REGENERATING SHORTLEAF PINE: RESULTS OF A 5-YEAR COOPERATIVE RESEARCH INITIATIVE

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ABSTRACT.—Shortleaf pine (*Pinus echinata* Mill.) is unique among the southern pines. It has the widest natural range and thrives on shallow rocky soils of the Interior Highlands, where most other pine species perform poorly. Although wood quality is excellent, it has been one of the most neglected species from both research and operational standpoints. It has a history of poor performance following outplanting with survival of less than 50 percent. The technology to change this situation was developed after formation of the Shortleaf Pine Artificial Regeneration Taskforce in 1984. Over a 6-year period, 15 studies were installed in Arkansas and Oklahoma to address seedling production and establishment. Information resulting from these studies resulted in increased seedling survival in both the Ozark and Ouachita National Forests. This paper summarizes research from these and other studies that led to the improved success in reforestation of the species.

INTRODUCTION

A limited number of studies have focused on the regeneration of shortleaf pine (*Pinus echinata* Mill.). Many sites that were originally forested with shortleaf pine have been regenerated with loblolly pine (*P. taeda* L.) because of loblolly's higher productivity on Coastal Plain soils. As a result, shortleaf pine has received little research and operational emphasis. During the 1970s and 1980s, the Ouachita National Forest in Arkansas and Oklahoma, and Ozark National Forest in Arkansas, developed major artificial regeneration efforts with shortleaf pine on their difficult highland sites. Traditionally, loblolly pine reforestation techniques were used as a model for shortleaf pine reforestation. Resulting regeneration success of this species was poor with survival typically averaging 50 percent or less (Walker 1992). The low success achieved with this loblolly pine-oriented approach became a major concern of U.S. National Forest System silviculturists, who concluded that there were research opportunities for developing the knowledge necessary to improve the field performance of planted shortleaf pine.

THE SHORTLEAF PINE ARTIFICIAL REGENERATION TASK FORCE

In late 1984, a group of 18 specialists representing USDA Forest Service management and research, the Weyerhaeuser Company, the Arkansas Forestry Commission, Oklahoma State University, and Louisiana State University met in Hot Springs, AR, to discuss the problems of shortleaf pine regeneration. The objectives of the session were (1) to identify causes of poor survival of planted shortleaf pine seedlings in the Ouachita and Ozark Mountains; (2) to determine research priorities for solving the problems of poor survival; and (3) to determine who could best work on each of the priority problems. The group agreed to form an ad hoc effort, the Shortleaf Pine Artificial Regeneration Task Force to be led by James Barnett and John Brissette of the USDA Forest Service's Southern Forest Experiment Station laboratory in Pineville, LA, to address these research needs.

The areas of research considered to be productive included: forest genetics, seed processing and handling, seedling production, seedling handling and storage, and stand establishment. Although all of these concerns had merit, the task force members felt that seed and seedling quality should have the highest research priority, and the initial research emphasized these topics. Determining optimum stratification or prechilling lengths was the highest-priority topic under seed quality. Identifying and evaluating seedlings that would perform well under stressful field conditions was considered important. So was determining differences in growth responses to nursery culture by families, so that families with similar growth patterns could be grouped together for improved seed efficiency and seedling uniformity. Another high-priority question concerned the best timing (as determined by budset and root growth potential) of lifting and storage to ensure good performance under stressful conditions.

During the 5+ years of the Task Force's effort, most of these topics were addressed to some extent. The purpose of this paper is to present a summary of these (Brissette and Barnett 1992) and other pertinent study results.

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SEED PRODUCTION

An early consideration in any reforestation program is the selection of superior seed sources for the region. Wells and Wakeley (1970) published guidelines for moving shortleaf pine seed. Most sites in the Arkansas and Missouri highlands should be replanted from local sources, or seed from east and north of the planting sites (Lantz and Kraus 1987). Tauer and McNew (1985) found relatively small variability among provenances and large variability among families. Schmidtling (2001) recently updated the recommendations for moving shortleaf pine seed sources (Fig. 1). Seedlings will survive and grow well if they come from any area having a minimum temperature within 5 ºF of the planting site's minimum temperatures. East-west transfers within temperature isotherms are usually successful. Southern movement of sources across one 5 ºF isotherm will generally result in faster growing seedlings (Schmidtling 2001).

Sufficient seed orchards are present to provide genetically improved sources (Mexal 1992). Seed collecting, handling, and processing may affect seed quality. Seed maturation varies by half-sib family and there is variation in dormancy, which can be measured by speed of germination (Barnett and McLemore 1970, McLemore 1969). Few studies have evaluated the effects of cone maturity on seed extraction and viability, and guidelines (when cone specific gravity reaches 0.89 or less) by Wakeley (1954) are generally followed.

Seed storage for shortleaf pine is usually not a problem. Barnett and Vozzo (1985) reported the maintenance of viability for 50 years under less than ideal conditions. Proper seed treatment maximizes the proportion of seed resulting in seedlings optimal for the outplanting site—target seedlings. Treatments include: clonal collection, sizing seed to improve uniformity, and prechilling to speed emergence. Implementing these techniques improves not only nursery practices, but also improves long-term growth and yield (Mexal 1992).

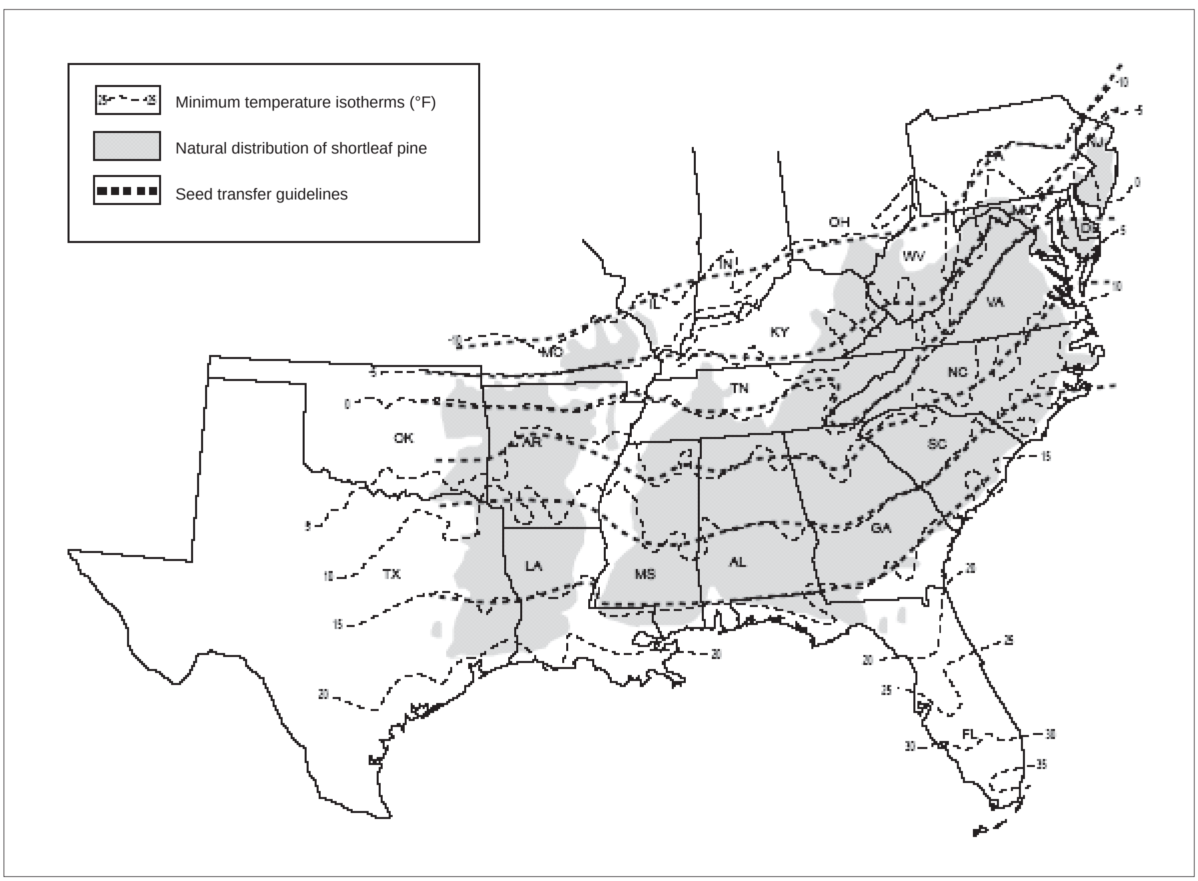

Figure 1.—Shortleaf pine distribution with seed transfer guidelines based on minimum temperature isotherms. Within isotherms movement east-west is usually successful (Schmidtling 2001).

NURSERY PRODUCTION

Significant advances in shortleaf pine seedling culture have been made over the last 40 years. As a result, target seedling specifications for bareroot stock have become more restrictive (Table 1). Standards for root/shoot (R/S) ratios and number of lateral roots have been developed (Mexal 1992). These data have been compiled from a number of studies over the years. Early studies were influenced by the small seeds of the species. Seedlings were grown at high seedbed densities (>500/m^2) (Wakeley 1954). As a result, seedlings were small when lifted, and survival after outplanting was often low.

Seed Treatment

Seed treatments should maximize the proportion of the seed that uniformly germinates and results in target seedlings (Barnett 1996). If collecting, processing, and storing activities result in good initial seed quality, seed treatments can enhance seed performance. Treatments may include: clonal collection and sowing, removal of empty and damaged seeds, sizing to improve uniformity, and stratification to speed emergence. Clonal collection, removal of empty and damaged seeds, and sizing are techniques commonly used to improve the uniformity of seedling germination and development of any southern pine species. Although seed sizing may improve germination of some portion of the seed lot, seed sizing improves uniformity of germination within the different sizing categories.

Stratification or prechilling recommendations are specifically developed for each species. However, this treatment is often inappropriately applied. Stratification treatments are usually based on laboratory tests that invariably indicate that 30 days of treatment result in the highest germination (Barnett 1992). However, the minimum length of stratification is longer, often 60 days, if the tests in the laboratory are conducted under lower temperatures that reflect actual nursery conditions.

The objective of stratification is to overcome dormancy and thus improve both amount and uniformity of germination, thereby increasing the number of target seedlings in the nursery. Stratification speeds germination, which permits earlier seedling establishment. Seedlings that emerge earlier in the season are more likely to survive and meet target seedling standards at harvest (Fig. 2). Seedlings emerging during the first 2 weeks after sowing were the largest at the end of the growing season, and accounted for 60 percent of the germinants meeting planting specifications (Barnett 1992).

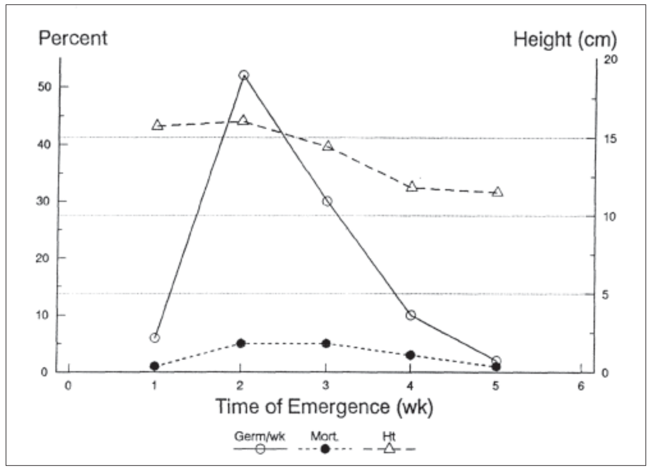

Figure 2.—Effect of time of emergence on mortality and height after one growing season of shortleaf pine seedlings (after Barnett 1992).

Table 1.—Changes in target shortleaf pine bareroot seedling specifications from 1954 to 1991 (Mexal 1992).

Parameter	Mexal and South 1991	Anon. 1989	Barnett et al. 1986	Wakeley 1954
Shoot height (cm)	15-25	20	15-25	10-30
Root collar dia. (mm)				
Cull	<4.0	--	<2.5	<3.0
Optimum	<5.0	<4.8	2.5-5.0	>3.0
Root/shoot ratio	>0.4	0.4	0.4	--
Lateral roots (no.)	>7	>5	7	--
Tap root length (cm)	--	15	10-20	--
Terminal bud	--	Present	Well developed	Present
Mycorrhizae	Many	Abundant	--	--

Seedling Quality

Seedling quality refers to seedlings that when planted will survive and show acceptable growth. The nursery system that produces quality stock incorporates the latest research information and applies it through the best technology available. Such technology for shortleaf pine includes: seed treatment as discussed in the previous section (Barnett 1992), sowing early and growing at low seedbed densities (about 200/m^2) (Brissette and Carlson 1987), and fertilizing at moderate rates of nitrogen (Brissette et al. 1989).

The aforementioned recommended nursery practices usually increase the size of shortleaf pine seedlings, and improve the balance between R/S biomass (Mexal 1992). The importance of the R/S in survival of loblolly pine seedlings was demonstrated by Mexal and Dougherty (1982). Research by Brissette and Barnett (1989) indicates it can also predict early growth of shortleaf pine (Fig. 3).

Shortleaf pine seeds collected from six half-sib families were grown as both bare-root and container stock and outplanted on two sites in the Ouachita Mountains of Arkansas. Survival and growth were measured at years 1, 3, 5, and 10 after planting. When outplanted, the bare-root seedlings had greater mean height and root-collar diameters than the container seedlings. However, the container seedlings had greater mean root volume and more favorable R/S ratios than the bareroot stock. Height growth of container and bareroot seedlings was correlated with R/S ratio following planting. Survival of both stock types was excellent, exceeding 90 percent after 10 years. The container stock performed consistently better than the bareroot at each interval measured, but there were no statistically significant interactions between stock type and half-sib family at 3, 5, or 10 years (Barnett and Brissette 2004).

Although visible presence of mycorrhizae on pine seedling roots has been known to improve survival for many decades (Jorgensen and Shoulders 1967), inoculation of seedlings in the nursery usually is not necessary (Mitchell and South 1992). Inoculation by airborne spores occurs in most nurseries within pine forest types. Harsh nursery lifting techniques can strip much of the visible mycorrhizae from seedlings and reduce survival.

SEEDLING CARE AND HANDLING

Care and handling activities include timing of lifting, sorting, length of storage, method of storage, and transportation. The handling practices for shortleaf pine might be expected to be similar to loblolly pine (Mexal 1992); however, Venator (1985) found shortleaf pine was sensitive to storage. Although unstored seedlings maintained fairly uniform survival when outplanted from early November through early April, seedlings stored 30 days at 36 ºF survived poorly when planted in November, March, and April (Hallgren 1992). Survival of seedlings stored 30 days averaged 10 percentage points lower than just-lifted seedlings during the optimum planting season (Fig. 4).

Ability to regenerate new roots is apparently correlated with survival of shortleaf seedlings. Brissette and others (1988) found root growth potential (RGP) of shortleaf pine sensitive to chilling hour accumulation (0 to 8 ºC at 200 mm above the ground). When lifting date was expressed in accumulated chilling hours, maximum RGP after lifting occurred after 610 hours, but no strong interaction occurred with cold storage. Hallgren (1992) did report maximum RGP following storage for seedlings lifted after 700 hours of chilling.

Improving storage life of shortleaf pine seedlings by treating the roots with a clay slurry-fungicide (Benomyl®) coating at packing significantly increased field survival. Barnett and others (1988) reported that treated seedlings could be stored for 6 weeks with no reduction in survival (Fig. 5). Survival

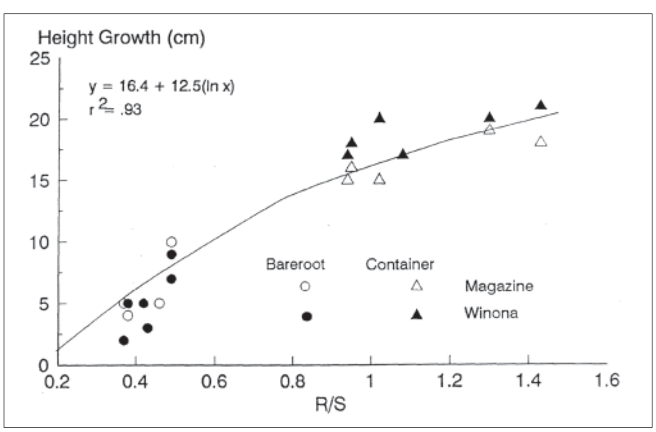

Figure 3.—Relationship between R/S and first-year height growth of bareroot and container shortleaf pine seedlings (after Brissette and Barnett 1989).

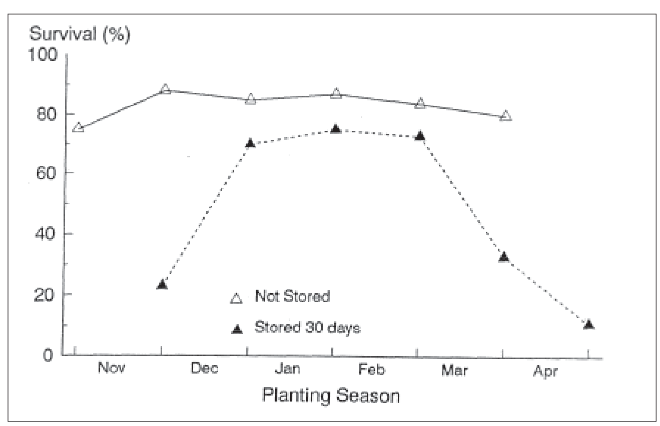

Figure 4.—Effect of lift date and 0-day or 30-day storage on the survival of shortleaf pine seedlings in Arkansas and Oklahoma (after Hallgren 1992).

of nontreated seedlings was reduced 15 percent after only 3 weeks, and 60 percent after 6 weeks of storage. These results with shortleaf pine were confirmed in a study by Hallgren (1992).

Although there was a strong effect of seedling storage on survival, growth following outplanting was not related to storage period or time (Hallgren 1992). Seedling heights after 2 years appeared more closely related to planting date. Maximum growth occurred for the December, January, and February plantings. Early planted seedlings provided greater opportunity for height growth the following spring and summer (South and Mexal 1984). In addition to reduced growth, planting late (mid-March and April) reduced growth 10 to 30 percent (Hallgren 1992).

SITE PREPARATION

Site preparation can be the most expensive activity in establishing a southern pine forest (Dougherty 1992). As with most expenditures, you usually get what you pay for. The key is to select those practices that are most appropriate for the site and species. Two practices that are commonly used for shortleaf pine regeneration on mountainous sites are ripping and chemical weed control (Mexal 1992). Ripping has been a common practice in the Ouachita Mountains for the last three decades (Sossaman and others 1980). The ripper blades tend to pull large rocks from the trench and increase the proportion of soil in the opening. Ripping usually improves plantability and soil moisture as the trench serves as a catchment basin for water flow (Mexal 1992). However, results of some long-term evaluations of ripping indicate that site preparation burning alone is equally effective in improving seedling survival and growth (Gwaze and others, in press).

Mountainous sites are typically droughty, and chemical weed control improves soil moisture by removing the vegetation that would otherwise increase stress due to competition. Yeiser and Barnett (1991) found that the growth response of shortleaf pine to weed control will last 2 years following either spot or total chemical application. The improved performance is likely due to improved water relations and light availability. In this study, total weed control was superior to spot control, but some weeds may actually protect shortleaf from severe infestations of tipmoth (*Rhyacionia frustrana* Cornstock) (Mexal 1992).

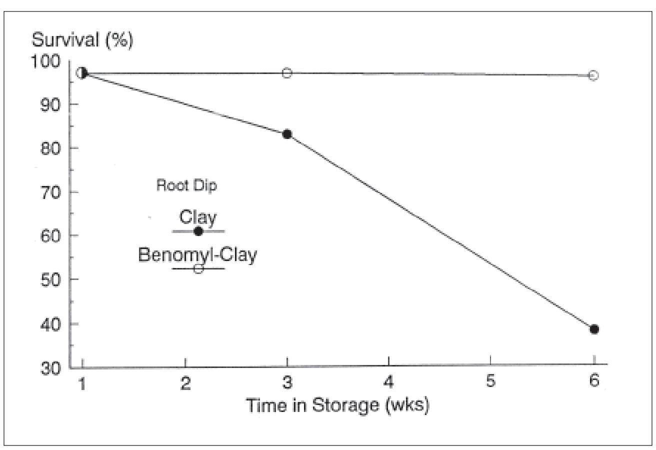

Figure 5.—Improvement in survival of stored shortleaf pine seedlings following treatment with Benomyl® (after Barnett and others 1998).

PLANTING

Successful reforestation requires a system of quality control through all phases of establishment. Poor planting can result in poor survival and reduced growth and yield, or both. Early evidence of poor planting is not always apparent (Mexal 1992). Harrington and others (1987) found that 30 percent of planted shortleaf pine seedlings lacked a taproot compared to 15 percent for seedlings seeded in place. Seedlings with a vertical taproot exhibited greater height growth than trees with root systems deformed by spiraling or shallow planting.

Harrington and others (1989) conducted additional studies on root orientation of surviving trees, but did not relate root deformation to survival. Brissette and Barnett (1989) found that deformation decreased survival of loblolly pine seedlings. Shallow planting was most detrimental, but J-rooting also decreased survival. Proper planting is key to improving survival and early seedling growth.

POST-PLANTING CARE

Regulating competition is probably the most important issue to address after planting to help achieve a successful plantation. Early weed control increases survival and growth (Yeiser 1992). Competition is commonly from grass, hardwood sprouts, and other planted pines. In a 12-year study reported by Cain and Barnett (2002), competition control from grasses and forbs increased survival by 68 percentage points for natural pines and 47 percent for planted pines. Volume gains of 150 to 200 percent were achieved after 12 years within the regeneration techniques as a result of release.

CONCLUSIONS

Successful artificial regeneration of shortleaf pine requires production of consistently uniform seedlings by either bareroot or container methods, adequate site preparation that improves the planting site, proper planting techniques, and control of competition for 1 or 2 years after outplanting. Successful establishment of shortleaf pine on its native sites is an accomplishment that is satisfying to many landowners in the highland areas of the South.

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