Twenty Years of Natural Loblolly and Shortleaf Pine Seed Production on the Crossett Experimental Forest in Southeastern Arkansas

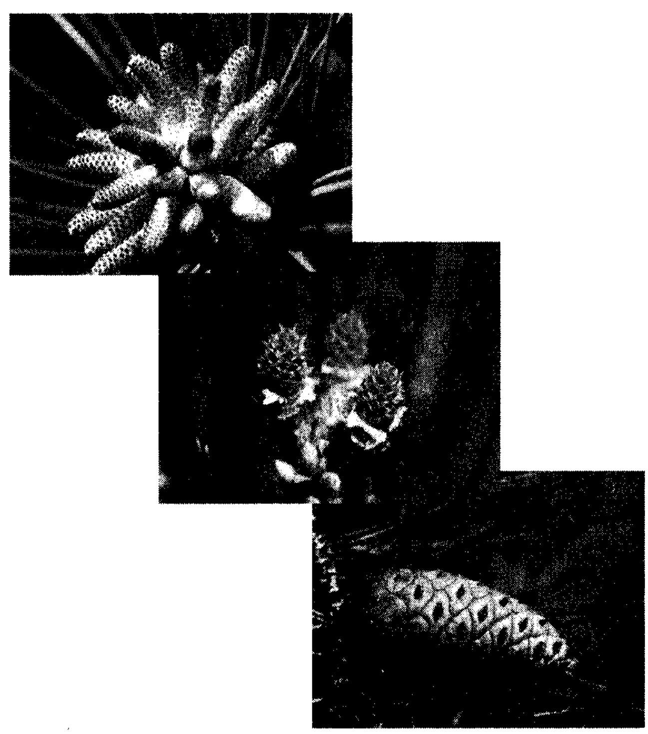
Michael D. Cain, *and* **Michael G. Shelton,** *USDA Forest Service, Southern Research Station, P.O. Box 3.516, Monticello, AR 716.56-3516*

ABSTRACT: (Pinus taeda ***L. and*** P. echinata ***Mill., respectively) seed crops were monitored for 20 consecutive years (1980–1981 through 1999-2000) using seed-collection traps in natural stands on the Upper Coastal Plain of southeastern Arkansas. Each seed-collection period began on October 1 and continued through the end of February of successive years. Sound seeds were separated from void seeds by use of a cut test. During 20 yr, sound seedproduction rangedfrom 0 to 2,000,000/ac. There were six bumper seed crops (>800,000 sound seeds/ac), nine good seed crops (40,000—800,000 sound seeds/ac), and five poor seed crops (<40,000 sound seeds/ac). Because no poor seed crops occurred back-to-back, the seed supply was adequate for successful natural pine regeneration over the entire monitoring period. During 8 yr of adequate seed production, when weekly seed counts were made, seed dispersal always peaked in early November; therefore, site preparation should be completed before November to maximize seedling catch. South. J. Appl. For. 25(1):40–45.***

Key Words: Natural pine regeneration, shortleaf pine, *Pinus* ***echinata*** Mill., loblolly pine, ***P. taeda*** L., seed crops, seed dispersal, uneven-aged management, Upper Coastal Plain.

Throughout the southeastern United States, the two most important pines for timber production are loblolly (*Pinus* ***taeda*** L.) and shortleaf ***(P. echinata*** Mill.). To sustain these pines in natural stands, four reproduction cutting methods are recognized: single-tree or group selection cuts, block or strip clearcuts, seed-tree cuts, and shelterwood cuts (Smith 1986). For private, nonindustrial forest landowners, an important advantage of natural versus artificial regeneration techniques is their low establishment cost (Barnett and Baker 1991).

Loblolly pine is a moderate seed producer, and shortleaf pine is less prolific than loblolly throughout their natural range (Barnett and Haugen 1995). Seed crops required for acceptable loblolly pine regeneration have been reported to range between 30,000 and 80,000 sound seeds/ac (Baker and Langdon 1990). However, we feel a more conservative range of between 40,000 and 90,000 sound seeds/ac for both loblolly and shortleaf pines is most likely to result in adequate natural regeneration when site and stand conditions favor pine establishment and growth.



In the spring, male and female flowers (upper left and center, respectively) of loblolly and shortleaf pines are crucial for producing a seed crop in maturing cones (lower right) 18 months later.

NOTE: Michael D. Cain is the correspondence author, and he can be reached at (870) 367-3464; Fax: (870) 367-l 164; E-mail: mcain@fs.fed.us. Manuscript received May 9, 2000, accepted August 8, 2000.

In a survey of seed production from southern pines, Wakeley (1954) reported years of heavy seed production and years of widespread failure, with no predictable pattern. This raises the question as to whether natural pine seed crops are dependable enough for landowners to rely on from year to year for regenerating their stands following harvest or natural disasters. In this article, we report 20 consecutive years of loblolly and shortleaf pine seed production that occurred in natural stands on the Crossett Experimental Forest, located on the Upper Coastal Plain of southeastern Arkansas. Results are presented in the context of managing stands for timber production by relying solely on these natural pine seed crops.

Methods

Study Area

In 1934, the Crossett Experimental Forest was established in the loblolly-shortleaf pine forest type of southeastern Arkansas as a USDA Forest Service research station. At that time, forest conditions were typical of understocked second-growth stands in southeastern Arkansas, northern Louisiana, and eastern Texas. Throughout the next 65 yr, the Experimental Forest was managed mainly for the production of high-quality pine sawtimber with pulpwood, poles, and pilings as secondary products. The principal reproduction cutting method was single-tree selection (Baker et al. 1996) in which the poorest quality trees were harvested during successive cutting cycles ranging from 3 to 10 yr. Pine basal area in merchantable-sized trees (>3.5 in. dbh) usually averaged from 60 to 80 ft^2/ac. Single-tree selection ensured that the best trees were retained to provide a seed source for natural regeneration while their merchantable value appreciated because of increased volume growth. When properly conducted, single-tree selection results in uneven-aged stands, and periodic regeneration of pines is crucial for creating or sustaining uneven-aged conditions (Shelton and Cain 2000).

The Experimental Forest contains 1,680 ac and is characteristic of productive sites for loblolly and shortleaf pines in the West Gulf region, which includes the Coastal Plain west of the Mississippi River and extends into East Texas and Oklahoma. Topography is flat to gently rolling. Soils are principally Providence and Bude (Typic and Glossaquic Fragiudalfs, respectively) silt loams, but also include Arkabutla (Aeric Fluvaquent) silt loam along ephemeral drains (USDA 1979). Site index for loblolly and shortleaf pines at age 50 yr ranges from 85 to 90 ft on Providence and Bude soils and 100 ft on Arkabutla soil. Annual precipitation averages 55 in., with seasonal extremes being wet winters and dry autumns. Daily temperatures average 72°F during the growing season (March-September) and 52°F during the dormant season (October-February}.

Seed Monitoring

In 1980, a monitoring system was set in place to assess the annual variability in pine seed crops on the Experimental Forest. All monitoring was done in uneven-aged pine stands except for the last 9 yr, when an unmanaged pine-hardwood stand (Cain and Shelton 1994) was included along with managed stands. Areas monitored for pine seed production were at least 5 ac. Since southern pine seed dispersal begins in autumn and is complete by the following spring, seed traps were monitored from October 1 to March 1 of successive years. An average of 29 seed traps was monitored each year.

Between 1980-1981 and 1992-1993, seedtrapsmeasured 2.18 ft^2 each (Grano 1973) and were monitored weekly. Beginning with the 1993-1994 seed year through the 1999-2000 seed year, seed traps measured 0.86 ft^2 each (Cain and Shelton 1993) and were monitored monthly. Whenever loblolly and shortleaf pine seeds were removed from these collection traps, they were separated by species and were judged as sound or void in accordance with a cut test (Bonner 1974) and species separation procedures described by Shelton and Cain (1996).

Data Analysis

Regression equations were developed using nonlinear least squares regression (SAS Institute Inc. 1988) for cumulative seed production during the year and percentage of total seeds that were sound. All presented regression coefficients significantly differed from zero at a probability of <0.05. Data for cumulative seed production consisted of 8 yr with sound seed production exceeding 40,000 seeds/ac from 1980 to 1992 when collections were made weekly. Weekly values were averaged for all monitored areas and accumulated by collection day for each seed year. Seedfall pattern was atypical for 1986, when 9 in. of precipitation were recorded during October and 13 in. during November; consequently, this seed year was dropped from the analysis. The independent variable for cumulative seed production was the number of days after October 1. The developed equation was solved for every day of the seed year, and successive values were subtracted to obtain the predicted daily rate. Percentage of total seeds that were sound was calculated from the mean values of all monitored areas for each of the 20 seed years. These values were regressed with total seed production (sound plus void) for the year. The reported tit index for the developed equations is analogous to the coefficient of determination reported for linear regressions.

Results and Discussion

Trends in Pine Seed Production

During 20 yr of seed collection, natural loblolly and shortleaf pine stands on the Crossett Experimental Forest produced an average of 175,000 sound seeds/ac (Figure 1). In the 1980s, 60% of the seed crops were below that average, while more than 175,000 sound seeds/ac were produced in 6 out of 10 yr in the 1990s. The increase in the number of sound seeds through time is partially attributed to ongoing management practices-competition control, harvest of poor quality trees during improvement cuts, and salvage of dead and dying trees-that enhanced overall forest health. These management practices coincided with initiation of the present study; whereas, in the 10 yr preceding this study, management of the Experimental Forest was of a custodial nature. During that decade, stands on the Experimental Forest became overstocked with pines and competing vegetation was not controlled (Cain and Shelton 2001).

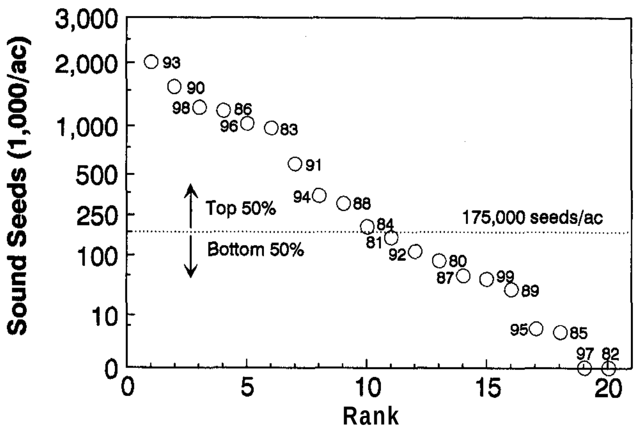


Figure 1. Numerical ranking of natural loblolly-shortleaf pine seed crops during 20 consecutive years (1980–1999) on the Crossett Experiment Forest in southeastern Arkansas. Year of seed crop shown adjacent to each symbol. V axis in cubed-root scale. The horizontal line represents the 20 year median of 175,000 seeds/ac.

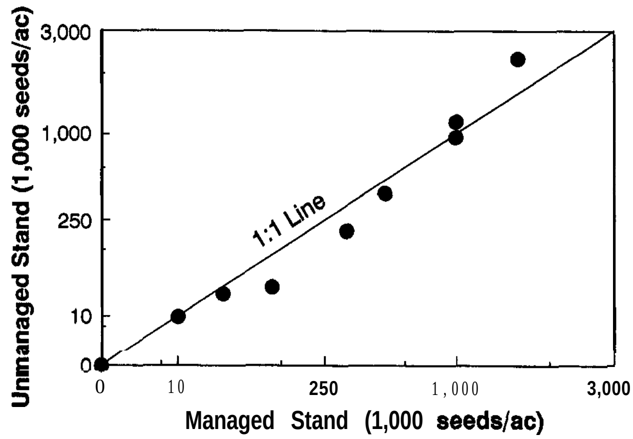


Figure 2. Relationship of sound seed production during 9 consecutive years for loblolly-shortleaf pines in an unmanaged pine-hardwood stand as compared to an intensively managed uneven-aged pine stand in southeastern Arkansas. X and V axes are sound seeds/ac in cubed-root scale.

In southern pines, more than 2 yr elapse between flower initiation and seed maturity. During that time, at least five chemical and physiological mechanisms contribute to the pine reproductive cycle: hormones, nutrients, soil moisture, light, and temperature (Barnett and Haugen 1995). To some extent, forest managers can manipulate certain stand conditions that influence seed production. On the Experimental Forest, the best pines-dominant and codominant trees with large, dense crowns-were retained for timber production, which was also favorable for seed production. Selection criteria for seed trees also included tree age (30-t yr), stem diameter (>12 in. dbh), and evidence of past cone production. However, in addition to tree and stand factors, seeding of southern pines will also vary by species, physiographic region, and climate.

In general, seed production from individual trees of loblolly and shortleaf pines can be enhanced in natural stands by thinning (Wenger 1954, Allen and Trousdell 1961, Yocom 1971) and controlling competition (Wittwer and Shelton in press). Thinning a pine stand to release crowns and controlling hardwoods usually increases seed production by improving light, nutrient, and soil moisture conditions for residual cone-bearing trees. Yet these practices do not always produce desired results. For example, Shelton and Wittwer (1996) found that shortleaf pine seed crops from stands thinned to create seed-production areas produced no more seed in 9 yr than did woods-run stands in the Ouachita and Ozark Mountains of Arkansas and Oklahoma. In this study, an unmanaged loblolly-shortleaf pine-hardwood stand that averaged 99 and 63 ft^2/ac in merchantable-sized pine and hardwood basal area, respectively, produced as many pine seeds during 9 consecutive years as did an adjoining but intensively managed uneven-aged loblolly-shortleaf stand that averaged 60 to 80 ft^2/ac in merchantable-sized pines and no merchantable-sized hardwoods (Figure 2). Although seed production was similar in these stands, the managed stands apparently produced more sound seeds per tree.

In dense, young stands that have regenerated naturally, loblolly pines tend to outperform shortleaf in growth (Cain 1990). But once the trees mature, growth and development of these two species are more alike than different when growing on good sites (USDA Forest Service 1976). Moreover, both species appear to have comparable seed production when growing on good sites. In addition to monitoring seed crops in mixed loblolly-shortleaf pine stands, we also monitored pine seed crops in pure loblolly and pure shortleaf stands for 10 consecutive years. Although there were two seed crop failures during these 10 yr, loblolly pines outproduced shortleaf in 3 yr, and shortleaf outproduced loblolly in 5 yr (Figure 3). But seed-crop failures are common on drier sites such as occur in the Ouachita and Ozark Mountains, where site index is less than 65 ft at 50 yr for shortleaf pines. During 9 yr of monitoring shortleaf pine seed crops on these Interior Highland sites, Shelton and Wittwer (1996) reported four consecutive years (1968-1971) that were judged as poor (10,000–30,000 sound seeds/ac) or failures (< 10,000 sound seeds/ac). Likewise, Cain (1995) found that another Ozark Mountain shortleaf pine stand produced seed-crop failures (<3,000 sound seeds/ac/yr) during 3 consecutive years (1990–1992). When natural reproduction cutting methods are planned on sites where adequate pine seed-crop production has an epi-

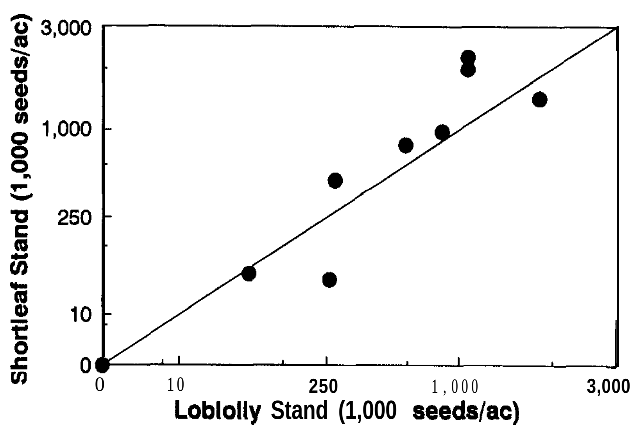


Figure 3. Relationship of sound seed production during 10 consecutive years for shortleaf pines versus loblolly pines in pure natural stands in southeastern Arkansas. Two points overlap at the origin. X and V axes in cubed-root scale.

sodic history, forest landowners may need to forecast potential cone crops (Trousdell 1950, Shelton and Wittwer 1995) several months in advance of seed dispersal.

Periodicity of Pine Seed Crops

Throughout the South, the frequency of good seed crops has been reported to be 3 to 6 yr for both loblolly pine (Baker and Langdon 1990) and shortleaf pine (Lawson 1990). Yet, during 20 consecutive years of monitoring on the Crossett Experimental Forest, adequate pine seed crops occurred about every 2 yr. Good pine seed crops (40,000 to 800,000 sound seeds/ac) tended to alternate with poor seed crops (~40,000 sound seeds/ac) at 1 to 2 yr intervals and occurred nine times in 20 yr (Figure 4). Moreover, bumper seed crops in excess of 800,000 sound seeds/ac occurred six times in 20 yr. Poor seed crops occurred five times in 20 yr, and there were no back-to-back seed-crop failures. So, pine seed production was adequate for natural regeneration 75% of the years.

The qualitative seed-crop ratings in Figure 4 are based on the number of sound seeds/ac, with an average seed crop (40,000 to 90,000 seeds/ac) being needed to adequately regenerate an area under average conditions. For example, on a scarified seedbed in an average seed year, only 40,000 sound seedslac may be needed to produce adequate regeneration. In contrast, 90,000 sound seeds/ac may be needed to produce the same density and stocking of pine seedlings on a site with a high proportion of herbaceous ground cover or logging slash.

Annual variation in pine seed crops far exceeds the manager's ability to influence seed production. For example, hail storms (McLemore 1977), frosts (Campbell 1955, Hutchinson and Bramlett 1964), and droughts (Schmidtling 1985) have been shown to be detrimental to pine seed crops. In addition, variation in seasonal rainfall and temperature during flowering appear to affect seed production of loblolly and shortleaf pines (Cain and Shelton 2000). Pine seed losses have also been attributed to squirrels (*Sciurus* spp.), lethal gene combinations, lack of pollen, self-pollination, and insects (Bramlett 1972, Fatzinger et al. 1980).

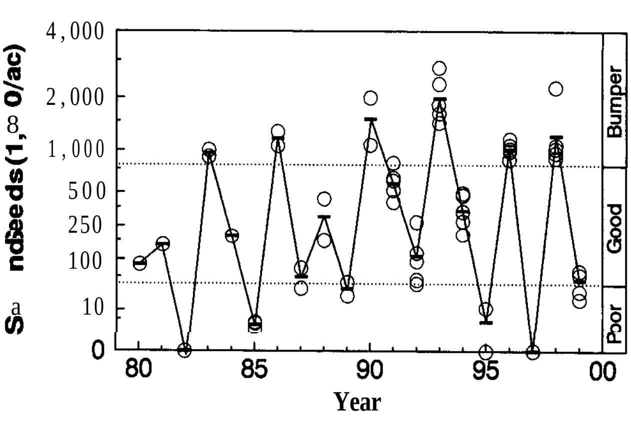


Figure 4. Periodicity of natural loblolly-shortleaf pine seed crops during 20consecutiveyears in southeastern Arkansas. Subjective seed-crop ranking in sound seedslac: poor <40,000; good from 40.000 to 800,000; and bumper >800,000. Y axis in cubed-root scale. Open circles represent individual stands and dashes represent means.

Depending on ground cover from competing vegetation, seedbeds may remain receptive for 2 yr on good sites (site index >85 ft) and perhaps longer on poorer sites (site index <65 ft), thereby increasing the probability of successful seedling catch from successive seed crops. For example, Trousdell(1954) found that in Virginia, favorable seedbed conditions for loblolly pine disappear 3 yr after logging. If we assume that 90,000 sound seeds/ac represent the upper threshold of seeds needed for successful natural regeneration on average sites, then the 2-yr sums of sound seeds/ac produced on the Crossett Experimental Forest were more than adequate for pine regeneration success throughout this 20 yr investigation (Figure 5).

Pine Seed Dispersal and Soundness

When relying on natural pine seed crops for regeneration, both the periodicity of dispersal and the relative soundness of the seeds are important considerations. During the 20 consecutive years that pine seedfall was monitored in this study, seeds were collected from traps on a weekly basis during the first 13 yr, 8 of which produced good to bumper seed crops (i.e., >40,000 sound seeds/ac). For those years, peak seed dispersal occurred in early November, and seed dissemination was 90% complete by the end of December (Figure 6). During poor seed years (~40,000 sound seeds/ac), timing of peak seed dispersal in autumn and winter is less predictable (Cain 1991). Autumn is generally the driest season of the year throughout the southeastern United States and is characterized by low relative humidity and light to moderate northwesterly winds as dry cold fronts pass through the region. These weather conditions promote the opening of mature cones in pine crowns and enhance seed dissemination.

Trends in seed dispersal for loblolly and shortleaf pines appear to be consistent throughout the southeastern United States. For example, an 8 yr evaluation of loblolly pine seed production and dispersal in North Carolina (Jemison and Korstian 1944) indicated that seedfall peaked in early November and was 84% complete by the end of December. Other investigations of loblolly and shortleaf pine seed dispersal in North Carolina (Pomeroy and Korstian 1949, Allen and Trousdell 1961), northern Louisiana (Campbell 1967), southeast Arkansas (Grano 1971), and east Texas (Stephenson

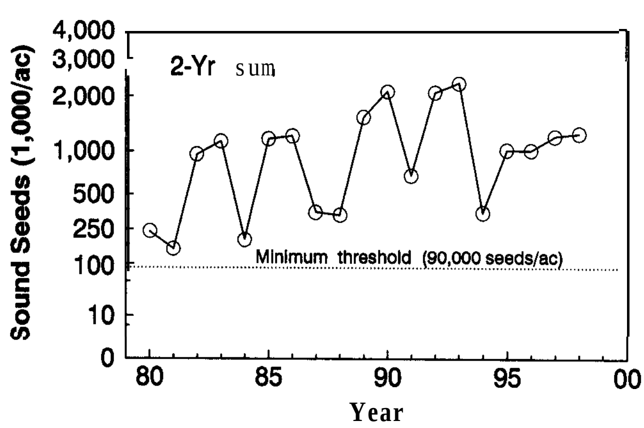


Figure 5. Two-year cumulative total for sound seed production during 20 consecutive years from natural loblolly-shortleaf pine stands in southeastern Arkansas. Y axis in cubed-root scale.

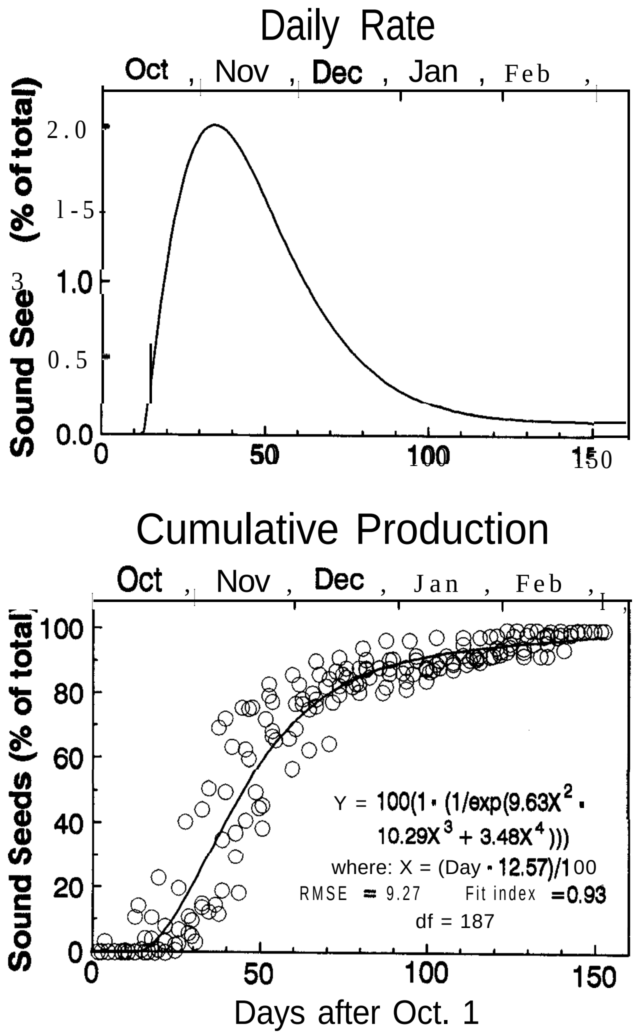


Figure 6. Seed dispersal pattern from natural loblolly-shortleaf pine stands during 8 yr when natural seed crops were monitored on a weekly basis. In the regression equation, Y = sound seeds expressed as a percent of total sound seeds; *X* = number of days after October 1; and RMSE = root mean square error.

1963) have also shown peak seedfall in November with 81%–92% completion by the end of December.

The percentage of sound pine seeds was well correlated with annual pine seed production on the Experimental Forest (Figure 7). This relationship probably occurs because good seed crops generally reflect a favorable environment for flower and cone development and because pest populations have a limited potential to damage the better seed crops. The regression equation indicates that percentage of sound seeds is nearly zero for seed-crop failures, increases rapidly through about 400,000 total seeds/ac, and thereafter asymptotically approaches 69% for larger seed crops. This relationship between seed crop size and seed soundness is consistent with that reported by Allen and Trousdell (1961), who found that seed soundness approached 70% when total seed production from loblolly pines averaged 500,000 seeds/ac.

Management Implications

The value of pine seed-crop and seed-dispersal information becomes apparent when forest landowners schedule harvesting and site preparation treatments for natural regeneration. To obtain maximum seed catch, site preparation treatments for naturally regenerating loblolly and shortleaf pines should be complete by late summer or early autumn to coincide with the time of peak seedfall, and should be done only when adequate seed crops are predicted (Cain 1987). A current year's seed crop can be predicted from cone counts made by viewing crowns of standing trees with binoculars beginning in mid-July, when maturing cones approach their full size and are yellowish green in color (Shelton and Wittwer 1995). Due to the sun's angle, maturing cones are most easily seen during early morning or late afternoon on sunny days. When bumper seed crops (>800,000 sound seeds/ac) occur, timing of site preparation (e.g., prescribed burning) can possibly be extended into the winter months because an average year's seed crop may be dispersed after such treatments are applied (Cain 1986, 1991). In addition, the intensity of site preparation can often be less when treatments coincide with bumper seed crops. Even so, scheduling of harvesting activities for optimum natural regeneration can be difficult for private nonindustrial forest landowners because timber-sale contracts may extend over 2 yr and stumpage prices often vary by season. Under these circumstances, more intensive site preparation may be needed in advance of the next good seed crop to facilitate pine seedling establishment. This is especially true on good sites that are rapidly occupied by herbaceous vegetation (grasses, vines, forbs, and semiwoody plants) after harvest. By following the basic tenets of proven silvicultural techniques, forest landowners should be able to rely on natural pine seed production to regenerate cutover or partially harvested pine stands on Coastal Plain sites.

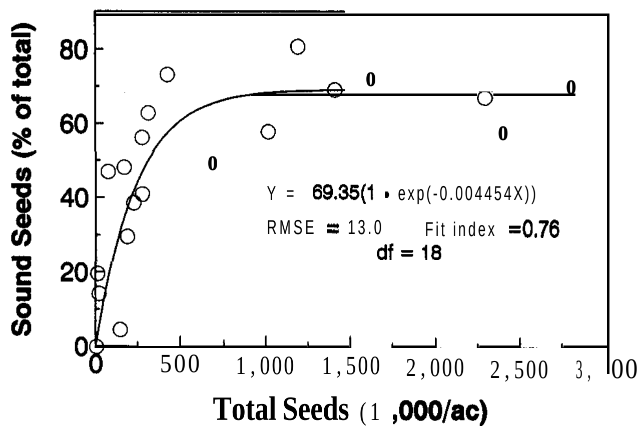


Figure 7. Relationship of sound seeds to total seeds (sound + void) based on 20 consecutive years of seed production from natural loblolly-shortleaf pine stands in southeastern Arkansas. In the regression equation, Y = yearly sound seed production expressed as a percent of yearly seed total (*X*); and RMSE = root mean square error.

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