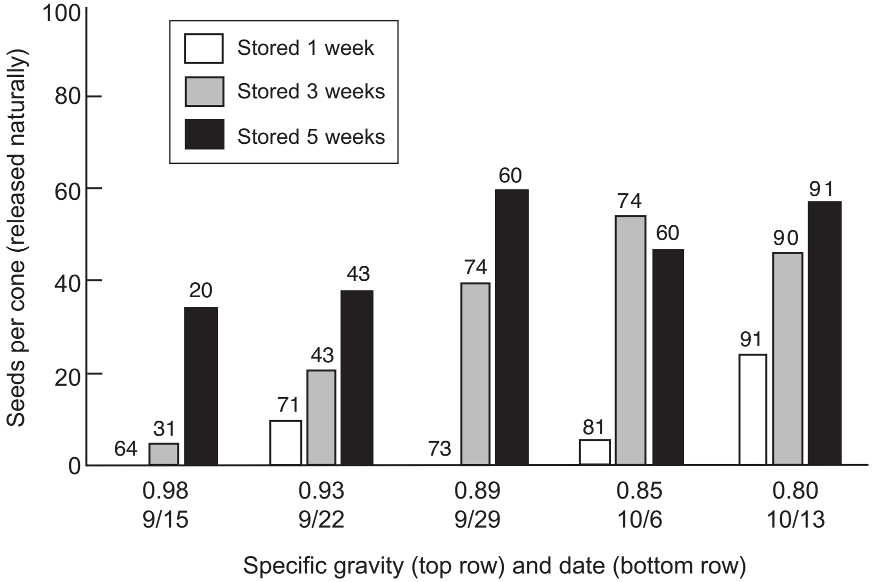

Figure 8—Seed yields and germination (shown above bars) of longleaf pine as affected by date of collection and cone storage (Barnett 1979a). When case hardened, seeds were removed artificially.

Handling Cones

The effectiveness of ripening immature cones to improve viability versus holding them before seed extraction is unclear (Barnett 1996b, Bonner 1987, McLemore 1975), but some cone storage is needed to improve seed yields. However, McLemore (1961) showed that delaying cone extraction beyond about 4 weeks may jeopardize seed quality (fig. 9).

How cones are stored is important. If cones are properly aerated and kept dry, you may store them in burlap bags, 20-bushel crates (fig. 10), or on drying racks. Exposure to rain can cause premature sprouting of the seeds in opening cones and significant reduction in quality. If cones remain wet, pathogenic fungi can develop, reducing seed viability and vigor and increasing mortality of newly germinated seedlings (Barnett and others 1999).

Drying normally takes place in a kiln (pressurized drier) where heated air is forced through the cones to reduce relative humidity. Drying duration depends on the moisture content of the cones when placed into the kiln and on the

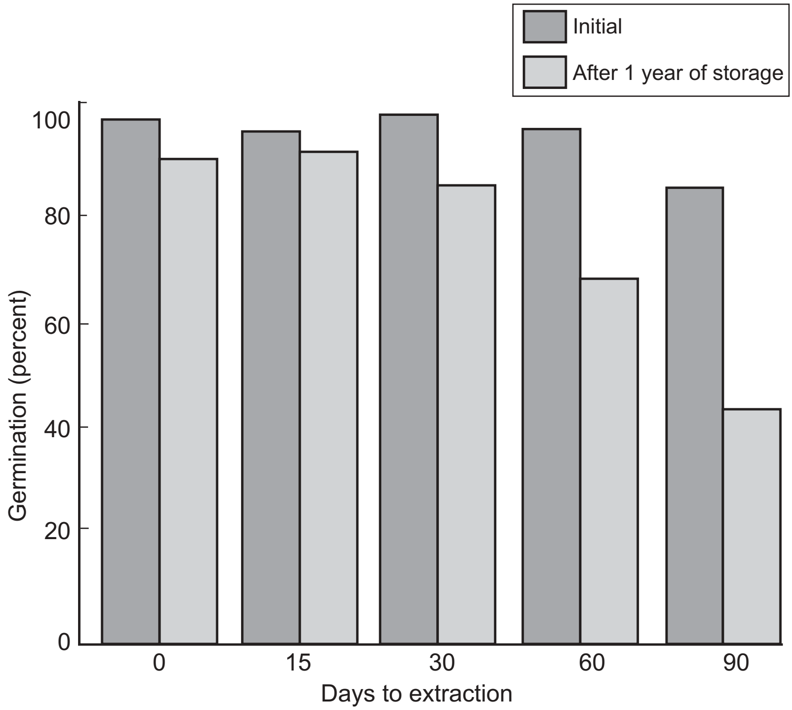

Figure 9—Effect of delayed cone extraction on longleaf seed germination initially and after 1 year of seed storage (McLemore 1961).

Figure 10—Storing longleaf pine cones in 20-bushel wooden crates prior to seed extraction.

outside temperature and humidity. Avoid drying on warm, rainy days. Cones dry in 24 to 48 hours at 30-percent relative humidity (Karrfalt, in press), but they stop drying at 50 percent. Be sure to use the lowest temperature feasible to reach the desired level of relative humidity. Never allow kiln temperatures to get higher than about 115 °F.

When the cones are dry enough to open and release their seeds, the next step is to place them in a tumbler, which usually contains a perforated cylinder that allows the seed to separate from the cones and fall through the holes. Promptly remove the seeds from the tumbler to avoid damage to the seedcoats.

Processing and Handling Seeds

Drying Seeds

Extracted longleaf seeds have unusually high moisture contents requiring immediate refrigeration to avoid deterioration, closely followed by drying to 8- to 10-percent moisture content (see instructions for cone drying). A separate seed drier is a necessary investment only if you are processing large quantities of longleaf seeds. Either way, do not discontinue drying until you have run moisture tests to ensure that the seed moisture content is at a safe level for storage. Seeds may then be sealed in moisture-proof containers, but they should be stored at a maximum of 35 °F if dewinging and final cleaning will not take place within 2 weeks (Karrfalt, in press).

Dewinging and Cleaning Seeds

Seed dewinging requires great care and appropriate equipment to reduce wings to stubs rather than completely removing them. Improper dewinging is a common source of quality problems in longleaf seeds and was shown to reduce germination by 13 percent (Barnett 1996a). Earlier studies showed that germination can be kept at a high level if longleaf seeds are dewinged carefully (Barnett 1969, Belcher and King 1968). Other sources of reduced seed quality are inadequate seed drying and damage during processing of the large-sized seeds.

A combination of screening and air separation is an effective method for removing detached wings, cone scales, and other trash. The next step is to remove empty and partially filled seeds on a gravity table (a shaking, inclined table with air blowing through it from the bottom). An intermediate step for some seed processors is to size the seeds for more efficient separation and increased uniformity of germination. However, Dunlap and Barnett (1983) showed that this intermediate step does not significantly improve total germination.

The cleaning process upgrades seed quality, but it cannot correct for poor handling at earlier stages. Every stage in seed handling from estimating cone maturity to operation of the gravity table must be done correctly to have the high-quality seeds needed for nursery operations.

Storing and Testing Seeds

To maintain quality, store the dried and cleaned seeds in moisture-proof containers such as cardboard drums or waxed boxes with foil or polyethylene liners (4- to 6-mils thick). Tightly sealing the containers keeps moisture content at the required 8 to 10 percent. You may store seeds for 3 years or less if you keep temperatures near freezing (35 °F). For longer periods, lower temperatures to subfreezing, preferably between 0 and 20 °F. Barnett and Jones (1993) showed that longleaf seeds can retain their viability for 20 years when held at 0 °F (fig. 11).

Before packaging and storing seeds, weigh them and run germination and purity tests to facilitate pricing and estimating the correct amount for sowing. Conduct follow-up germination and moisture content tests every 2 years, 2 to 3 months before sowing, immediately before selling seeds, and immediately after delivery of purchased seeds to check for damage during storage and transport. The germination tests are especially important in guarding against crop failure because they reduce the risk of sowing poor viability seeds.

Treating Seeds

Although early researchers suggested that some seedlots might benefit from short periods of prechilling or stratification (U.S. Department of Agriculture, Forest Service 1948; Wakeley 1954), they also cautioned that longleaf pine seeds frequently begin to germinate during stratification. As knowledge about proper collecting, processing, and storing of longleaf seeds increased, most researchers and practitioners concluded that stratification is unnecessary. In recent years, however, interest in stratification of longleaf seeds has reemerged—resulting from the desire to upgrade or improve performance of poor-quality lots. Karrfalt (1988) reported that stratification for 14 days (imbibed on media in germination dishes) improved both speed and total

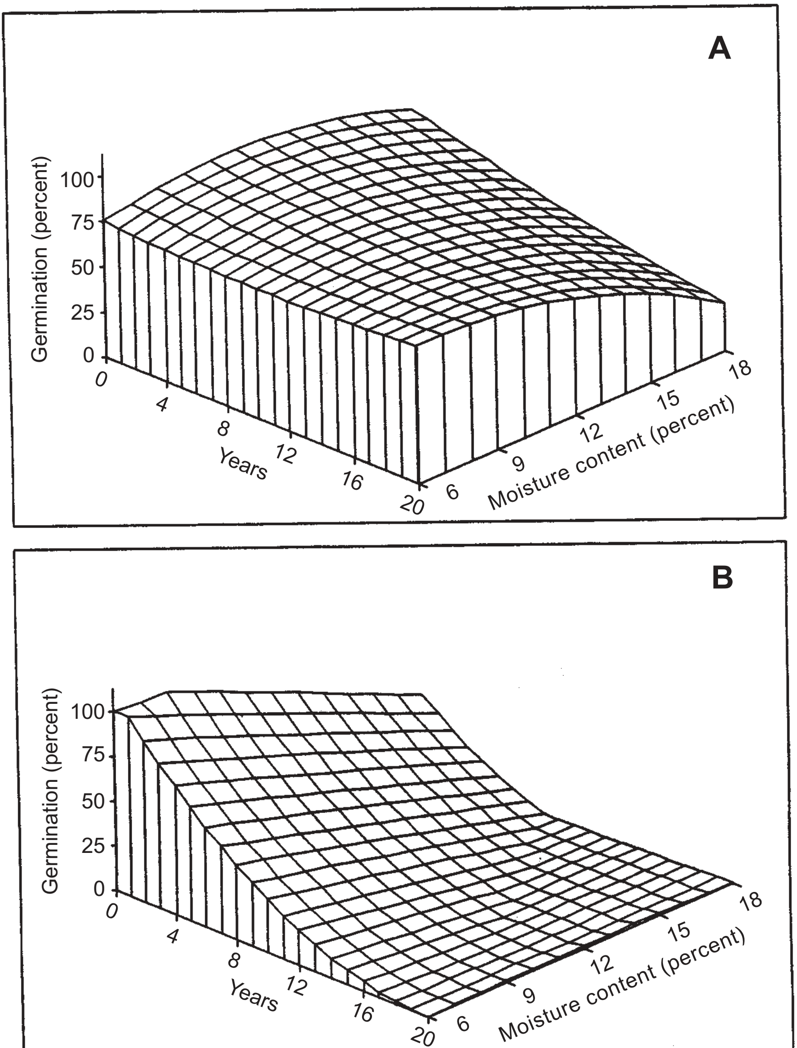

Figure 11—Germination of longleaf pine seeds as influenced by moisture content and years of storage at (A) 0 °F and (B) 34 °F (Barnett and Pesacreta 1993).

germination in almost all the 54 seedlots tested, most of which had relatively low viability. Others showed that stratification (imbibed by soaking overnight in water) hastened germination about 2 days but also reduced total germination by about 10 percent (Barnett and Jones 1993). The disparity in these results may relate to the method of moisture imbibition and reinforces the advice that adoption of this procedure be made with caution. A preliminary small trial will help you to learn the technique and to be sure it works in your seedlots.

Longleaf pine seedcoats are hosts to significant populations of pathogenic fungi (Barnett and Pesacreta 1993, Pawuk 1978). Germination of less vigorous seeds may be improved by treating them with a sterilant, such as hydrogen peroxide (Barnett 1976), or by applying a drench of a fungicide such as benomyl (fig. 12). A 30-percent hydrogen peroxide soak for an hour improves seedling establishment by as much as 14 percent (table 2), but it requires careful handling because it is a strong oxidant that can cause skin and eye injuries. Tests show that 10-minute drenches of seed in a fungicide solution such as benomyl are equally effective (table 3), safer, and less expensive.

Sowing Seeds and Caring for Seedlings

Whether done in a bare-root or container nursery, the ideal timing of sowing depends on environmental conditions. Longleaf pine seeds require appropriate temperature, moisture, and light conditions to germinate promptly. If moisture conditions are adequate, longleaf seeds have little dormancy and normally germinate in the fall—soon after release from the cones. Therefore, the optimum temperature for longleaf germination (about 68 °F) is cooler than it is for the other southern pines (Barnett 1979b). For this reason, springtime sowing should take place in late April or May while temperatures are still low (fig. 13).

Because longleaf seeds have little dormancy, they are not greatly sensitive to light levels. Some covering (about one-fourth inch) helps to maintain good moisture conditions for germination (fig. 14), but deep covering of seeds will inhibit germination because longleaf hypocotyls are too short to push the seedlings to the surface. Seeds that are deeply covered and kept moist for an extended period are also likely to succumb to pathogenic fungi (Barnett 1978).

Uniform moisture conditions are needed to obtain uniform germination and seedling development. Proper irrigation requires considerable skill to maintain desired moisture levels. Lack of appropriate moisture control frequently causes

Figure 12—Longleaf pine seeds without (A) and with (B) an application of a sterilant to reduce pathogenic fungi on the seedcoat. (Photos courtesy John P. Jones, Louisiana State University, Baton Rouge, LA.)

Table 2—Longleaf pine seedling percentages from seed and seedling treatments

Seedling treatment	Seed treatment[a] Control	Hydrogen peroxide	Average
	- - - - - - - - - - - *Percent* - - - - - - - - - - -		
Control	78	92	85a
Benlate®	85	93	89b
Fungo-flo®	88	94	91b
Fungo-flo® plus Subdue®	90	94	92b
Average	85a	93b	

[a] Seedling percentages (numbers plantable in November divided by numbers with an initial germinant) are averages for 288 seedling cavities for each of 3 replications. Averages within columns and across rows followed by the same letter are not significantly different at the 0.05 level.
Source: Barnett and McGilvray (2002).

Table 3—Germination of longleaf pine seed and seedling stocking following treatments in 1997 under laboratory and nursery conditions[a]

Treatments	Peak day[b]	Germination STF	Germination NTSL	Germination CN1	Germination CN2	Stocking[c] CN1	Stocking[c] CN2
	No.	- - - - - - - - *Percent*					- - - - - - - -
Control	7.0ab	76b	71c	75bc	72c	66bc	64b
Hydrogen peroxide	7.2a	84a	84a	70d	81ab	70b	78a
HP + 16-hr water soak	6.0bc	71b	74c	84a	85a	81a	80a
HP + WS + 14-day strat.	4.4d	76b	78b	79abc	85a	77a	82a
WS + 14-day strat.	4.0d	85a	84a	79bc	77bc	54d	50c
Mist + 14-day strat.	5.0c	86a	82ab	80ab	76bc	62c	65b

HP = hydrogen peroxide; WS = water soak.
[a] Germination 28 days after sowing in the Pineville Laboratory (STF), the Dry Branch Laboratory (NTSL), and the Claridge Nursery (CN1 and CN2 are two separate tests of the same treatment applications sown 2 weeks apart). Averages within columns followed by the same letter are not significantly different at the 0.05 level.
[b] Peak day is the time when maximum daily germination occurs and is a measurement of germination speed.
[c] Seedling stocking is the percentage of seeds that became viable seedlings 90 days after sowing.
Source: Barnett and others (1999).

Figure 13—Sowing longleaf pine seeds in containers—typically in late April.

Figure 14—A crop of longleaf pines seeded and grown in containers under uniform moisture conditions.

poor germination and problems in early seedling development. Too much moisture may cause preemergence damping off, and too little may delay germination and cause erratic development.

Conclusions

High-quality seeds are essential for the uniform production of high-quality pine seedlings either in containers or in bare-root nurseries. Steps that are critical for obtaining quality longleaf pine seeds include: delaying collections until cones are fully mature, processing properly stored cones within 4 to 6 weeks after collection, promptly drying extracted seeds to moisture contents of 10 percent or less, dewinging seeds very carefully to avoid coat damage, cleaning seeds to remove trash and empty or partially filled seeds, storing at low temperatures, and treating before sowing to remove seedcoat pathogens. Adapting these principles and procedures to your operations will improve seed viability and lower overall costs.

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