CHAPTER 5—SEED HANDLING

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INTRODUCTION

Acquiring seed to grow nursery seedlings is an extremely important step in the regeneration process. The quality of the seedlings produced depends on both the proper seed source (provenance) and the correct processing, storage treatment and sowing of the seed. Although the cost of genetically improved seed is substantially higher than the cost of seed from wild stand collections, the higher yields of wood produced far outweigh the additional cost of the seed.

This chapter provides information about the collection, processing, handling and storage of southern pine seeds. Additional information about these topices and about the individual species can be found in Agriculture Handbook No. 450, *Seeds of Woody Plants in the United States*. This handbook is the basic reference about forest tree seeds in the United States.

CONE COLLECTION

Seed yields and viability increase with cone and fruit maturity; however, if all collections were delayed until complete maturity, a lot of seed would be lost because of natural seed dispersal. Therefore, cones are usually collected as soon as maturity guides indicate they are ready (Stein et al 1974, McLemore 1959). Lengthening collections by one week could increase seed harvests by 30 to 50 percent (McLemore 1975) for southern pines but not for eastern white pine (Jones et al 1967) nor longleaf pine. See table 5-2 for cone and seed data.

Agriculture Handbook No. 450, mentioned above, will help you with specific species problems. A few days delay can be crucial where seeds are dispersed quickly or where they are at the mercy of birds and mammals that have a limited food source.

All collections should be tagged at the source with weatherproof labels to maintain seed lot identity. The label should give species, geographic location, date and personnel responsible for collection. A summary of average collection dates for southern pines is given in table 5-1. All sacks should be thoroughly checked for cleanliness before they are used. Old cones, seeds, and tags remaining in the bags should be removed to avoid confusing collection data.

Artificial Ripening

Church and Sucoff (1960) found that Virginia pine cones could be collected as early as 9 weeks before natural opening. They also found that trees felled for 1 to 4 weeks had seeds as viable as the day of felling when trees were cut in early August. In contrast, Barnett (1978) found that

Table 5-1. — Summary of collection dates[1] for southern pine species.

	Wild stands	
Species	Approximate date to collect	Date of natural opening[1]
Loblolly	Sept. 20-Oct. 10	Oct. 10-30
Slash	Sept. 1-20	Sept. 20-30
Longleaf	Oct. 1-20	Oct. 20-Nov. 10
Shortleaf	Oct. 11-30	Oct. 20-Nov. 10
Virginia	Oct. 1-20	Oct. 20-Nov. 10
Eastern white	Aug. 10-20	Aug. 20-Sept. 10

[1]Cone ripening dates in seed orchards may vary from the above. Individual clones will vary widely.

Source: Wakeley 1938, Church and Sucoff 1960.

Table 5-2. — Cone and seed data of southern tree species.

Species	Avg. closed cones per bushel	Avg. seeds per cone	Seeds per pound
	- - - - - - - - - - - - -	Number - - - - - - - - - - - - -	
Fraser fir	- - -	- - -	53,500-78,750
Arizona cypress	- - -	90-120	46,900-176,220
Eastern red cedar	- - -	1	3,700-55,000
Bald cypress	3,000	18-30	2,540-8,360
Sand pine (Ocala variety)	830	57	47,200
Sand pine (Choctawhatchee variety)	1,010	56	56,100
Shortleaf pine	2,000	23	32,100-72,900
Slash pine	200	68	9,610-19,300
Spruce pine	2,000	23	40,000-52,000
Longleaf pine	100	49	3,000-7,000
Pond pine	1,600	34	47,000-63,000
E. white pine	460	58	17,500-53,000
Loblolly pine	500	36	12,300-26,400
Virginia pine	1,700	33	45,700-91,100
Pitch pine	1,560	40	42,500-82,200

Source: Wakeley 1938, USDA 1974, Barnett 1972a

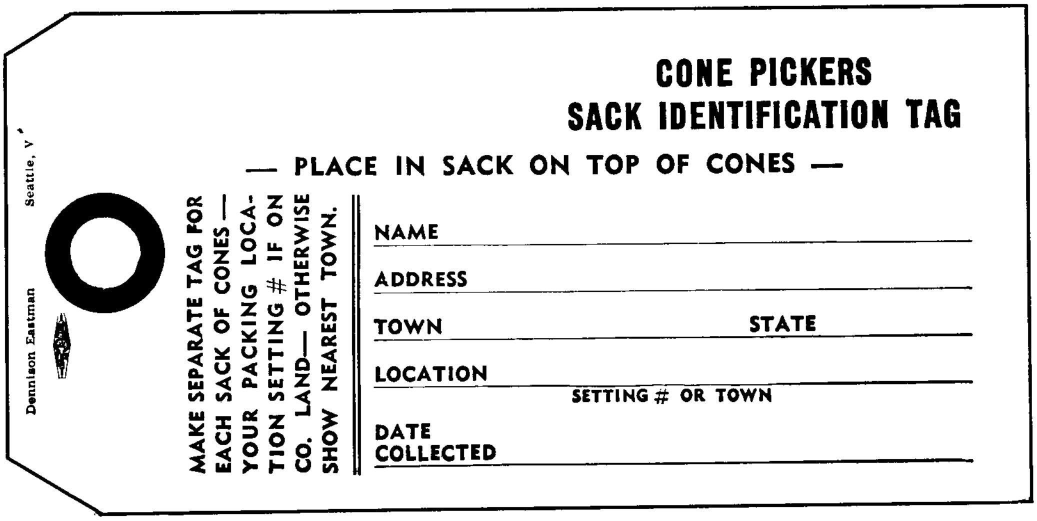

Figure 5-1. — Cone sack tag.

once longleaf pine cones are collected the seeds do not continue to mature during storage.

Collections of loblolly, slash and shortleaf cones can be made 3 to 5 weeks before normal collections and artificially ripened (Lantz 1979, Kundt and Lantz,[1] Barnett 1976a, Wasser 1979). The best method of artificially ripening the cones is to spread them out in a shaded area and provide alternate wet-dry cycles. Although this method will permit a longer collection period, seed quality could be reduced if mold should occur. There is also a danger of loss from rodents.

PINE CONES

The moisture content of southern pine cones is between 120 and 140 percent at maturity (Barnett 1976b). Without proper ventilation, these high moisture contents can lead to heating and fungal growth. Cones transported from collection points to a processing point should be protected from the heat of a bright sun on a clear day as cone temperatures can rise rapidly. Transport the cones as quickly as possible and spread them out in trays to air dry before extraction.

The bottom tray should have a fine mesh bottom to prevent loss of seed. Drying cones should not be layered more than two cones deep. Provide ample air movement, either naturally or artifically by fans to prevent heating and molding. Small lots can be easily handled in small trays placed in an office or work area with dry heat or air conditioning. A 3 × 4 foot tray will hold 3 bushels of longleaf, 2 bushels of slash and loblolly and 1 bushel of shortleaf when piled two cones deep. All trays should be twice as deep as the layer of cones to allow for expansion as the cones open. The smaller the cone the greater the area needed by a given volume of cones. Longleaf requires 8 square feet per bushel for opening, slash 10, loblolly 15 and shortleaf 20 square feet.

Crowded conditions restrict the scales' ability to open on the cones, and they become set in an unopened or partly open position. These cones can only be fully opened by rewetting to close them and then redrying to fully open them. If trays are stacked without space between them, apply forced air to dry the cones. If the cones are open-stacked to take advantage of natural air movement, the space between trays should be twice the depth of each tray. This spacing permits sufficient air passage after cone expansion.

Because collections take place over time, cones should be stored by collection date. In general, the earlier collections are likely to be the least mature and therefore should be stored the longest. The cones from the last collections should be dried first, working back to the first collections.

Longleaf pine cones are very sensitive to air drying and should be processed as soon as possible. Loblolly pine cones are next in sensitivity, with slash pine cones the least sensitive (Swofford, 1960). Knowledge of the anticipated collection date is important to avoid extra handling of cones. The cones collected most recently can be put immediately into a kiln to better use space. A typical kiln arrangement, is shown in figure 5-2. Once the cones are in the kiln, turn on the fans immediately to promote circulation and remove moist air. Heat should not be applied until cones crack when twisted. Even after 1 or 2 weeks of air drying in the trays, the cone moisture may be near 70 percent for the first collections. Heat applied to cones before the moisture has dropped to 50 percent or less may lead to case hardening. Delaying the heat will

[1]Kundt, John F.; Lantz, Clark W. Cone ripening study of loblolly, Virginia and shortleaf pines. Unpublished report. North Carolina State University Cooperative Tree Improvement Program; 1968. 9 p.

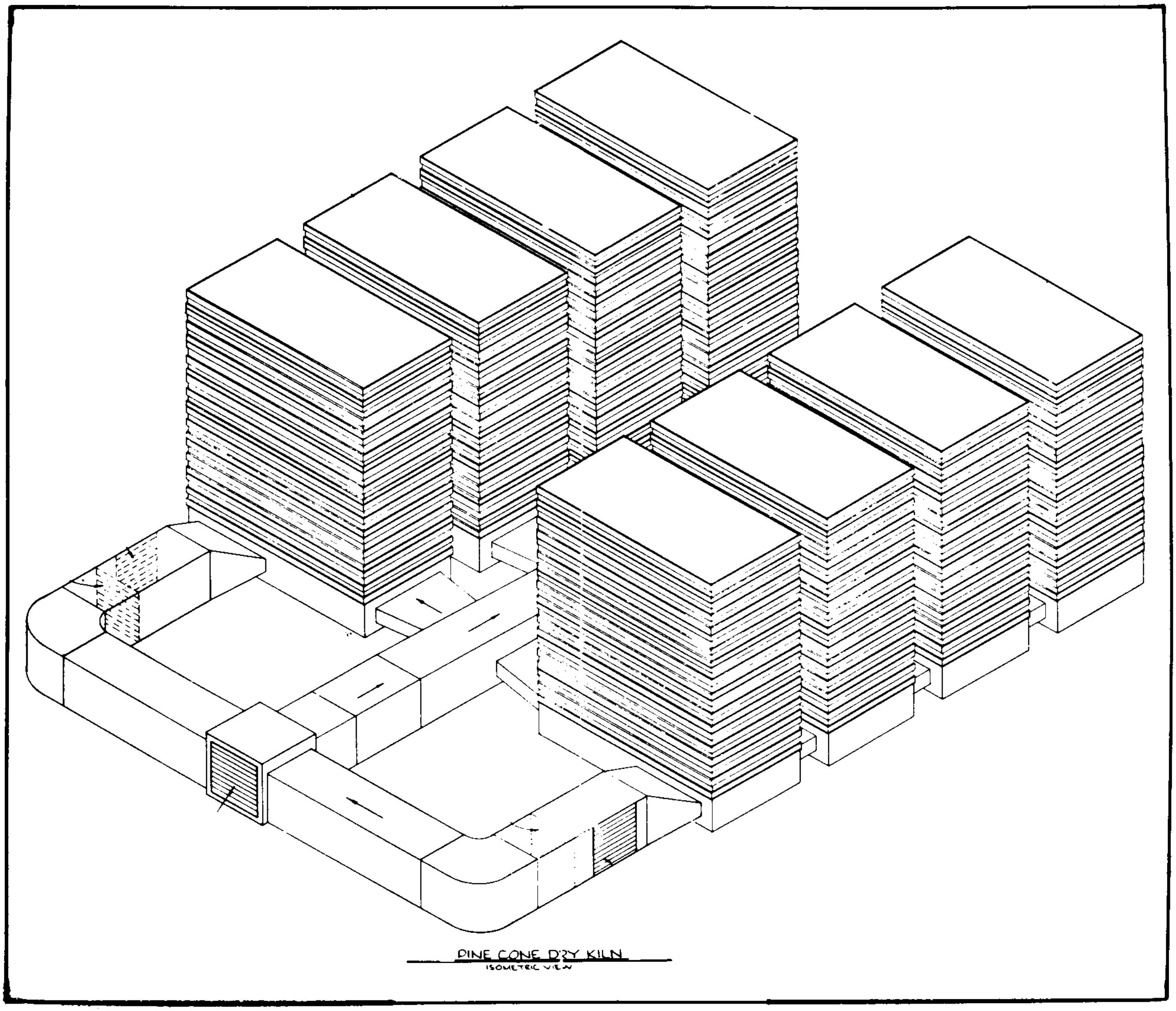

Figure 5-2. – Cone kiln with removable trays.

also permit removal of freely evaporating moisture and conserve energy. Some protection from rodents may have to be considered.

ALTERNATIVE SYSTEMS

If trays are not available, alternative methods must be considered. Any system that avoids heating and permits drying may be satisfactory. Storage of cones in polyethylene bags should be totally avoided because the bags do not permit moisture to evaporate. Storage in burlap sacks is satisfactory only if an adequate air flow is provided. Sacks should never be more than half full to allow for expansion. Place cones in cold storage only temporarily (less than 1 week). Although refrigeration keeps the cone temperatures down, it does not permit any decrease in cone moisture; therefore, mold may form. If a shaded area is available, the cones can be spread on the ground under trees or on sheltered concrete floors. Make sure the cones are spread in thin layers and that there is air movement. Concrete holds moisture and can lead to cone mold if air movement is not adequate. Storage of longleaf and white pine cones on concrete has led to losses in seed viability (Jones and Belcher 1964).

Sand pine cones are an exception to the alternative systems just described. Cones from the Ocala variety of sand pine can be stored dry because they are serotinous (See glossary at the end of this chapter). However, it may be simpler to dip them in hot water (180-200 °F; 82-93 °C) upon arrival and put them in trays to be handled as are the other pine species (Barnett 1972; Barnett and McLemore 1965). If there are clonal differences and some open before others, delays in dipping can be detrimental to those opening early. In this case bare seed may be damaged by the hot water.

SEED EXTRACTION

In the Soil Bank period of the 1950's and 60's the emphasis was on maximum kiln size. Large amounts of wild-collected cones needed to be processed *en masse*. The current maturity of seed orchards and emphasis on genetic improvement has moved cone handling in the East toward that experienced by the Western United States; that is, an increase in the number of seed lots and a decrease in lot size. This change entails the use of smaller kilns and more intensive handling of cones to maintain seed lot integrity. Several small kilns have been designed (Rietz 1936; Lowman and McLaren 1976, and McConnell 1974 to handle from 2 to 30 bushels. Tumblers have also been designed (Harris 1970, Willcock 1970, and Fisher and Widmoyer 1977) for small lots of 1/2 to 5 bushels. See figure 5-3.

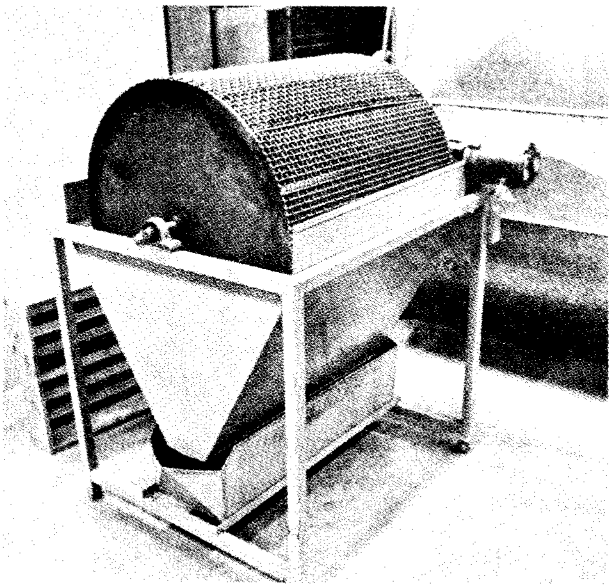

Figure 5-3. — Cone tumbler.

CURRENT METHODS

Seeds are dried and extracted by air drying the cones to a moisture content of 35 percent or less (Belcher and Lowman 1982). Fully dried cones generally have less than a 10-percent moisture content. To reach this level, 6 to 20 pounds of water must be removed per bushel of cones. Water is removed from the cones by forcing "dry" air over the cones. The most common system for "drying" air is the use of heat to reduce the relative humidity, enabling the air to absorb more moisture from the cones.

Three types of kilns are used to apply heat: rotating, progressive and tray. The cones are dried and tumbled to remove the seeds. The most sensitive part of this process is the drying temperature. The lethal limit for most tree seeds is about 160°F (Rietz 1939a; Rietz and Torgeson 1937; and Foster 1956), but lower temperatures have affected seed germination. Rietz (1939b) found a decrease in seed viability of longleaf pine seed dried at temperatures above 115°F. He found a 5 percent decrease in viability per 5-degree increase in temperature above 115°F.

White pine cones contain a lot of resinous material which can be a problem. These cones should be opened with the lowest heat possible. Temperature is not nearly as important as relative humidity and patience. All cones will open at relative humidities near 35 percent regardless of temperature.

Another problem is serotinous cones. The opening of serotinous cones was increased by 15 percent with the use of Javex at 1 part to 20 parts water (Meseman, 1973); however, no trials were made with southern pines. The hot water treatment previously mentioned under Alternative Systems is usually effective.

ALTERNATIVE METHODS

A growing interest in energy conservation has stimulated work on alternative methods of opening cones (Barnett 1979). Equipment is available that can chemically dehumidify the air with commercial dehumidifiers (Belcher and Karrfalt 1978). The radiant heat rays of infrared lamps reduced energy needs in Michigan, but costs were reduced only when more than 500 bushels of cones were processed (Carmichael 1949).

Solar cone kilns have been built by the Tennessee Valley Authority (Barnett and Scanlon 1978), the Virginia Division of Forestry and the USDA Forest Service (Elliott 1980). Depending on the local climate substantial energy may be saved. See figure 5-4.

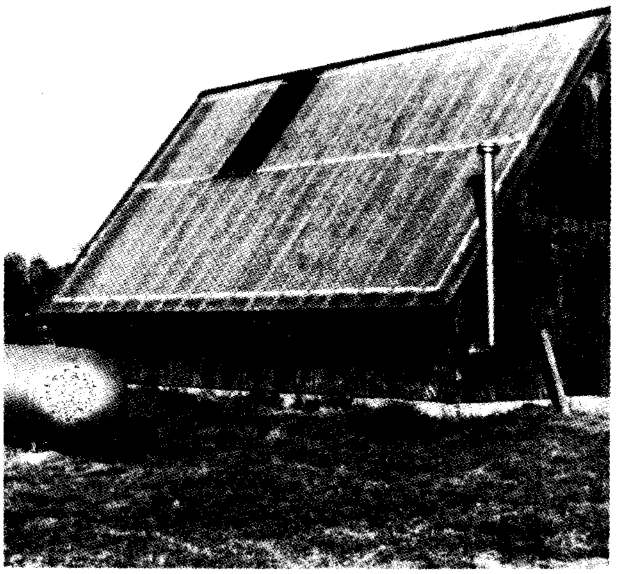

Figure 5-4. — Solar cone kiln. (Virginia Division of Forestry)

Another alternative is freeze drying. This method combines refrigeration with a vacuum, where refrigeration lowers the vapor pressure of the moisture. Moisture levels of about 13 percent have been reduced to 2 percent. Unfortunately the use of equipment of this type on an operational basis would be very expensive.

Microwave is another possibility. At room temperature, a microwave will open a green cone in about 6 minutes, but because it removes water by boiling it, the seed will be killed. When placed in a partial vacuum, water can be boiled at 100°F, which should not reduce germination. The energy requirements are about one-third those of air-convection systems (Belcher and McKinney 1981). Commercial models of up to 10 kilowatts are available, and design of a model with two 50-kilowatt units is possible. The 10-kw unit will handle about 7 bushels at a time. Cones at a 35-percent moisture content can be opened in 2 hours.

CONE POTENTIAL

Research studies show that it is possible to produce 85 percent of the maximum cone potential with many southern pines (Bramlett 1974). This potential then provides us with three measures of accomplishment: actual production from extraction, actual production of the cone and potential production. For example, assume that a loblolly cone produced 35 seeds after drying and shaking, retained 15 seeds, and had enough fertile scales to produce 120 seeds. Use these figures to calculate the extraction efficiency, which would be 70 percent (35 divided by [15 + 35] × 100).

Van Haverbeke (1976) found that soaking Scotch pine cones in water after extraction could increase seed yields by one-third. He soaked cones from the extractory for 30 minutes at 85°F and allowed them to air dry before re-heating them.

Karrfalt (1979) provided a procedure to estimate when reprocessing of cones would be profitable. The practicality of reprocessing depends on the value of the seed, and extraction efficiency. From one to more than ten seeds may remain after extraction. If your yield was 17,000 seeds per pound and 400 cones per bushel, an average of five sound seed may be left in each cone, and you would lose 1 pound of seed for every 8.5 bushels.

In the earlier example, 50 seeds (15 + 35) were produced in cones capable of producing 120 seeds. This is a production efficiency of 42 percent (50 divided by 120 × 100). If all elements could be controlled in the orchard so that the cone would more nearly reach its potential, the orchard manager would be able to double the seed production from the same number of cones. The potential seed yields of several southern pine species have been determined by Bramlett (1974) and Karrfalt (1977). See table 5-3.

Table 5-3. — Seed potentials for southern pines.

Species	Seed potential (no. seeds)
Loblolly pine	150-155
Slash pine	170-175
Longleaf pine	157
Shortleaf pine	87-96
Virginia pine	84-88

SPECIES ORGANIZATION

Handle cones quickly if they're from species that have short-lived seeds. Organize the extraction operation to maximize seed viability. This work is often difficult when cones are being shipped from the field according to collection dates and several species are being simultaneously received at the processing plant. Of all the pines in the South, eastern white pine is the earliest to be collected, followed by slash, longleaf and loblolly (table 5-1).

Because white pine cones require lower temperatures to minimize resin problems, place the cones in trays in a holding area. Do not hide them or bury them by surrounding them with other trays. Promote a good flow of air over the cones by natural or artificial means and let them dry naturally.

The next species to be harvested is slash pine. The cones of this species also can be placed in storage trays. Put the last of the slash pine cones in a kiln and blow unheated air through them. Slash pine cones have the best storage qualities of the southern species and can be held until time permits you to process them, if necessary to delay handling.

Before the slash pine harvest is completed loblolly and longleaf cone collections begin. Store cones from all collections for a short time in trays, to decrease the moisture content before applying heat. Process the slash pine cones while the loblolly and longleaf cones are drying naturally.

Longleaf pine cones should be processed next. Do not store them for more than 5 weeks (McLemore 1975); 3 weeks are preferable. Following longleaf, loblolly pine cones are processed.

Processing may vary, depending on the species involved, but one point to consider when sufficient staff is not available is that the critical step is to get the seeds out of the cone as soon as possible. The seeds can be processed later. Thus, if the workload is too great, extract the seeds, place them, with wings, in moisture-proof storage containers and chill at 34°-36°F until time permits further processing. Many seeds are lost because of delays in extracting them or when workers try to extract seeds too fast. For each 1-percent increase in moisture content between 5 and 14 percent the life of the seed is halved (Barnett 1978). Proper extraction will produce seeds that can be safely stored.

SEED PROCESSING

Once the seeds have been extracted from the cones, the real art of seed processing begins. There is no universal processing system, but there are four major objectives: (1) remove large debris, (2) dewing, if necessary, (3) precision-clean the seed and (4) upgrade seed. The process selected to achieve these objectives will vary by species, quantity, available vendors, finances and time restrictions of the agency. Small operations require only two pieces of equipment (precision cleaner and dewinger) while larger operations may require more equipment to maintain a continuous flow operation or for specialized processing. Regardless of size, every system should be designed and operated to maintain identity and integrity of seed lots through processing.

Removal of Large Debris

Large debris can be removed in several ways. Flotation will remove cone scales, sticks, pine straw and other bouyant material if the water is moving or if a system is used to dip out the debris before it becomes waterlogged. These particles can also be removed by a scalper, which is a one- or two-screen cleaner. See figure 5-5. Pine needles have also been removed from seed with a peanut combine, inclined draper and even a fan. Table 5-4 describes eight pieces of cleaning equipment. Heavier materials such as stones and resin balls are usually too small to be removed by this machinery. (Belcher and Karrfalt 1978).

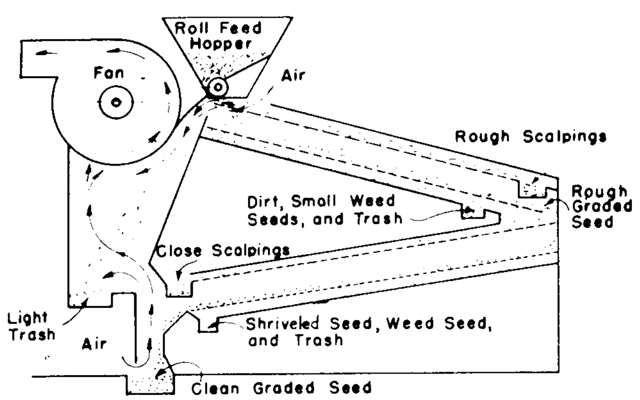

Figure 5-5. — Air screen cleaner.

Dewinging

There are two basic methods of removing wings from pine seed: dry or wet. Dry dewinging has been the accepted method for years, but is slowly becoming less prominent. Seed are put through machinery with brushes, paddles or other material to rub the wing free of the seed. These machines can be very damaging when not properly used and have been responsible for substantial losses in viability of southern pine seed. However, when properly adjusted, they will even decrease the wing of the fragile longleaf pine seed without damage (Belcher and King 1968). Examples of dry and wet dewingers are shown in figure 5-6.

Most dewinging of the future will use the wet method. The wings of pine seed are hygroscopic so if a small amount of moisture is added the wing will absorb it and be released from the seed. The process can be speeded up with agitation. Wet dewinging should not be used on longleaf pine because the wing cannot be completely removed. Maximum reduction of the longleaf pine seed wing requires a very dry wing. Wet dewinging has not been desirable because of past practice. Few nursery workers had the patience to wait for the wing to absorb moisture and to release the seed. Workers often added excessive water to speed the dewinging process. The seed then needed to be redried. There is now machinery which monitors the water and sprays it in a fine mist. The moisture content of the seed will increase less than 1 percent.

Precision Cleaning

At this stage, the seed material includes dust, stones, dirt, small debris and empty seed. The objective is to select a series of operations that will provide maximum production of high quality seed. Generally, the best way to do this is to keep the equipment simple. Besides selection of equipment and technique, nursery operators must be conscious of safety, OSHA requirements and good care and maintenance of the machinery.

The first step is to remove the debris. A screen cleaner can do this best. A laboratory model will adequately handle 50- to 100 pounds per hour (Banton 1946), which is adequate for most tree improvement work. The average inventory in a southern nursery is better handled on a medium size, four- screen cleaner. The cleaner should remove large particles with the top screen while seed and small debris pass through. The first fan will remove dust and light debris. If long debris tends to go through the top screen, fasten a piece of plastic or plastic-coated cloth over one-fourth of the top screen. The cloth will keep the debris flat on the screen. Also, covering the lower part of the top screen will help improve separations when debris drops through too soon. Efficient accomplishment

Table 5-4. — Processing equipment for precision cleaning of seed.

Name of equipment	Description, function	Reference
Screen cleaner	Available in laboratory size and in larger, bulk-handling models. Contains 2-4 screens and 0-2 fans. Removes dust, small debris and physically sizes seed.	
Aspirator	Available in laboratory size and in larger, bulk-handling models, either continuous-flow or batch operation. Separates seed, small debris and dust.	Silen, 1964; Woollard and Silen, 1973
Magnetic separator	Available in laboratory size and in larger, bulk-handling models. Separates seed on basis of roughness of seed coat. Seeds are coated with iron powder and passed over a magnetic drum. Rougher seeds hold more iron than do smooth seeds.	Brandenburg, 1977
Electrostatic-separator	Used mostly in the mineral industry. The seeds are fed into an electric field where they are charged. Separation depends on ability of the seeds to conduct and hold a surface charge. Not yet proven very beneficial in forestry.	Brandenburg and Parks, 1977 Sundahl, 1974
Inclined draper	Available in laboratory and bulk handling models. An adjustable belt travels at 6-58 rpm at an angle of 0-45°. Material is dropped on the belt for separation. Smooth material rolls down the belt while rough materials adhere to it. Separations depend on texture of belt surface, angle and speed of belt.	Hergert et al 1971
Gravity separator	Available in all sizes. Material is separated by the vibration of the table, tilt of the table and amount of air being blown through the material.	Thomas, 1978
Dewinger	Either dry or wet. The dry dewingers were originally designed as popcorn polishers. Newer models have since been designed. Several types of wet dewingers have been devised.	Lowman, 1978
Hammermills	Used to grind up the empty pine cones.	Mugford, 1969

Source: Bonner (1977) and U. S. Department of Agriculture (1978)

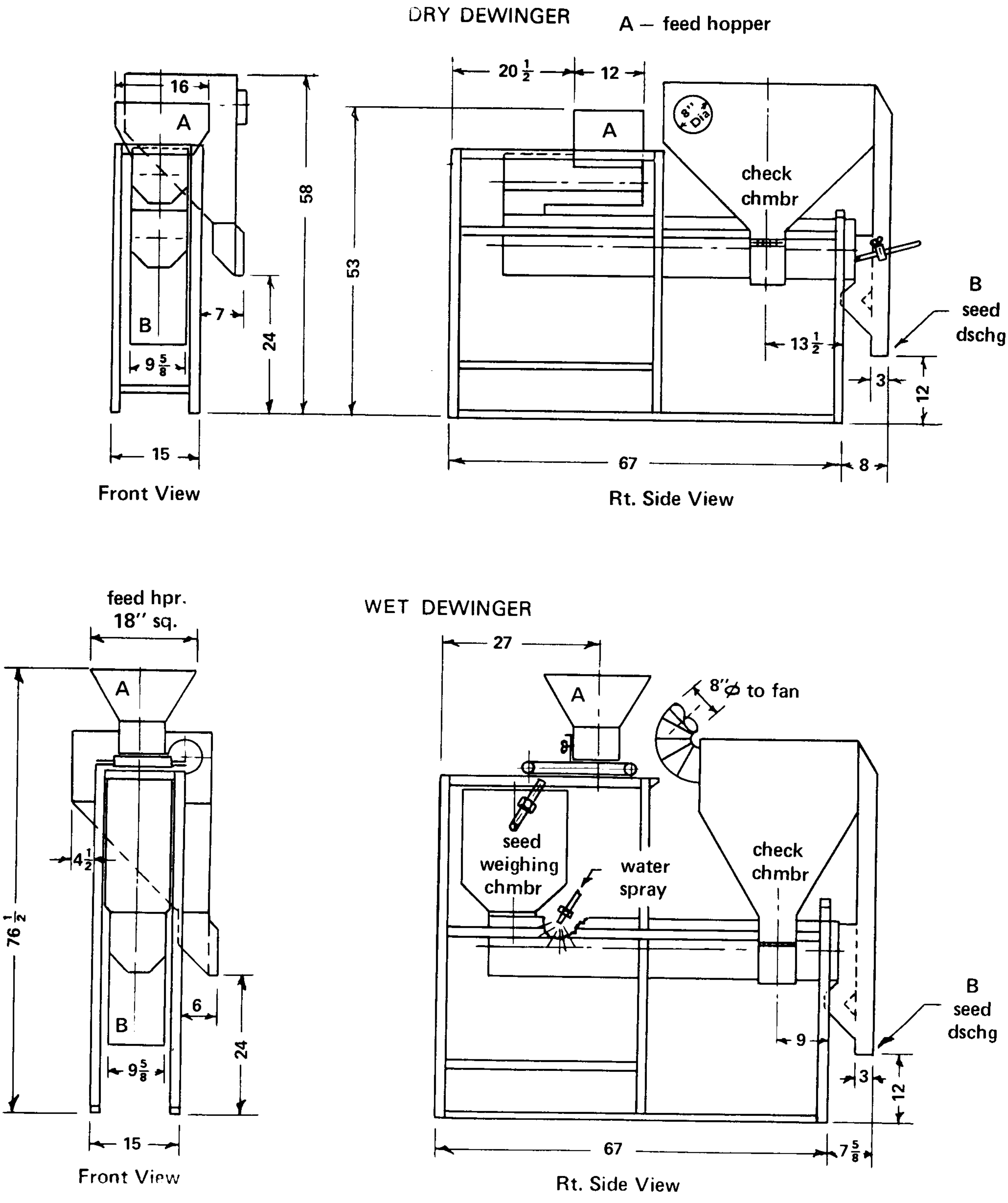

Figure 5-6. — Wet and dry dewingers. (Crippen Mfg. Co.)

requires a positive and even feed to minimize the over- and under-use and take the most advangtage of air separation. Seed from the screen cleaner should be about 99 percent clean by visual observation. If the second air fan is properly set, most of the empty seed will be removed. With the move toward improved seed however, there has been a tendency to hold a few more empty or partly filled seed to avoid discarding any of the valuable seeds. This practice can lead to quicker seed deterioration in storage (Belcher and McConnell, 1974). If a large quantity of seed is being processed, two screen cleaners operated in series may be more beneficial. A series of screens and air velocities may then be set to improve the product.

Additional cleaning may be done with an aspirator or a gravity separator (figure 5-7). These units can be helpful if a special problem exists. Final results should produce the levels of purity, filled seed and germination given in table 5-5.

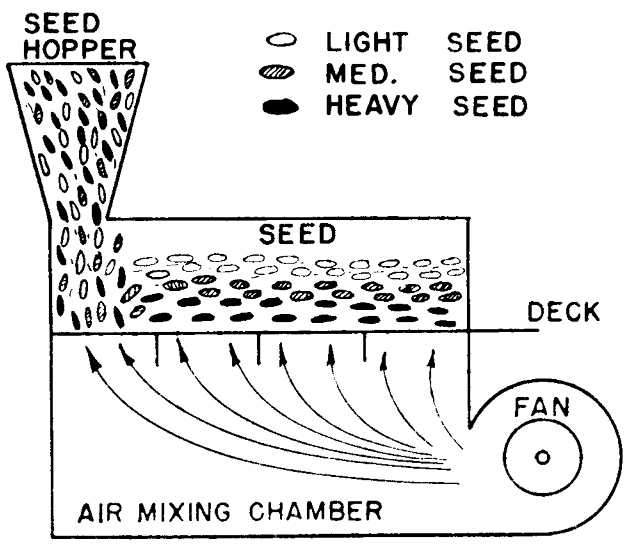

Figure 5-7. — Gravity separator.

Table 5-5. — Minimum results of seed analysis following precision cleaning.

Species	Purity	Filled seed	Germination
	- - - - - - - -	-percent-	- - - - - - - -
Fraser fir	90	60-80	50
Arizona cypress	80	30	30
Eastern redceder	90	90	80
Bald cypresss	60	60	60
All pines	95	90	80

Upgrading Seed

Even the best processing operation may not provide the desired seed quality. A continuous flow operation must process seed based on the average condition of the seed rather than the variation within the lot. Also, after periods of storage, deterioration may have reduced the seed viability to an unacceptable level. These problem lots are normally recognized after a seed test has been made. Low viability is the first sign of need for upgrading. First, a determination must be made of what to remove (see Use of Laboratory Data) and then how to remove it.

If the problem is low purity or empty seed which were not removed in the routine process, a gravity table should be considered. Removal of debris such as resin balls from white pine may require the use of an inclined draper. Some debris can be removed with a screen cleaner by changing screens. Slotted holes or triangular holes may be more effective than round holes.

Partly filled seed and dead filled seed are the most difficult to remove, but if not removed they pose a source of further deterioration. The effort spent on this type of removal will depend on financial considerations. Improvements in separation require a gravity separator and a method to obtain density differences between living and dead seed. This may be obtained by soaking the seed and redrying it for a short time. Dead seed will dry faster than live seed because of the loss of cellular pressures, and the difference can be magnified by this process.

Seed Sizing

The real benefits of seed sizing are more uniform germination in the nursery and a more uniform seedling density in the seedbed. Both of these qualities are very important in the nursery to increase the seedling-to-seed ratio. There are two basic means of grading southern pine seed: (1) screens and (2) gravity. Gravity-sizing requires screen-sizing first because a gravity table can only make a one-way separation (cannot separate physical size and density at the same time).

A recent study of sizing slash pine showed that gravity separation did not significantly add to seedbed uniformity but screen sizing did. (Belcher, et al 1984). Seedling height, root collar diameter and seedling weight were all related to seed size. See figure 5-8.

Use discretion in sizing seed. It is possible to become so dogmatic in sizing that sized portions are too small to adequately handle. A reasonable recommendation is not to establish separate sizes for portions of lots which constitute less than 10 percent of the total. Portions that small should be thoroughly mixed with the next size.

Sizing should not be considered with lots so uniform in size that less than 20 percent of the total falls into any one size.

Sizing seed has been criticized on the basis that it may eliminate some genotypes (Righter 1945; Langdon 1958; Hellum 1976; Silen and Osterhaus 1978). Actually, no genotypes are lost unless one or more seed sizes are discarded. In fact, sizing may preserve slower germinating genotypes (Wasser, 1979).

State nurseries serving many landowners may need to consider genetic diversity when seedlings are grown from sized seed. Some landowners may desire mixed seedlings to produce a more heterogeneous stand. These seedlings could withstand a greater variety of environmental hazards.

Quality Control

Improvements in seed processing can only be obtained with quality control. These evaluations should be made in the processing plant and at a seed testing laboratory. The National Tree Seed Laboratory offers a free service to evaluate processing machinery. You need only collect a small sample of seed after it has been processed by each machine and send it to the laboratory. Be sure all the seed comes from the same lot so all samples are related. The Seed Laboratory will return a complete report on the effect of each machine and the effect on the total operation.

Each machine must be adjusted for efficient operation, and proper adjustment requires monitoring of the operation. This work may require a cutting test or an x-ray evaluation. Radiographs have the advantage over cutting tests by providing permanent file copies, which are more accurate in detail. In addition, a radiograph can be made in about 1 minute and evaluated within 2 or 3 minutes, which is much faster than cutting tests and does not destroy the seed.

Following the processing, an evaluation should be made of the moisture content, particularly if the seed will be placed in storage immediately. Although samples can be sent to a seed laboratory, an electronic moisture meter at the processing plant will save time, improve accuracy and provide an opportunity to take immediate action.

Laboratory tests are essential for identification of possible changes during storage, identification of problem lots and providing needed data for computing sowing rates. (See Seed Testing). The National Tree Seed Laboratory

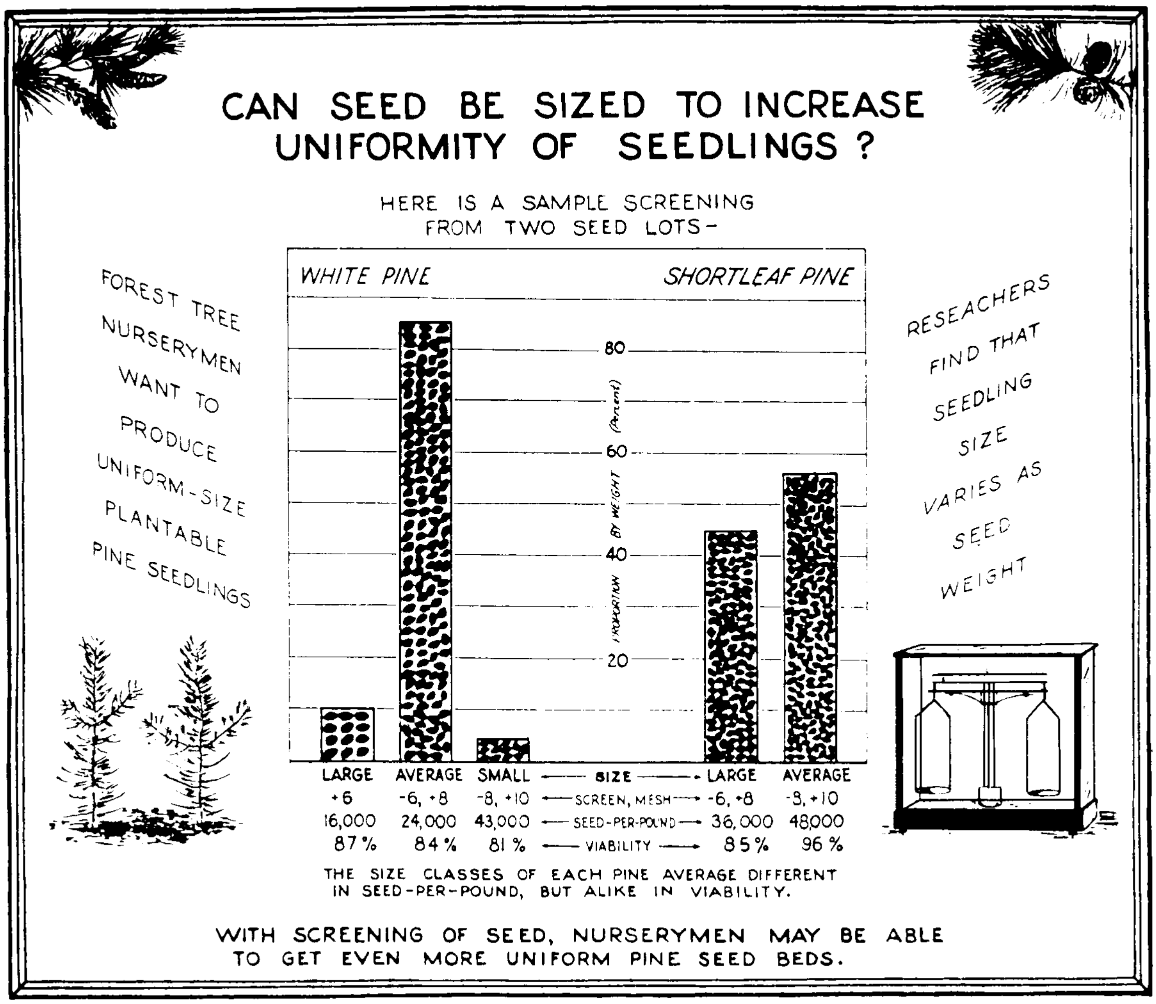

Figure 5-8.—Seed sizing produces uniform seedlings.

also provides a free service for solving seed processing problems. If a problem in seed processing arises, send a working sample of the seeds. The seed laboratory will attempt to solve your problem on its laboratory machines and provide a report on the results.

SEED STORAGE

Because of variations in crop production, seeds of many species are either not available every year or not available in the needed quantities. Therefore, you must collect seeds in good crop years and store them until needed. But, storage itself is not enough. You also want to maintain viability during that storage period, and to do that you must minimize seed respiration. To do this effectively, several factors must be considered: seed moisture, storage temperature, containers, length of storage and record keeping.

SEED MOISTURE

The single most important factor in seed storage is seed moisture. The total effect of moisture depends on storage temperature. Recordings are made with an instrument like the one shown in figure 5-9. Most southern pines are stored best in a dry condition, preferably below a 10-percent moisture content. For these species, fungal growth becomes a problem at 10- to 14 percent moisture. As the moisture increases, chemical changes begin, respiration increases and heating occurs. If germination is restricted at this stage, the seeds deteriorate. Moisture uptake will continue, if not inhibited, to 20- to 40 percent, at which time germination takes place (Barnett 1978).

Figure 5-9. — Electronic moisture meter.

On the other extreme, seeds having a moisture content nearer to 6 percent store better and seldom have a mold problem (Magini 1962). Even lower moisture contents will not necessarily be detrimental. Zero percent moisture of loblolly and ponderosa pines was found not to affect germination (Schoorel 1960). Further, sampling of 12 species with moisture contents from 1.3 to 3.9 percent all provided germination rates above 80 percent (Belcher and Benson 1968). Low moisture is not as critical as how it was achieved. Drying seed too fast may create a vapor lock on internal structures (Belcher and McKinney 1981). If the pressure is great enough, cells can be ruptured. Drying to low moisture contents should be done slowly.

STORAGE TEMPERATURE

The threshold value of storage temperature is about 41 °F (5 °C). Above this, temperature respiration increases and leads to deterioration if germination conditions are not favorable. As the moisture content increases, temperature becomes more critical.

Dry seed store well at 34° to 36 °F; however, at this temperature there is no margin of safety (see table 5-6). Reducing the temperature to 20° to 25 °F provides some margin of safety. When storage units are not available, commercial storage must be used. At 0 °F in commercial storage, the moisture content should be reduced to 4 to 6 percent. Higher moisture content can lead to loss of viability through rupturing of cell walls by crystalization of cellular water. Studies are being conducted on storage in liquid nitrogen (−196 °F); however, at present such storage would not be reasonable with the large quantities of seed being stored at many nurseries.

CONTAINERS

Under optimum storage, each nursery planting would completely use up one container of seed. However, this situation is not usually the case. Instead, the largest containers are used so there will be fewer containers in the storage room and thus simplify record keeping. A 55-gallon drum will hold more than 200 pounds of loblolly pine seed. Depending on the circumstances, (e.g., a seed lot in low demand) this drum may hold a 5-year supply of seed. Therefore, for 4 years the drum is only partly filled. Every time the drum is opened, the air in the empty portion is replaced with oxygen-rich, and possibly moist, air. Moisture in the air condenses on the seed with temperature changes and thereby raises the moisture content of the top layer of seed. The oxygen in turn will increase respiration. This combination will slowly and subtly initiate deterioration.

Seed containers should contain a vapor barrier to minimize moisture changes. Containers should be kept as full as possible. If only half of a 30-gallon container is used, the rest should be moved to a 15-gallon container. When planting can be related to the number of containers to be used rather than the portion of a container, the comparison of lab and field results will be much closer. The test sample should only represent that portion of a lot to be planted and not the whole lot.

The optimum size containers for southern nurseries seem to be 10-, 20- and 30-gallon containers. The containers may be glass, plastic, metal or cardboard. Glass is good, but poses a possible hazard. If plastic is used, it should be a rigid plastic more than 5 mils thick to ensure stabilization of moisture. Polyethylene will permit exchange of air and moisture if 2 mils or less in thickness (Swofford 1959). That is why polyethylene is satisfactory for stratification. There has been some concern about possible harmful effects caused by polyvinyl chloride vapors given off by plastic containers. No evidence is yet available with southern species of tree seeds but again this emphasizes the need to keep containers filled to reduce the amount of free air. Although metal containers are rigid, they are subject to condensation with temperature changes, which can cause seed moisture to increase over time. Cardboard containers with a vapor barrier are the most popular in the South because of their light weight, rigidity and ease of handling.

Open air storage of seed, either in cloth sacks or unsealed containers, invites deterioration of southern pine seed. Longleaf pine held 1 year in a stratification room with a 76 percent relative humidity increased moisture content from 9.2 to 13.9 percent (Barton 1941). Most storage units have a relative humidity nearer to 90 percent. If seed must be held for a short time outside of a container, it should be at a low relative humidity. Slash pine seed stored at a 9-percent moisture content in open containers for 2 months at 30, 70, 90 and 100 percent relative humidities gained in seed moisture content to readings of 7.5, 11.5, 22.5 and 32.0 percent, respectively (Coile 1934). As shown by Wakeley's table on equilibrium moisture (table 5-7), the relative humidity should be below 50 percent, and preferably near 35 percent for open storage at room temperature.

Table 5-6. — Summary of published storage data on conifers grown in southern nurseries.

Species	Moisture content (%)	Storage temperature (Degrees) F° C°	Length of storage (Year)	References
General pines	12	25 (-4)	1	Barnett and McLemore, 1966
	6	35 (2)	5	Jones, 1962b
	6	25 (-4)	5	Jones, 1966
Longleaf pine	6	38 (3)	-	Nelson, 1938, Barnett, 1969
Sand pine:				
Choctawhatchee	9	25 (-4)	3	Barnett, 1970
Ocala	12	25 (-4)	5	Barnett and McGilvray, 1976
Spruce pine	6	0-25(-18-4)	1	Barnett and McLemore, 1967
Fraser fir	6-8	0(-18)	13	Speers, 1974
Austrian pine	6-10	34 (1)	10	Heit, 1967

Table 5-7. — Equilibrium moisture content of longleaf pine seed.[1]

10-percent moisture			8-percent moisture		6-percent moisture	
Temperature (°C)	Temperature (°F)	Relative humidity (percent)	Temperature (°F)	Relative humidity (percent)	Temperature (°F)	Relative humidity (percent)
22.0	70	55	70	43	70	25
15.6	60	53	60	37	60	18
10.0	50	47	50	32	50	17
4.4	40	42	40	27	40	16

[1]This is the seed moisture content derived when the seed is held at the given combination of temperature and relative humidity.

Source: Wakeley 1951.

SEED TESTS

No matter how good processed seed may look, the actual value is the number of seedlings it will produce. Germination and other background tests should be conducted under optimum, reproducible conditions so changes can be identified (Swofford 1957). These determinations can be made by your agency or firm, your State agricultural laboratory or the National Tree Seed Laboratory.

Sampling

The most critical step in evaluating a seed lot is the drawing of a representative sample. If drums are filled in consecutive order during processing, a 1,000-pound seed lot can be quite variable. Most likely, the first drum will not relate to the last drum in test results. Also, unless the whole 1,000 pounds is to be sold or sown at one time, the test results may not truly apply to the portion to be sold or sown and the samples drawn accordingly.

The most complete method is to take three probes, from top to bottom, of each container with a seed trier. Place all probe samples in a bucket, mix thoroughly and subdivide to obtain sample size (see table 5-8).

For very small lots (10 pounds or less) of improved seed, it is better to pour the seed into a conical pile and subdivide them with a stick or ruler into quarters. If one-quarter is still too large, repeat the process with that portion.

Shipping Requirements

Seed to be sent to a seed testing laboratory should be placed in a container that will not break. If moisture content is to be determined, the seed should not be permitted to dry during shipment. Moisture changes can be retarded by double bagging the seed in poly bags and heat sealing or folding the tops down and holding them with a closure. Because poly bags can be punctured easily, place them in a rigid container such as a box before shipment. All mail shipments should be made on Monday or Tuesday so they will not sit in a warm post office over a weekend.

Determining Moisture Content

This is the most critical measurement a nurseryman can make. It is important that most species remain above or below a threshold value while in storage. Determine the moisture content every year even if no other tests are made. This task can be done with reasonable accuracy at the nursery with an electronic moisture meter. (figure 5-9). Because electronic meters do not handle large seed, (e.g., larger than longleaf) an oven would be necessary

Table 5-8. — Summary of sample size and test duration for laboratory testing of seed of southern tree species.

Species	Size of sample to be submitted (oz)	(g)	Total time to allow for test (days)	Test usually requested
Pines:				
Sand pine	1.0	25	40	unstratified
Shortleaf	1.5	45	70	paired test
Slash	5.0	140	40	unstratified
Spruce	1.0	25	62	30-day strat.
Longleaf	7.0	200	33	unstratified
Pond	1.5	45	36	unstratified
White pine	3.0	85	78	30- 45-day strat.
Loblolly	4.0	115	68	paired test
Virginia	1.5	45	33	unstratified
Pitch	1.5	45	56	30-day strat.
Other conifers:				
Fraser fir	1.0	25	63	30-day strat.
Arizonia cypress	2.0	60	60-75	30-day strat.
Eastern redcedar	2.0	60	147	90-day strat.
Bald cypress	11.0	310	77	45-day strat.

to obtain the moisture content of a large seed. The oven could also be used for small seed if an electronic meter is not available. If neither are available, a sample should be sent to a seed-testing laboratory. If an oven is used for moisture tests follow these steps:

1. Heat oven to 221 °F.
2. Weigh seed container (wire basket or aluminum dish). Use tongs, as fingers will deposit moisture on the basket.
3. Weigh the basket and seed.
4. Place them in the oven for 16 to 24 hours.
5. Remove them with tongs and place in desiccator for 2 hours to permit seeds to cool without gaining moisture.
6. Weigh dried seed and basket
7. Compute the moisture by this formula:

$$\text{moisture content} = \frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$$

This procedure provides a moisture content reading on a wet-weight basis, as do all seed laboratories. The advantage of a wet-weight determination is that the moisture content expresses actual water in the seed by weight: Example: A 6.7 percent moisture content means that in a 100-pound seed lot 6.7 pounds is water. Evaluate two samples from each lot at the same time so errors can be easily spotted.

Determining Purity

This is a measure of cleanliness. Another viewpoint is that it indicates how well the seeds were processed. Purity is obtained by separating trash from a given sample of the seed lot. This task is very tedious and time consuming. A purity test is important when sowing seed by weight or number of particles because trash is excluded from germination tests. In performing the purity test a given sample is weighed, the trash and impurities are separated and both separations are weighed. If the weight of the original sample and the total of the components differ by more than 1 percent, draw another sample. Purity is computed by the formula below:

$$\text{Percent purity} = \frac{\text{weight of clean seed}}{\text{weight of total sample}} \times 100$$

Because purity is based on weight, any determination of good or bad cleaning must refer to the type of impurity. Seed wings are light and therefore a lot of wings would have to be present to reduce the purity to 90 percent, while resin balls are heavy and are hardly noticeable at 90 percent purity.

Determining Seeds per Pound

Used to calculate the sowing rate and to determine the size of the seed. The results are determined from the pure seed fraction of the purity test. If a purity test is not made, the seed can be blown clean and the remaining debris removed by hand, providing no seed are blown out. A measurement of seeds per pound include both filled and empty seeds. The results are determined by counting five replicates of 100 seeds. Weigh each unit of 100 seeds and record the figure. Total the weights and divide by five to get an average. Subtract the weight of the heaviest sample from the lightest weight of the five units recorded. If the difference is greater than 10 percent of the average, new samples must be drawn.

Example: (slash pine)

Sample 1	5.30 g
Sample 2	5.31 g
Sample 3	5.42 g
Sample 4	5.44 g
Sample 5	5.58 g
	27.05

Average = 5.41 × 10 percent = 0.54
heaviest (5.58) minus lightest (5.30) = .28

If 0.28 had been greater than 0.54, a retest would be made.

If results are acceptable, double the 500-seed total to get the 1,000-seed weight and then compute the number of seeds per pound by the following formula:

$$\text{Seeds per pound} = \frac{453{,}600}{\text{1,000-seed weight (in grams)}}$$

Example: 27.05 × 2 = (1,000-seed weight)

$$\frac{453{,}600}{54.10} = 8{,}384.5 \text{ seeds per pound}$$

Because of variations in sampling, it is impossible to predict closer than 100 seeds. Therefore, the final step is to round these figures to make the last 2 digits zero. Thus, 8,384.5 becomes 8,400 seeds per pound.

Quick Tests

Also known as viability estimates, quick tests are made to provide a quick evaluation of seed viability. They are usually not as reliable as germination tests, but will provide necessary data when time is limited. Three tests are of interest to nursery workers: excised embryo, tetrazolium and X-ray.

The excised embryo test is very tedious and time consuming (Heit 1955). This test may help shorten the evaluation of eastern white pine and shrubs. The test is conducted by exposing or removing the embryo from the seed and thereby overcoming the seed dormancy. Most seeds require a few days to soften the seed coat before it may be cut. Usually, results can be obtained in 20 days or less.

The tetrazolium test is a chemical (staining) measure of an enzyme. Seeds must be softened, cut to permit the chemical to move in, soaked 2 hours in water and then overnight in a tetrazolium solution. The results are affected by pH of the solution, temperature and light. Evaluation can be made in 5 days or less.

Radiography of tree seeds provides a quick means to assess the internal anatomy, but will provide reliable viability data only in very limited cases with fresh collected seed (Belcher 1979b). The test does provide information on filled and empty seed, insect damage, mechanical damage and developmental problems. When combined with the tetrazolium test, it provides more accurate data than either test alone. X-ray data can be available in 24 hours or less (Belcher 1973). The most common use of radiographs is the evaluation of the processing operation.

Germination Tests

Germination is measured under optimum, reproducible conditions so changes in seed viability can be identified. The Association of Official Seed Analysts (AOSA 1970) has established a set of rules for testing seeds. These rules help establish uniform results among laboratories and may be obtained from the Secretary of AOSA. For a current address contact your state laboratory or the National Tree Seed Laboratory.

Each test is composed of four replicates of 100 seed. Each replicate is placed in a plastic box on a sterile medium. The medium may be sterile sand, perlite or crepe paper. In the past, filter paper, blotting paper, and paper towels have been recommended. However, these media do not provide enough moisture for tree seed. They tend to dry out too fast and therefore inhibit tree seed germination.

Tree seeds need light for maximum germination, so the containers should not be stacked or covered. Increased illumination beyond the threshold value of 100 foot-candles has not proved to be beneficial (Jones 1961).

Tree seeds are basically moisture tolerant. Most species will germinate well on substrate moistures ranging from 30 to 70 percent of the water-holding capacity. Three exceptions have been identified (Belcher 1975). Sand pine and Scotch pine are both moisture-intolerant and do best on substrates with less than 20 percent of the water-holding capacity. On the other hand, long-leaf pine is drought-intolerant. It does best on substrates with 50 to-60 percent of the waterholding capacity.

Temperature is important to seed germination (table 5-9). As temperatures increase, the speed of germination increases, but not always total germination (Jones 1962a). Longleaf pine and eastern redcedar are very temperature-specific, with optimum germination at 68 °F for longleaf

Table 5-9.—Germination temperatures for southern tree seed.

Longleaf pine	68°F (20°C)
Other pines	72°F (68-86°F) (22°C)
Eastern redcedar	59°F (15°C)

and 59 °F for redcedar. Maximum germination of loblolly pine occurs at 72 °F. Equal results may be obtained at an alternating temperature of 68 ° to 86 °. However, the germination speed is a little slower. Stratification enhances the effect of temperatures (Belcher and Jones 1966).

Germination should be recorded not less than weekly, with a total of not less than three counts. The more counts made the better the picture of the germination of a given sample. Germination usually begins at 4 to 7 days, peaks at 14 to 17 days and is complete at 28 days. See figure 5-9 for a typical germination curve. Thus, the most informative counts are from the 10th to the 20th days. When you record the germination, identify abnormal seedlings. There are 11 specific categories of seedlings that will germinate under ideal conditions but will not survive under the stress of field conditions. These seedlings are most commonly associated with seed damage during processing, but also include genetic mutants and seed partly damaged by pathogens. See table 5-10.

When a seed dormancy occurs, seed must be stratified before germination if maximum germination is to be obtained (Graber 1965, Belcher and Hitt 1965, Barnett and McGilvray 1971, Barnett 1972, Belcher and McConnell 1972). It is also important to allow sufficient time for transportation of samples and receipt of results when scheduling tests.

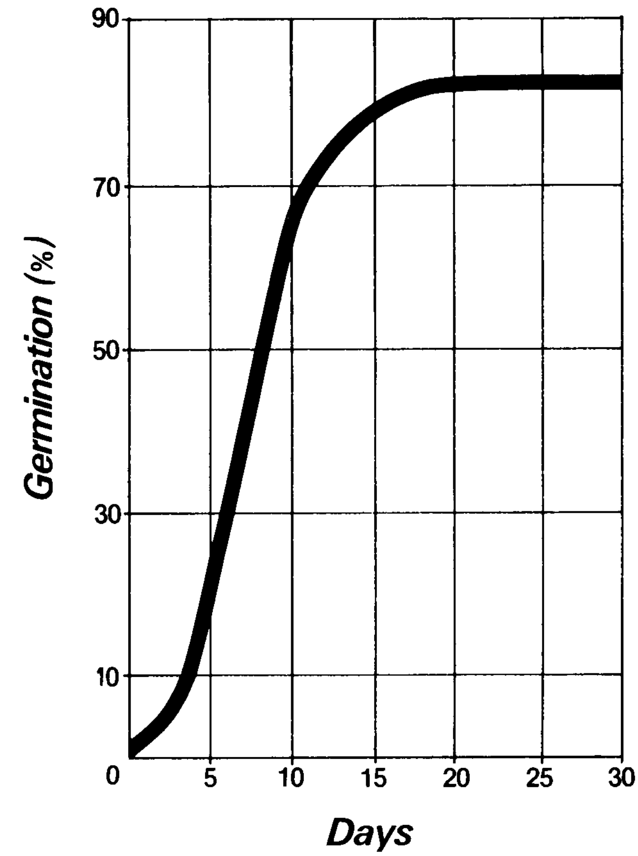

Figure 5-10.—Typical germination curve for slash pine.

USE OF LABORATORY TEST DATA

Condition of Seed

The fact that germination may not reach the expected level is important, but more important is *why*. Use the form in figure 5-11 to help you to examine critical factors. A few species of pine will increase in germination after 1 year of storage because of chemical changes following physical maturation. Further storage can only result in lower viability. If all factors are ideal, viability may be stabilized for several years. If not, deterioration will begin and, once started, it cannot be stopped. The most common cause of seed deterioration is increased moisture content. Nursery workers should examine the moisture content and be sure it is not creeping up. If seed moisture has risen to about 10 percent and further storage is anticipated, the seed should be redried. Viability may be improved by removing empty seed and trash if they account for more than 10 percent of the total seed lot.

Table 5-10. — Categories of abnormal conifer seedlings.

	Description	Occurence (%)	Possible cause
1.	Short, stunted or nearly nonexistent root	1-10	Impact damage from dewinger, genetics
2.	Any essential part of seedling destroyed by fungus that develops from that seed	1-50	Pathogen, may be combined with mechanical damage or age
3.	Seedling short and weak, or unbalanced development	1-50	Impact, genetics
4.	Failing to develop green color (albino)	1-5	Genetics
5.	Root lacking geotropism	Rare	Impact damage from dewinger
6.	Double embryos fused together	Rare	Genetics
7.	Endosperm collar	1-20	Genetics, mechanical damage, age
8.	Cotyledons emerging before primary root, except inverted embryo of polyembryonic seed	1	Genetics
9.	Seedling is translucent or glossy	1	Genetics
10.	Portion of seed trapped by seed coat and not released during test period	1	Genetics
11.	Primary root development from a part other than the micropyle	Rare	Mechanical damage, genetics

Measurement of Seed Vigor

After you examine the presented facts on a germination report, evaluate the comparative value of lots. If more than one lot exists for each source, use the lot that will survive the shortest time in storage. In other cases, selection may have to be made on the intended use of the seed. Will it be used for direct seeding, bare-root seeding or container stock?

The simplest evaluation embraces the concept that seeds die progressively and not all at once. Therefore, a given seed lot contains dead, weak and dying seed as well as sound seed. The germination test provides a measure of the living and the dead; therefore, we must calculate the weak and dying from the living portion (Belcher 1978). Assume that the same portion is dying that has already died. Use this formula:

$$\text{weak and dying} = \text{germination} \times (\text{percent dead seed})$$

Thus, a seed lot with 75-percent germination contains 25 percent dead seed and, further 25 percent of the living seed are weak and dying. The weak and dying seed

A. Actual germination reported (percent)	______
Identifiable bad seed:	
Percent trash (100 percent purity)	______
Percent empty (100 percent full seed)	______
Percent insect damage (X-ray)	______
Percent mechanically damaged (X-ray)	______
Percent other bad seed (X-ray)	______
B. Total nongerminable seed	______
C. Maximum potential viability (100%)	______
D. Deterioration (A-C)	______
E. Moisture content	______
F. Approximate value of seed A - (A x 100 - A)	______

Example: 70% germination = .70 - (.70 x .30)

= .70 - .21

= .49

Figure 5-11.—Evaluation criteria form for each seed lot.

would be 19 percent (.75 × .25). So the potential of that lot would be 56 percent (75 − 19) (item F on figure 5-11). The greatest loss (21 percent) of trees in forest nurseries is caused by failure of the seed to germinate (Rowan 1970). This loss results from the lack of recognition of the interaction between seed vigor and environmental stress. Decreasing seed vigor is reflected in lower germination. In a seedbed situation, laboratory germination rates will seldom be realized.

A second evaluation can be made by plotting the germination data over time. Note on the germination curve in figure 5-9 the number of days to reach the "shoulder" or break in the curve. To calculate the number of days rather than use a graph, multiply the total germination by 90 percent; then calculate the number of days to reach that point. Most seedlings produced after this point in the laboratory will not result in a tree in the nursery. The more vigorous the seed the shorter the number of days to reach 90 percent of the total. Tests producing a slow-rising germination curve will be subjected to longer field conditions during germination, which will result in lower field germination. Some nursery managers prefer to use the time required to reach 50 percent germination rather than 90 percent.

A third method to measure seed vigor is to use Czabator's germination value (Czabator 1962). The value is a combination of germination speed and germination quantity with emphasis on speed. Germination speed should be of prime importance to nursery managers. If germination starts slowly, the seed will become prey to birds, rodents, fungal organisms and any adverse environment. The germination value (GV) is calculated by the formula:

$$GV = PV \times MDG$$
$$GV = PV \times \text{mean daily germination}$$

The peak value (PV) is obtained by dividing the germination rate by the number of days at that count. This average will increase at each count to some peak value and then decrease. The mean daily germination (MDG) is the average value on a given day, usually the last day of the test. When you compare seed lots, use the same final day. The faster the seed germinate, the shorter time required between counts to estimate the true peak value. For example:

Day of count	*Germination*	*Mean*
7	2	0.28
14	52	3.71
21	74	3.52
28	76	2.71

PV = 3.71   MDG = 2.71 at 28 days.

Thus GV = 3.71 × 2.71 or 10.05

Germination values per se are meaningless, but when two lots are compared or when two tests on the same lot are compared, the more active or vigorous lots can be identified by the higher value.

SEED STRATIFICATION

When southern pine cones are collected and dried, followed by seed extraction and processing, many seed lots become dormant to some degree. The treatment to overcome this dormancy is similar to the natural over-wintering process and is called stratification.

Originally, seed were placed in burlap bags and layered in drums with sphagnum moss. Ice was placed on top and as it melted the cold water moved through the moss and soaked the seeds. In a cleaner technique developed in Canada, seeds were soaked overnight in water, drained and placed in polyethylene bags. The bags were sealed and refrigerated at 34 to 36 °F (Hosner, et al 1959). This is the most common procedure used in the South.

Dry seeds cannot be stratified! The seeds must be imbibed before stratification. Seeds are imbibed with a 24-48-hour water soak, usually at room temperature. Studies at the National Tree Seed Laboratory in 1965 and 1966 showed that water soaking alone promoted field germination. Germination in most cases was at a percentage rate between that of stratified and non-stratified seed. Soaking seeds more than 48 hours was harmful to seed viability (Barnett and McLemore 1967) unless the water was aerated. Bubbling air through the soak water with a fish tank pump for up to 60 days provided germination nearly equivalent to that of stratified seed for loblolly pine.

Stratification not only promotes germination, but also increases the *speed* of germination. The increase in germination speed is of great importance. The longer the time required for germination, the more the seeds are subject to adverse conditions and the less likely they are to germinate. Also, the slower the germination the less uniform is the resulting seedbed density and seedling height. Even longleaf pine (under special circumstances) has benefited by short (14 days) stratification to produce faster, more uniform field germination. Unless test results indicate a decrease in total germination by 6 percent or 6 days in speed, stratification is recommended.

The optimum length of stratification varies by species and handling techniques. A prime example of the latter is eastern white pine, which usually requires 30 to 60 days for stratification. In a recent study, several samples of fresh-collected seed were tested, which required no stratification at all. Because each seed-lot need varies, the stratification period should be determined by test results. In the absence of test data use the recommended periods of stratification in table 5-11.

Most studies at the National Tree Seed Laboratory show that at least 21 days are required for stratification to be effective on slash and loblolly pine seed. Germination speed has increased with the length of stratification (USDA 1974); however, in 60 and 90 days the seed would begin germinating in stratification. Nursery managers can avoid this problem by planning to sow the seed at least half-way between optimum and maximum length of stratification. This timing allows for continued stratification if the weather does not permit planting. Another technique with slash and loblolly pine is to remove the seed, dry it to a 26 percent moisture content and place it back in cold storage (36- to 38 °C) until ready. This technique enables you to store loblolly pine seed for up to 10 months and slash pine up to 5 months (Belcher 1982). If the seed will not be used in this period, dry it to 6 to 9 percent and place it back in freezing storage. This treatment will induce a dormancy in some lots but not in others. The decision to restratify should be based on test results.

Procedure for Stratification in Plastic Bags[1] [2]

1. Bring seeds to a high moisture content. Full imbibition is essential for stratification in plastic bags without a moisture-holding medium. The usual procedure is to soak the seeds overnight at room temperature; then drain them for several minutes over wire screens.
2. Place seeds loosely in bags; do not pack. Close the bags tightly to prevent loss of moisture.
3. Label all containers clearly, and place them in the cooling facility. (36 to 38 °F).
4. Inspect bags periodically. Poor aeration is more of a problem in naked stratification than it is when a medium is used, especially for large lots. There is some gas exchange through the bag walls, but frequent inspections and turnings are necessary. One easy means of detecting a lack of oxygen is to open the bags and smell the contents. An odor of alcohol indicates that anaeroic respiration is occurring because of insufficient oxygen. A faint smell of alcohol does not mean that the seeds are ruined, but it serves as a warning of imminent danger. Inspect the bags more often than weekly if you have large lots, and open and *turn* all bags.

[1] Adapted from U.S. Department of Agriculture 1974.

[2] Polyethylene bags—no more than 4 mils thick.

Table 5-11. — Recommended stratification periods for southern pine seeds.

Pine species	Recommended length of stratification: Fresh seeds	Recommended length of stratification: Stored seeds
	Days	
Loblolly	30-60	30-60
Longleaf	0	0
Pitch	0	0
Pond	0	0-30
Sand		
Choctowhatchee (var. immuginata)	0-15	0-21
Ocala (var. clausa)	0	0
Shortleaf	0-15	15-60
Slash	0	0-30
South Florida (var.. densa)	30	30
Spruce	30	30
Table Mountain	0	0
Virginia	0-30	30
Eastern white pine	30	60

[1]Adapted from U. S. Department of Agriculture, 1974.

5. Remove and wash the seeds at the end of the stratification period. Washing at this point may not be necessary, but it will remove some potentially damaging microorganisms, especially with large hardwood seeds. Sowing soon after removal is recommended as for any stratification procedure.

BUYING SEED

In lean years, the need may arise to supplement collections with seed purchases. There are some important considerations in buying seed, such as age, quality and price.

Age

All nursery workers should realize that most seeds are at their maximum viability at the time of collection. As the seeds age their vigor declines. Improper handling and adverse environments will shorten the life of seeds dramatically. However, if the seeds have been properly handled a high viability may be maintained for years. Reports have identified 18-year-old loblolly pine seeds with 90-percent germination (Belcher and Karrfalt 1976) and 6-year-old longleaf pine seeds with 91 percent germination (Belcher and McConnell 1974).

Quality

The buyer should obtain the best quality of seeds available. Because the top quality cannot always be obtained, the nursery manager must decide on the lower limit of acceptance. It is penny-wise and pound foolish to buy seed regardless of quality just because a particular source is needed. Improper sources should not be used in any case. Although the use of less than the best seeds may be dictated by management occasionally, this practice increases the nursery's expense for growing planting stock derived from such seeds and therefore is not a sound business practice.

A general agreement should be established between the buyer and seller as to maximum acceptable moisture content, minimum germination, purity and full-seed percents.

Price

Whatever the going price for seed may be, some other important considerations may govern your final decision. One of these is moisture content. The purchase of 1,000 pounds of seed without regard to moisture can be costly. At $10 per pound and 9 percent moisture you are buying $10,000 worth of seed and 90 pounds of water. If the moisture is increased to 15 percent (150 pounds of water), 60 pounds of seed would be replaced by water. In other words, you would be buying 60 pounds less actual seed but a more moist seed. This disparity becomes more dramatic when converted to the number of seeds and bed area these two lots can sow.

Contract

A purchase order or contract to buy seed should include: species, source, minimum germination, minimum purity and maximum moisture content. The contract price can be negotiable, firm or on a sliding scale. In the sliding scale, the contract price is specified for the quality stated. Increases or decreases in quality would increase or decrease the price proportionately. This factor provides an incentive for the seed dealer to produce a better product.

Certification

Seed certification is a voluntary program operated by each State to improve seed quality and ensure genetic purity and identity in seed distribution. Plants that process certified seed must adhere to the labeling and inventory control procedures required by the certifying agency.

Seed certification doesn't just happen; it must be planned and then carried out in the proper sequence (Belcher 1979a). For information on forest seed certification in your State contact the appropriate seed certifying agency (table 5-12).

OECD

The Organization for Economic Cooperation and Development has established a scheme for shipment of forest reproductive material between countries, which encourages maximum integrity of species and source identification. The United States representative is on the Cooperative Forestry Staff, USDA Forest Service, Washington, D.C. The program is conducted by each State in conjunction with their own certification procedures. For assistance in using the program contact your State seed certifying agency or the National Tree Seed Laboratory.

Table 5-12. — Seed certifying agencies in the South.

State	Contact	Address
Alabama	Secretary, ACIA	S. Donahue Dr. Auburn University Auburn, AL 36830
Arkansas	Secretary, ASPB	P. O. Box 1069 Little Rock, AR 72203
Florida	Administrator, FDA Cert. Section	Mayo Building Tallahassee, FL 32304
Georgia	EXT. Agron., GCIA	925 West Whitehall Rd. Athens, GA 30605
Kentucky	Secretary, KSIA	P. O. Box 12008 Lexington, KY 40511
Louisiana	State Entomologist, LDA	P. O. Box 44153 Capitol St. Baton Rouge, LA 70804
Mississippi	Secretary, MSIA	P. O. Drawer MS Mississippi State, MS 39762
North Carolina	Director, NCCIA	P. O. Box 5155 State Univ. Station Raleigh, N.C. 27607
Oklahoma	Secretary, OCIA	369 Ag. Hall Oklahoma State Univ. Stillwater, OK 74047
South Carolina	Head, Dept. of Seed Cert.	RM 265, P & AS Bldg. Clemson Univ. Clemson, S.C. 29631
Tennessee	Secretary, TCIA	P. O. Box 11019 Nashville, TN 37211
Texas	Asst. Dir., TDA	P. O. Drawer 12847 Capitol Station Austin, TX 78711
Virginia	Secretary, VCIA	10 Sandy Hall VPI & SU Blacksburg, VA 24061

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GLOSSARY

Afterripening.—Processes which complete natural maturation of seeds and fruits after harvest.

Case hardening.—Failure of cones to open because of immaturity or improper processing.

Certified Seed.—Seed attested by a recognized certifying agency to be of specific source or genetic characteristic or superiority.

Cone.—The reproductive structure of conifers. As used in this book it refers to the female cone which bears the conifer seed.

Cotyledons.—First leaves developed in the embryo of a seed.

Dormancy.—In seeds, a state that prevents germination under environmental conditions favorable for growth.

Embryo.—Portion of seed that produces a seedling.

Endosperm.—Storage tissue of nonconiferous seeds.

Epigeal.—Type of germination in which the cotyledons are forced above the ground by elongation of the hypocotyl.

Fruit.—Reproductive unit of a seed-bearing plant.

Full seed.—Seed having an interior volume more than half-filled with storage and embryo tissue.

Germination.—Resumption of active growth in the embryo of a seed. Germination tests measure the development of plant parts that indicate a potential for growth of the seed into a normal plant.

Germinative capacity.—Percentage of sound seed, as measured by a staining test (tetrozolium).

Germinative energy.—Percentage of seeds that germinate in a given test period under specific test conditions.

Hypocotyl.—Part of the axis of an embryo or stem of a seedling.

Imbibition.—The absorption of water by seeds.

Radicle.—Portion of the axis of an embryo from which the root develops.

Seed.—Matured ovule containing an embryo and nutritive tissue enclosed in layers of protective tissue (seed coat).

Seed coat.—Protective layer on a seed.

Seed lot.—An identified quantity of seed from a single seed source.

Seed source.—Geographic location of the original trees from which seeds were collected.

Serotinous.—Cones that remain closed on the tree for several months or a year or more after maturity.

Shrub.—Perennial woody plants with no major central stem.

Sound seed.—Seeds that are filled with living tissue and that are potentially viable.

Stratification.—Pregermination treatment to break dormancy in seeds and to promote rapid uniform germination. Accomplished by subjecting imbibed seeds to a prechill treatment.

Vigor.—Measure of seeds' ability to germinate under various environmental conditions.

Viability.—Capacity of seeds to germinate.