SOUTHERN PINE SEED QUALITY: INFLUENCE OF SEED ORCHARD MANAGEMENT

J. P. Barnett

Abstract.--Tree improvement programs have significantly influenced the quality of southern pine seeds produced when compared to collections from native stands. Studies show that seed orchard management practices such as fertilization increase seed size and reduce seed dormancy. These result in the need for less complex pregermination treatments. Repeated cone collections from the same clones facilitate collections according to ripening (cone specific gravity), which can improve seed germination and storage. However, cultural practices may result in seed properties that are more sensitive to damage during processing procedures and result in lower quality unless special care is provided during this stage of handling. The effect of orchard management practices on seed quality also varies by species, with loblolly pine being less affected than longleaf pine.

Keywords: Pinus spp., seed germination, seed dormancy, seed storage, cone maturity.

INTRODUCTION

Remarkable progress has been made in tree improvement of the southern pines (Pinus spp.) during the past four decades. Seed orchards produce seeds for the vast majority of the more than 1 billion pine seedlings produced annually in the southern United States. In fact, the more than 10,000 acres (4,000 hectares) of southern pine seed orchards now produce seeds of most species in quantities in excess to our current needs. During the development of these orchards and incorporation of improved seeds into nursery practice, there has been a shift in seed management practices to adjust to differences in seed properties caused by more intensive tree culture.

Much of the definitive research on physiology of southern pine seeds was conducted with seeds collected from native stands. Through the years, there has been a modification of practices to reflect the character of seeds from managed orchards. Since this has been a gradual process, there has been no critical evaluation of the impact of tree improvement on seed quality. However, there have been a number of changes in methodology that reflect impact of more intensive tree culture. The purpose of this paper is to review the influence of seed orchard management on seed quality. Since there are few studies designed to compare these effects, many of the influences are documented from personal observation, evaluation of data from related studies, and from changes in seed processing practices over time.

---

[1] Chief Silviculturist, USDA Forest Service, Southern Research Station, Pineville, LA 71360.

ORCHARD MANAGEMENT

The goal in managing seed orchards is to produce high-quality seeds with a desirable genotype mix in quantities sufficient for regeneration needs in the shortest time (Pait et al. 1991). Rapid, juvenile growth is achieved by controlling weeds, insects, and water stress and ameliorating soil nutrient deficiences. Management activities shift as orchards begin to produce cones. Fertilization continues to maintain desirable levels of nutrients for overall tree vigor and cone production. Irrigation to reduce moisture stress, subsoiling to overcome compaction, and applications of insecticides to control insects are additional practices that may improve vigor and enhance cone and seed production of orchard trees.

CONE COLLECTION AND SEED MATURITY

Wakeley (1954) reported the germination of southern pine seeds is directly related to cone maturity at the time of extraction and cones are mature enough for collection when their specific gravity drops below 0.89. The critical determinant of maturity is cone moisture content, but measuring specific gravity by flotation is the quickest way to estimate cone moisture. Wakeley (1954) determined specific gravity by flotation in oil, but another simple method is described by Barnett (1979a). Typically, cones were collected over a 2- to 3-week period, and seed extraction was accomplished within a few weeks after collection. However, as the demand for southern pine seeds escalated and seed orchards came into production, this period was too short to allow collection of enough cones to provide an adequate seed supply. It became necessary, then, to extend the collection period by beginning a few weeks before the traditional specific gravity index.

An extended collection period is possible if slightly immature cones are stored or precured prior to kilning (Barnett 1976a, McLemore 1975). It became obvious that there were different responses in seed maturity that are related to cone collection and storage. Collections of loblolly (P. *taeda* L.) and slash (P. *elliottii* Engelm.) pine cones can begin 2 or 3 weeks before maturity if specific gravity is 1.0 or less, but seed yields from these immature cones may decrease even after cone storage. Acceptable yields and germination can be obtained when collections of loblolly pine cones begin about mid-September (specific gravity <1.0) and when collections of slash cones begin in late August (specific gravity 0.95). Generally, optimum yields and germination are possible only if the cones are mature when collected (Barnett 1976a). Early collections are advisable only if large quantities of seeds are needed immediately or if labor or the collectable crop is limited. Seeds from immature loblolly pine cones are apparently mature when extractable, and slash pine seeds continue ripening during cone storage. However, viability of longleaf pine (P. *palustris* Mill.) seeds from immature cones decreases during cone storage. Therefore, only mature longleaf cones should be collected. Once ripe, longleaf cones can be stored or precured for 3 to 5 weeks to increase seed yields without reducing viability, but the storage period for mature cones should not exceed 8 weeks (McLemore 1961).

The method of cone storage has varied from burlap bags to 20-bushel (7 hL) wire-bound boxes, outdoors or in unheated indoor facilities. Although several studies of the influence of the type of cone storage on seed quality have been conducted (Barnett 1979b, Bonner 1987), there has been no clear indication of the superiority of one method over the other when collections are restricted to the major southern pines (loblolly, slash, longleaf, and shortleaf (P. <u>echinata</u> Mill.).

The greatest emphasis in southern pine seed orchard production has been on loblolly pine. It is fortunate this species is, of the southern pines, the least affected by seed orchard practices that require extension of cone collection and processing. Such extended periods are feasible without any major reduction in seed quality of loblolly pine. However, seed quality of slash and longleaf pines can be markedly reduced by changes in collecting and processing variables.

Orchard managers normally determine the relative sequence and approximate dates of ripening of all their clones. Once this clonal cone ripening sequence is determined, collections should be scheduled to start with those maturing early and follow the order of ripening. The time between ripening dates of the earliest and latest clones in one orchard was documented as 50 days (Zoerb 1969). The use of this collection strategy will reduce the adverse effects of early cone collections.

An alternative to collecting cones by hand is the net retrieval system that is used to collect loblolly, Virginia (P. <u>virginiana</u> Mill.), and eastern white (P. <u>strobus</u> L.) pine seeds (Pait et al. 1991, Wynens and Brooks 1979). Polypropylene netting is spread on the orchard ground before cone opening. Seeds fall to the netting naturally as the cones open (McConnell and Edwards 1985). When most of the seed crop is judged to be on the netting, it is rolled up and the seeds are recovered. High seed moisture contents are common and can be troublesome during retrival and processing. However, with proper care, good quality can be maintained in loblolly pine seeds for use immediately or after at least 1.5 years of storage (Bonner and Vozzo 1986).

CONE AND SEED PROCESSING

<u>Extraction</u>

Seeds are usually extracted from southern pine cones in forced-draft kilns. Temperature and duration of kilning are critical for southern pine cones, particularly longleaf: temperatures of 115 °F (46 °C) or more markedly reduce germination (Rietz 1941) and those under 90 °F (32 °C) may not result in effective cone opening (Bonner 1987). Optimal temperatures are 95 °F (35 °C) to 105 °F (41 °C). Increases in the length of treatment may also reduce viability. A general recommendation is that cones and seeds should be removed from kilns as soon as cones open sufficiently to release the seeds.

<u>Cleaning</u>

After seeds are extracted, they must be dewinged, cleaned, and dried. The wings on seeds of all southern pines, except longleaf, are completely removed by brushing and tumbling in mechanical dewingers. The structure of longleaf seeds makes dewinging difficult; the wings are mechanically reduced to stubs, so dewingers must be carefully regulated to prevent injury to these thin-coated seeds. Wing removal that is done carefully and does not damage the seed coat has no effect on seed storability (Barnett 1969, Belcher and King 1968), but dewinging is a common cause of seed injury and loss of viability. Orchard management practices generally result in larger seeds and thus increase seed sensitivity to damage during processing activities such as dewinging. The dewinging process for species other than longleaf is hastened and improved by moistening dry seeds, but this moisture may need to be removed prior to seed storage.

Before seeds are used or stored, empty seeds should be removed from the seedlot. This is the easiest means of upgrading a seedlot. This can be accomplished by mechanical cleaning equipment, or, when lots are small, as in progeny tests, it is often convenient to use flotation in water or organic solvents to separate unfilled seeds. In the appropriate liquid, sound seeds sink, while unsound ones float and can easily be skimmed off. Examples of appropriate solvents for seed separations are: water for loblolly pine, n-pentane for longleaf pine, and 95-percent ethanol for slash, shortleaf, sand (P. clausa [Chapm. ex Engelm.] Vasey ex Sarg.), and spruce (P. glabra Walt.) pines (Barnett and McLemore 1970). To maintain seed quality, flotation in ethanol should be delayed until just prior to use, because if the ethanol is not thoroughly removed by drying, seeds so treated rapidly loose viability in storage (Barnett 1971).

Sizing

The reported effects of seed size on germination and early seedling growth are conflicting. The operational objective of sizing is to produce a uniform crop of seedlings. Medium to medium-large seeds have been reported to produce larger and more uniform seedlings than smaller seeds (Ghosh et al. 1976). Larson (1963) reported that although seed size can influence subsequent seedling development when seedlings are grown under uniform conditions as in greenhouses, seed size has a more pronounced effect on germination. Uniform speed of germination may, therefore, be the most important consideration in sizing. More recent tests under laboratory conditions of minimal environmental stress have shown that germinant size after 28 days of growth was strongly correlated with seed size (Dunlap and Barnett 1983). The faster germinating seeds in each size class produced larger germinants after 28 days of incubation (fig. 1). All seeds reached a maximum germination rate by the sixth day, but smaller seeds were slower to initiate germination (fig. 2).

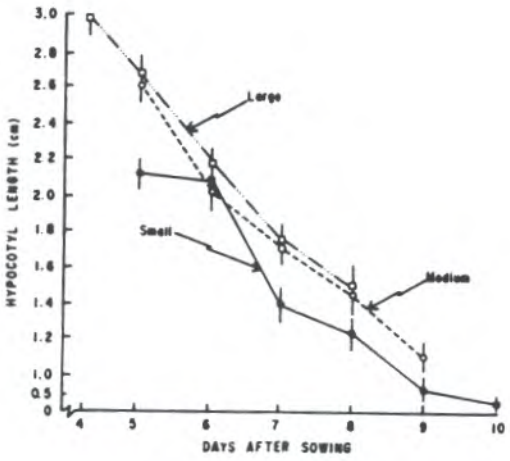

Figure 1. Mean hypocotyl length of loblolly pine germinants 28 days after germination (Dunlap and Barnett 1983).

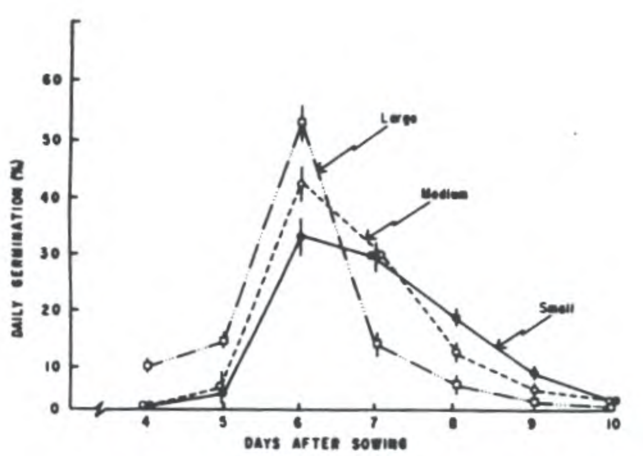

Figure 2. Mean daily germination of loblolly pine seeds from the large medium and small classes (Dunlap and Barnett 1983).

These results are in agreement with Venator's (1973) findings indicating faster growing Caribbean pine (P. *caribaea* var. *hondurensis* Barrett and Golfair) seedlings tend to develop from early germinating seeds. Consequently, seedling size and possibly uniformity of growth are primarily a function of germination patterns, which are partially determined by seed size.

It is generally recognized that seed size varies by genetic and geographic source, and fertilization practices commonly used in seed orchards increase seed size (McLemore 1975). When orchard collections are bulked into a single lot, sizing can result in the exclusion of certain families. Some seed managers may be tempted to discard the small-seed fraction of their lots; however, such a practice could eliminate certain families and narrow the genetic base of the planting stock (Silen and Osterhans 1979). All sizes of seeds should be used in seedling production.

Seed processing techniques have been developed specifically for loblolly pine since it is the species more often produced in southern pine seed orchards. Of the southern pines, loblolly seeds are the most dormant, hardseeded, and the least susceptible to damage during processing. It is not surprising then that application of the processing technology developed primarily for loblolly pine to a species like longleaf pine may result in damage that reduces seed quality and performance.

SEED STORAGE

Inconsistent cone crops require that seed managers store seeds to offset years of low production. Though good seed-orchard management has reduced the fluctuations in southern pine cone crops, seed supplies must be maintained in storage for unanticipated needs. Fortunately, seeds of southern pines are relatively easy to store for long periods. Viability of slash and shortleaf seeds stored for 50 years at above-freezing temperatures was 66 and 25 percent, respectively (Barnett and Vozzo 1985); vigor declined as expected, but no serious chromosomal damage was noted. Longleaf seeds, which are the most difficult of the southern pines to store, have been held for 20 years at low seed moisture and subfreezing temperatures without significant losses in viability (Barnett and Jones 1993).

Careful control of seed moisture content and storage temperatures is essential to maintain viability (Barnett and McLemore 1970, Barton 1961, Jones 1966). General recommendations for long-term storage are to dry seeds to 10 percent or less moisture content and store at subfreezing temperatures. Seeds that are damaged or are known to have low vigor can be preserved by drying to 8 to 10 percent and lowering storage temperatures to about 0^{o}F (-18^{o}C)(Kamra 1967). The genetic source of the seeds seems to have little effect on their storage capabilities (Barnett and McLemore 1970).

SEED DORMANCY AND PRETREATMENT

Seed dormancy in the southern pines seems determined by the magnitude of seed coat constraint. The ratio of the seed coat to total seed weight provides a means of rapidly estimating relative seed dormancy among closely related species (Barnett 1972, 1976b; Carpita et al. 1983). The theory is that thicker and heavier seed coats of the more dormant seeds restrict imbibition by preventing swelling of the megagametophyte and embryo and thus limit water absorption sufficient for germination. Loblolly pine seeds are considered the most dormant, and longleaf pine seeds, the least dormant of the southern pines. Although not thoroughly documented, one of the more significant effects of seed orchard culture may be on seed dormancy. Orchard fertilization increases seed size. Dunlap and Barnett (1983) found larger seeds tend to germinate more quickly and produce larger germinants than smaller ones, although final germination is typically lower in the larger seeds. Therefore, seed orchard management results in seeds with *less* dormancy than those from native stands.

Maternal factors such as seed coat properties that influence the speed of germination can obscure the nature of genetic control of subsequent growth processes (Perry 1976). Seed dormancy varies by geographic location or ecotype (Barnett 1991). Less than 15 percent of the weight of a conifer seed is in the embryo, which is the only portion with a genetic component from the male plant. In nature, moist prechilling or stratification is usually optimized as a result of natural conditions, but in nursery production, the genetic component from the male parent may be obscured when managers do not optimize the prechilling needs of the seedlot. Prechilling needs should be determined under the stress conditions that relate to nursery bed conditions where seeds are to be sown.

Overcoming seed dormancy is one of the major steps to ensure prompt and uniform germination. Presowing treatments to speed germination are discussed in detail by several authors (Bonner et al. 1974, Tanaka 1984). Typically, prechilling is done after an 8 to 24 hour period of moisture imbibition. Fully imbibed seeds are placed in polyethylene bags and held at temperatures of 34° to 40° F (1° to 5°C). The length of treatment varies by the extent of dormancy present in the seeds.

In recent years, techniques other than prechilling have been investigated in an attempt to accelerate the dormancy-breakage process or obtain more desirable germination patterns for genetically improved seeds (Barnett 1989). However, none of these newer presowing treatments have been developed to the point where they are as consistently effective as conventional moist prechilling.

PREDICTING SEED PERFORMANCE

For decades, nursery managers and seed physiologists have sought techniques, generally with little success, that would more accurately predict seed performance in the nursery. In an evaluation of the problem, Barnett and McLemore (1984) found that laboratory germination tests performed on prechilled seedlots provide the best predictors of nursery-tree yield for southern pines. Germination tests are standardized by conducting them under optimum light and temperature conditions (AOSA 1980). However, tests conducted under optimum conditions do not reflect germination of dormant seeds on nursery beds were temperatures and photoperiods are often considerably less than optimal (table 1). Since orchard culture results in changes in seed properties, comparative tests of untreated and prechilled (various durations) seeds are needed to develop optimal recommendations. A technique to improve prediction of seed performance is to determine prechilling needs under stress conditions that relate to the nursery conditions where the seeds are to be sown (Barnett 1992). The prechilling period should be extended to minimize the effect of the less than optimal conditions on initial seedling development.

CONCLUSIONS

Tree improvement programs have significantly influenced the properties of southern pine seeds produced compared to seeds from native stand collections. The effects of orchard cultural practices include:

1. Varying responses among species to management practices. Fortunately, loblolly pine, which is the major southern species produced in tree improvement programs, is most tolerate to cultural manipulation. Longleaf pine seeds are the most sensitive to impacts of management.
2. Reductions in seed quality related to extended cone collections result from the processing of immature cones and seeds. Repeated collections (year after year) from the same clones allow orchard managers to collect by ripening sequence and thus overcome some of the problems of collecting large quantities of immature cones.
3. Increases in seed size, resulting from orchard fertilization, reduce dormancy levels in loblolly pine seeds, increases sensitivity of longleaf pine seeds to damage during processing, and changes the nature of presowing treatments in most species.
4. Insignificant effects on seed storability.
5. The reevaluation of prechilling needs based on comparative germination tests is required and germination should be optimized for nursery-bed conditions.

Table 1. Effect of length and method of stratification of a mixed loblolly pine seedlot in two testing environments (McLemore 1969).

Days stratification	Stratified in refrigerator at 34°F: Germination percent	Stratified in refrigerator at 34°F: Germination value[a]	Stratified outdoors: Germination percent	Stratified outdoors: Germination value
	Tested at 60°F with 11-hour photoperiod			
0	< 1	0.0	< 1	0.0
30	68	7.1	59	6.0
60	95	17.3	91	11.4
113	99	24.0	98	19.6
	Tested at 72°F with 16-hour photoperiod			
0	96	20.8	96	20.8
30	99	37.6	98	41.8
60	99	47.1	99	47.0
113	100	50.3	99	56.3

Germination **values represent** the speed as well as completeness of germination (Czabator 1962).

LITERATURE CITED

Association of Official Seed Analysts. 1980. Rules for testing seeds. J. Seed Technol. 3(3): 1-126.

Barnett, J. P. 1969. Long-term storage of longleaf pine seeds. Tree Planters' Notes 20(2): 22-25.

Barnett, J. P. 1971. Flotation in ethanol reduces storability of southern pine seeds. For. Sci. 17: 50-51.

Barnett, J. P. 1972. Seed coat influences dormancy of loblolly pine seeds. Can. J. For. Res. 2: 7-10.

Barnett, J. P. 1976a. Cone and seed maturation of southern pines. USDA Forest Service Res. Pap. SO-122. Southern Forest Experiment Station, New Orleans, LA. 11 p.

Barnett, J. P. 1976b. Delayed germination of southern pine seed related to seed coat constraint. Can. J. For. Res. 6: 504-510.

Barnett, J. P. 1979a. An easy way to measure cone specific gravity. In: Proceedings of the seed collection workshop, May 16-18, 1979, Macon, GA. USDA Forest Service Tech. Bull. SA-TP 8. State and Private Forestry, Atlanta, GA: 21-23.

Barnett, J. P. 1979b. Southern pine cone maturation and storage. In: Proceedings of the seed collection workshop, May 16-18, 1979, Macon, GA. USDA Forest Service Tech. Bull. SA-TP 8. State and Private Forestry, Atlanta, GA: 11-20.

Barnett, J. P. 1989. Seed, cultural practices, and seedling uniformity. Forestry 62(Suppl.): 95-105.

Barnett, J. P. 1991. Relating the seed coat of Pinus to speed of germination, geographic variation, and seedling development. In: Proceedings of the 21st southern forest tree improvement conference, June 17-20, 1991, Knoxville, TN. Southern Forest Tree Improvement Committee, Knoxville, TN: 266-275.

Barnett, J. P. 1992. Production of shortleaf pine seedlings. In: Proceedings of the shortleaf pine regeneration workshop, October 29-31, 1991, Little Rock, AR. USDA Forest Service Gen. Tech. Rep. SO-90. Southern Forest Experiment Station, New Orleans, LA: 20-31.

Barnett, J. P. and J. P. Jones. 1993. Response of longleaf pine seeds to storage conditions and pregermination treatments. South. J. Appl. For. 17: 180-187.

Barnett, J. P. and B. F. McLemore. 1970. Storing southern pine seeds. J. For. 68: 24-27.

Barnett, J. P. and B. F. McLemore. 1984. Germination speed as a predictor of nursery seedling performance. South. J. Appl. For. 8: 157-162.

Barnett, J. P. and J. A. Vozzo. 1985. viability and vigor of slash and shortleaf pine seeds after 50 years of storage. For. Sci. 31: 316-320.

Barton, L. V. 1961. Seed preservation and longevity. Leonard Hill Books, Ltd., London. 216 p.

Belcher, E. W. and J. King. 1968. Storage of dewinged longleaf pine seed is possible. Georgia Forestry Research Council Res. Pap. 51. Macon, GA. 4 p.

Bonner, F. T. 1987. Cone storage and seed quality in longleaf pine. USDA Forest Service Res. Note SO-341. Southern Forest Experiment Station, New Orleans, LA. 4 p.

Bonner, F. T., B. F. McLemore and J. P. Barnett. 1974. Presowing treatment of seed to speed germination. In: Seeds of woody plants in the United States (C. S. Schopmeyer, tech. coord.). USDA Forest Service Agricultural Handb. 450. Washington, D.C.: 126-135.

Bonner, F. T. and J. A. Vozzo. 1986. Effects of the net retrieval system on quality of seeds collected in pine orchards of the southern United States. In: Proceedings international symposium on seed problems under stressful conditions. IUFRO P.G. P02.04.00 Schrift Forst. Bundesv. Berichte, Vienna: 91-97.

Carpita, N. C., A. Skaria, J. P. Barnett and J. R. Dunlap. 1983. Cold stratification and growth of radicles of loblolly pine (Pinus taeda) embryos. Physiologia Planturam 59: 601-606.

Czabator, F. J. 1962. Germination value: an index combining speed and completeness of pine seed germination. For. Sci. 8: 386-396.

Dunlap, J. R. and J. P. Barnett. 1983. Influence of seed size on germination and early development of loblolly pine germinants. Can. J. For. Res. 13: 40-44.

Ghosh, R. C., B. Singh and K. K. Sharma. 1976. Effect of seed grading by size on germination and growth of pine seedlings. Indian Forester 102: 850-858.

Jones, L. 1966. Storing southern pine seed: what are the best moisture and temperature conditions. Georgia Forestry Research Council Res. Pap. 41. Macon, GA. 8 p.

Kamra, S. K. 1967. Studies on storage of mechanically damaged seed of Scots pine (Pinus sylvestris L.). Studia Forestalia Suecica 42. Royal College of Forestry, Stockholm, Sweden. 17 p.

Larson, M. M. 1963. Initial root development of ponderosa pine seedlings as related to germination data and size of seed. For. Sci. 9: 456-460.

McConnell, J. L. and J. L. Edwards. 1985. Net retrival seed collection. In: Proceedings conifer tree seed in the Inland West symposium. USDA Forest Service Gen. Tech. Rep. INT-203. Intermountain Research Station, Ogden, UT: 125-128.

McLemore, B. F. 1961. Prolonged storage of longleaf cones weakens seed. USDA Forest Service Southern Forestry Notes 132. Southern Forest Experiment Station, New Orleans, LA.

McLemore, B. F. 1969. Long stratification hastens germination of loblolly pine seed at low temperatures. J. Forest. 67: 419-420.

McLemore, B. F. 1975. Collection date, cone-storage period affect southern pine seed yields, viability. Tree Planters' Notes 26(1): 24-26.

Pait, J. A., III, D. M. Flinchum, and C. W. Lantz. 1991. Species variation, allocation, and tree improvement. In: Duryea, M. L. and P. M. Dougherty (eds.), Forest Regeneration Manual. Kluwer Academic Publishers, Dordrecht, Boston, London: 207-231.

Perry, T. 0. 1976. Maternal effects on the early performance of tree progenies. In: M.G.R. Carrnell and F.T. Last (eds.), Tree Physiology and yield improvement. Academic Press, New York: 473-481.

Rietz, R. C. 1941. Kiln design and development of schedules for extracting seed from cones. U.S. Department of Agriculture Tech. Bull. 733. Washington, DC. 70 p.

Silen, R. and C. Osterhans. 1979. Reduction of genetic base by sizing of bulk Douglas-fir seed lots. Tree Planters' Notes 30(1): 24-30.

Tanaka, Y. 1984. Assuring seed quality for seedling production: cone collection and seed processing, testing, storage, and stratification. In: Forest Nursery Manual: Production of Bareroot Seedlings (M. L. Duryea and T. D. Landis, eds.). Martinus Nijhoff/Dr. W. Junk Publishers, The Hague/Boston/Lancaster: 27-39.

Venator, C. R. 1973. The relationship between seedling height and date of germination in Pinus caribaea var. hondurensis. Turrialba 23: 473-474.

Wakeley, P. C. 1954. Planting the southern pines. U.S. Department of Agriculture Agric. Monograph 18. Washington, DC. 233 p.
Wynens, J. and T. Brooks. 1979. Seed collection from loblolly pine. Georgia Forestry Commission Res. Pap. 3. Macon, GA.
Zoerb, M. H., Jr. 1969. Clonal variation in time of cone ripening in loblolly pine. Union Camp Corp. Woodlands Res. Note 22. 3 p.