PINE SEED TREE GROWTH AND YIELD ON THE CROSSETT EXPERIMENTAL FOREST

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Abstract—In late 2002, three small tracts of loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pine on the Crossett Experimental Forest in Ashley County, AR, were cut using a seed tree method. Immediately after harvest, these cutting units averaged 7.7 stems and 13.8 square feet of pine basal area per acre. By 2006, live seed tree density dropped to 7.4 stems per acre, while basal area increased to 14.4 square feet per acre. Per acre residual sawtimber volumes initially averaged 2,076 board feet (Doyle) or 12.1 tons, increasing to 2,266 board feet (12.8 tons) after 3 full growing seasons. Due to an annual mortality rate of approximately 1.2 percent, net stand growth was low, averaging only 2.9 percent in board foot volume and 1.8 percent for sawtimber tonnage. However, individual seed trees fared noticeably better. For most, annual board foot growth ranged between 4 and 9 percent, and yearly sawtimber tonnage growth averaged between 3 and 6 percent. In general, small diameter seed trees added volume most rapidly and presented the lowest risk of mortality-based loss. Though modern harvesting techniques pose new challenges, seed tree management remains a viable alternative for mixed pine stands.

INTRODUCTION

Even though pine plantations are the fastest increasing forest type in the Southern United States, most regions are still dominated by naturally regenerated stands (Conner and Hartsell 2002). For landowners not interested in the relatively high impact treatments associated with plantations, seed tree harvests are an effective means to regenerate loblolly (*Pinus taeda*) and shortleaf (*Pinus echinata*) pine-dominated stands. Long-term observations have shown the efficacy of this technique in mixed pine forests in southern Arkansas and other regions (Cain and Shelton 2001a, Wahlenberg 1960, Williston 1987, Schultz 1997).

Over the years, most research on seed tree silviculture in loblolly and shortleaf pine forests has focused on ensuring pine regeneration (for example, Baker 1982, Grano 1949, Grano 1954, Lotti 1953). More than twenty years of experience on the Crossett Experimental Forest (CEF) has shown seed production in mature loblolly and shortleaf pine stands is rarely a limiting factor, with annual sound seed production averaging about 175,000 per acre (Cain and Shelton 2001b). Although there were some years that registered as unequivocal failures (less than 10,000 sound seeds per acre), 2-year cumulative totals during this period never fell below 100,000 sound pine seeds per acre, which is thought to be more than adequate to fully stock a properly prepared site (Cain and Shelton 2000, Cain and Shelton 2001b).

Given these decades of experience, it may seem that there is little worth studying in seed tree harvests of loblolly and shortleaf pine. However, only limited guidance has been provided on the growth, yield, and survivorship potential of the residual overstory following a seed tree harvest in this cover type. As with any silvicultural system dealing with a residual overstory, successful seed tree management involves balancing growth with the risk of loss. This paper focuses on the management of the residual trees, or overwood, using observations from a recent study of seed tree harvests.

METHODS

Study area

The Crossett Experimental Forest is located on the Upper West Gulf Coastal Plain in Ashley County, AR, approximately seven miles south of the city of Crossett and just north of the Louisiana state line. Slopes are < 5 percent across the entire forest and there are no permanent stream drainages. A thin loess cap covers most of the CEF and low, circular prairie mounds are common. Soils on the CEF fall into one of three main types: Arkabutla silt loams (Aeric Fluvaquents) along the ephemeral drainages; Providence silt loams (Typic Fragiudalfs) on the side slopes of the drainages; and Bude silt loams (Glossaquic Fragiudalfs) on the upland flats (Gill and others 1979, Shelton and Cain 1999). The three study sites were found on either Providence or Bude soils and are virtually level. Elevation of the CEF ranges from 125 to 135 feet above sea level, and the growing season is approximately 240 days, with an average annual precipitation of about 55 inches (Shelton and Cain 1999). Long-term climate records for the area show that there is no marked seasonality in precipitation, but it is not unusual to have dry periods in the late summer and fall, or wet winters and springs.

The presettlement upland forests of the region were largely old growth, with the composition being a relatively even mixture of loblolly and shortleaf pine and a scattering of hardwoods (Bragg 2002, Chapman 1913). The area that would eventually become the CEF was cleared of its virgin timber by the Hickory Grove Camp of the Crossett Lumber Company between 1915 and 1920 (Darling and Bragg 2008). The land then reseeded naturally over the next couple of decades, even though portions were repeatedly burned and heavily grazed until the property was leased to the Southern Forest Experiment Station in 1933 (Reynolds 1980). The CEF officially came into existence in 1934, and the stands were rehabilitated using a variety of low cost techniques. Over the years, the Forest Service acquired fee title to the property, and many of these stands have been managed and harvested for decades.

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The present day forests of the CEF are naturally regenerated stands of loblolly pine with a significant component of shortleaf pine. Management practices have kept hardwoods noticeably less common and largely restricted to areas along ephemeral streams, or occasionally in stands studied for mixed composition. For this study, the stands are managed exclusively for pine, and any hardwoods are eliminated when they start to compete with the pines. Pine seedling establishment is generally good to excellent on the CEF, especially when the logging activities clean the site and expose favorable mineral substrates. Competition from graminoids, forbs, vines, briars, shrubs, and hardwood trees can be intense on these relatively fertile sites, and the window of opportunity for good pine establishment rarely exceeds more than one or two growing seasons (Wahlenberg 1960, Williston 1987).

Silvicultural Treatments

The three parcels of interest were logged in November of 2002. Prior to harvest, these mature, even-aged pine stands had been thinned repeatedly. Generally similar in structure, composition, site, and age prior to their seed tree harvests, these stands were part of two different studies (fig. 1). The Block and Strip parcel (hereafter, B&S, 5.0 acres in size) is part of a demonstration on the potential of naturally regenerated pine stands to produce large quantities of timber over relatively short time periods. The other two tracts (hereafter, MOC1 and MOC2, both 4.4 acres in size) were replicates in a study of cutting methods, which is a long-term comparison of the productivity of different regeneration techniques (Cain and Shelton 2001a). Each stand was harvested using a conventional seed tree approach for loblolly and shortleaf pine forests. On average, parcels were cut to a residual density of 7.7 trees per acre and 13.8 square feet per acre of basal area.

Measurements and Analysis

Annual inventories have been conducted of each seed tree cut starting in spring 2003 and continuing every year to 2006. During these cruises, each pine seed tree was checked to see if it was still alive. Live trees had their diameter at breast height (d.b.h.) measured to the nearest 0.1 inch with a steel diameter tape. Pines that died were flagged in the records as deceased, and then no longer tracked. Because the focus of this project was on overwood growth, yield, and survivorship, no effort was made to track seed production. In the spring of 2006, increment cores were taken at d.b.h. from a sample of 7 to 10 seed trees from each stand spanning the range of diameters and, presumably, will approximate the current age structure of the parcels.

Individual tree volume estimates were produced using the following local formula (Farrar and others 1984):

$$V_D = 170.10568 - 37.68584\,d.b.h. + 2.34851\,d.b.h.^2 \quad [1]$$

where V_D is the board foot volume (Doyle rule). Since no height data were available at the time of the measurement, pine sawtimber weight estimates were derived by first using:

$$V_C = -92.48602 + 20.01464\,d.b.h. - 1.58044\,d.b.h.^2 + 0.06591\,d.b.h.^3 - 0.00088\,d.b.h.^4 \quad [2]$$

where V_C is the sawtimber cubic foot volume (Farrar and others 1984). Each cubic foot of pine sawtimber was assumed to weigh 64 pounds (green weight; Patterson and others 2004), so sawtimber tonnage was calculated as: (V_C × 64) / 2000. Per acre estimates of board foot volume and tonnage were arrived at by summing all values by parcel, and then dividing by the cutting unit acreage. Individual tree growth rates were also expressed as a percent. From the annualized percent growth increment for board foot volume, an exponential decay regression model was fit to generalize growth expectations of individual seed trees, using initial bole diameter as the independent variable.

Since the seed trees were chosen without regard to statistical design, it is inappropriate to make comparisons of significance between response variables. For example, even though both loblolly and shortleaf pines were retained as seed trees, contrasting differences in their growth rates would not be appropriate because there was no attempt to control for other sources of variation in their selection. All results will be discussed as case studies, since there were no other companion treatments using some other regeneration technique for comparison.

RESULTS AND DISCUSSION

Tree Size and Age

The somewhat older stands (average of 56 years, with some seed trees up to 70 years old) in this study had an average tree size of 285 board feet Doyle (including some stems over 500 board feet) (fig. 2). Not surprisingly, leaving almost eight seed trees per acre of this size guaranteed that relatively high volumes would be retained. In fact, given the size and age of the overstory of these treatment areas, the cutting units contained almost twice the residual volume as we conventionally recommend.

Stand Stocking and Mortality Patterns

In the spring of 2003, basal area averaged 13.8 square feet per acre across the three stands. Three years later, overwood pine basal area had increased to 14.4 square feet per acre (table 1). The gain came from seed tree basal area growth, not the recruitment of new trees. Stocking actually decreased slightly, with seed tree density dropping from 7.7 to 7.4 trees per acre during the same period, or an average annual seed tree mortality of about 1.2 percent. After three full growing seasons, mortality varied between stands, ranging from 0 percent to 8.1 percent of the initial seed tree number, with individuals succumbing to causes such as logging damage, lightning, and insects.

Over enough time, all of these sites will experience at least some mortality. However, given this low rate, there is little to be concerned about regarding long-term sustainability. During the observation period, no stand lost more than 3 total seed trees, and the highest annual mortality rate for any given cutting unit (MOC2) did not exceed 2.8 percent of the initial number of seed trees. At this rate, almost half the overwood would still remain 20 years after the regeneration harvest, and assuming a conservative growth rate of 3 percent per year and no salvage of dead seed trees, more than enough sawtimber should remain to provide for an operable cut. Even though individualistic mortality of seed

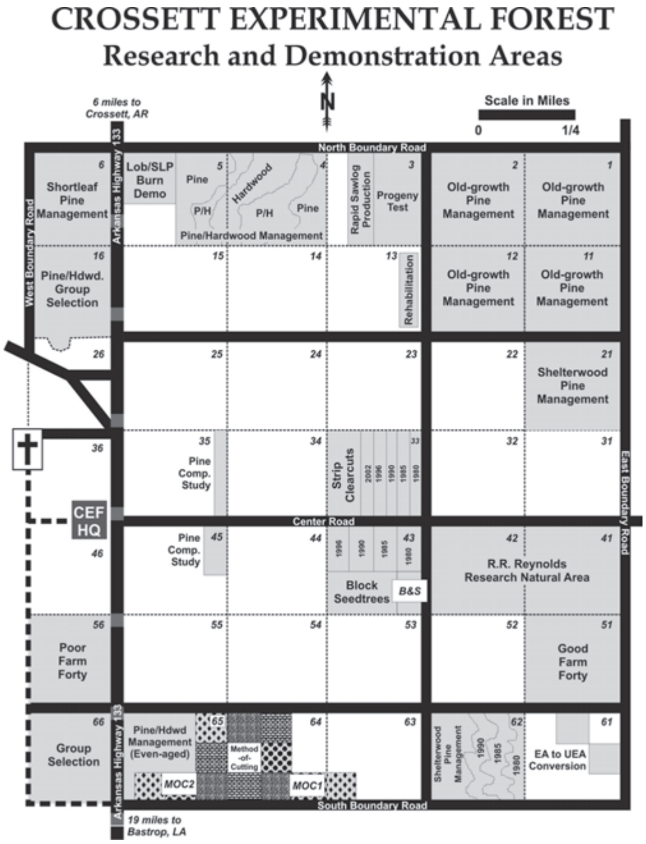

Figure 1—Map of the Crossett Experimental Forest in extreme southern Arkansas, with the three cutting units (B&S, MOC1, and MOC2) identified by italicized text.

trees is not a major problem, a catastrophic event—a severe windstorm, perhaps, could topple the exposed pines en masse and seriously impact the overwood.

Overwood Growth and Yield Performance

Per acre residual sawtimber yield averaged 2,076 board feet (Doyle) or 12.1 tons in 2003, increasing to 2,266 board feet or 12.8 tons, respectively, over the observation period (table 2). Individual cutting units produced anywhere from zero (or even slightly negative) net growth to as much as 165 board feet (0.70 tons, green weight) per acre per year, depending on growing conditions and the size of seed trees that died. However, on average, the cutting units added net growth of between 37 and 94 board feet per acre (0.12 to 0.38 tons per acre) per year during the observation period. This is somewhat less than the 148 board feet (0.8 tons) per acre per year reported in Cain and Shelton (2001a) for seed tree cuts on the CEF, but those stands were cut to 13 seed trees per acre. In contrast, fully stocked stands of approximately the same preharvest age (about 50 years) on similar sites produce about 400 to 600 board feet (2.1 to 2.6 tons of sawtimber per acre) per year (Cain and Shelton 2001a). While the understocked stands left after these seed tree cuts cannot be expected to perform like fully stocked stands, net growth was still positive. Furthermore, the yield of these stands was decidedly lower than its potential due to mortality losses, so stand-level realized growth averaged only 2.9 percent for board foot volume and 1.8 percent for sawtimber tonnage. However, most surviving seed trees fared noticeably better. For most, annual board foot Doyle growth ranged between 4 and 9 percent, and annual sawtimber tonnage growth averaged between 3 and 6 percent.

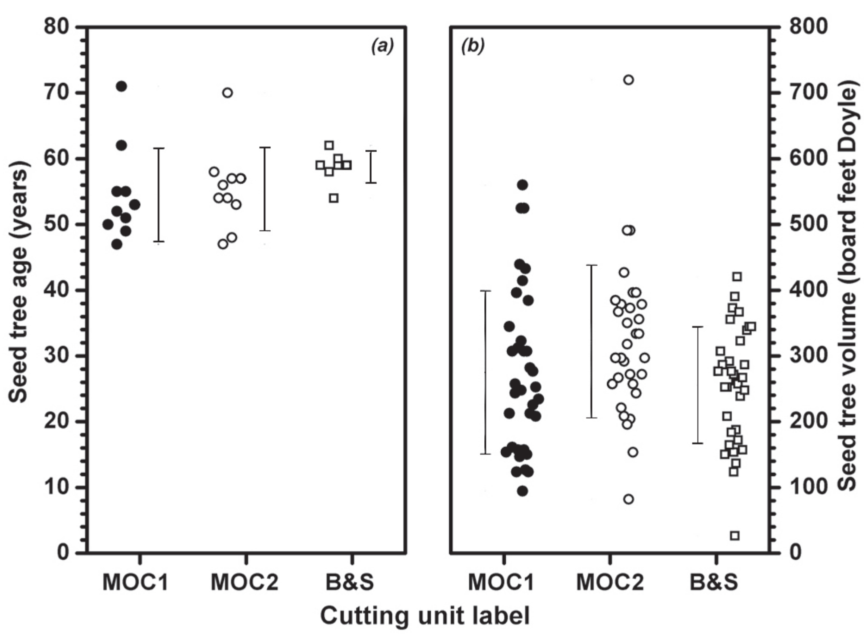

Figure 2—Sample seed tree age distribution by cutting unit *(a)* and range of initial tree board foot volumes for all pine seed trees (b) for this study on the Crossett Experimental Forest. The bars alongside each set of points represents plus or minus 1 standard deviation around the mean. Cutting unit labels follow discussion in text.

Table 1—Basic statistics of seed tree cutting units following regeneration harvest in November of 2002 (all measurements taken in the late spring of each year)

		Cutting unit				
Variable	Year	Block & Strip	Methods-of-cut #1	Methods-of-cut #2	Average of stands	Standard deviation
Live seed trees		---------- number/unit ----------				
Loblolly pine in	2003	37	29	27	31.0	5.29
Shortleaf pine in	2003	0	8	6	4.7	4.16
Loblolly pine in	2006	34	29	26	29.7	4.04
Shortleaf pine in	2006	0	8	5	4.3	4.04
Live seed trees		---------- number/acre ----------				
	2003	7.4	8.3	7.4	7.7	0.53
	2004	7.2	8.3	7.2	7.6	0.65
	2005	7.0	8.3	7.0	7.4	0.78
	2006	6.8	8.3	7.0	7.4	0.84
Live seed tree basal area		---------- square feet/acre ----------				
	2003	12.0	14.6	14.7	13.8	1.51
	2004	12.0	14.8	14.7	13.8	1.57
	2005	12.1	15.3	14.5	14.0	1.67
	2006	12.1	15.8	15.2	14.4	2.01
Cumulative dead seed trees		---------- number/unit (% of initial) ----------				
	2003	0 (0.0)	0 (0.0)	0 (0.0)	0.0 (0.0)	0.00 (0.00)
	2004	1 (2.7)	0 (0.0)	1 (3.0)	0.7 (1.9)	0.58 (1.66)
	2005	2 (5.4)	0 (0.0)	2 (6.1)	1.3 (3.8)	1.15 (3.33)
	2006	3 (8.1)	0 (0.0)	2 (6.1)	1.7 (4.7)	1.53 (4.22)

Table 2—Growth and yield of the pine seed trees on the three cutting units of the Crossett Experimental Forest

	Measurement year				Growing season		
Cutting unit	2003	2004	2005	2006	1	2	3
	---------- Net sawtimber yield (board feet/acre)[a] ----------				-- Net growth (board feet/acre) --		
Block & Strip	1740	1763	1805	1825	23	42	20
Methods-of-Cut #1	2168	2220	2353	2449	52	133	96
Methods-of-Cut #2	2322	2358	2358	2524	36	0	165
Average	2076	2114	2172	2266	37	59	94
Standard deviation	301.7	311.6	317.9	383.4	14.5	67.9	72.5
	---------- Net sawtimber yield (tons per acre) ----------				-- Net growth (tons per acre) --		
Block & Strip	10.4	10.4	10.5	10.6	0.04	0.13	0.01
Methods-of-Cut #1	12.7	13.0	13.6	14.0	0.24	0.60	0.43
Methods-of-Cut #2	13.2	13.2	13.2	13.9	0.07	-0.08	0.70
Average	12.1	12.2	12.4	12.8	0.12	0.22	0.38
Standard deviation	1.50	1.56	1.64	1.94	0.105	0.344	0.348

[a] Board feet, using the Doyle log rule.

An exponential decay model predicting annualized percent-based growth rates in terms of board foot volume (Doyle) based on initial tree diameter behaves in an expected manner—small diameter trees added increment at a considerably greater rate than large diameter pines (fig. 3). At least some of the higher rate of growth is due to the ability of small pines to more efficiently exploit resources following a regeneration harvest. However, much of this trend is due to how the change in growth rates was expressed. Since there is a base log diameter threshold for sawtimber (in this case, trees greater than 9.5 inches d.b.h.), the sharp initial decline of an exponential decay model is appropriate. After all, when expressed in terms of percentages, any tree crossing the threshold from sub-sawtimber (yield of zero) to minimal sawtimber experiences an infinite increase. The model also behaves reasonably as tree size increases—growth percentages will decline, substantially at first, then more gradually, approaching but never falling below zero. Linear functions (unless fitted piecewise for certain portions of the size class range) that follow this same basic pattern will eventually show negative growth, which is impossible.

The fit index (a non-linear analog to R^2) indicates that initial tree diameter accounts for slightly less than half of the variation in the data. Although more data near the extremes of the regression would be helpful in defining the curve, both the 95 percent prediction and 95 percent confidence bands are relatively narrow (fig. 3), suggesting that the general trend is acceptable. Given the nature of this study, it is virtually impossible to explain the noise, although it likely arose, in part, to factors such as logging-related damage, genetic variation in growth potential between individual seed trees, and events that have happened since the regeneration harvest—hardly controllable circumstances. However, some of the noise in the growth data may also be attributable to variation in initial crown density, which can be silviculturally manipulated. Grano (1957) reported that post-harvest growth of seed trees was related to the fullness of their crowns, with the diameter growth of denser crowned pines approximately 25 percent higher than less foliated individuals. Hence, it is conventionally recommended

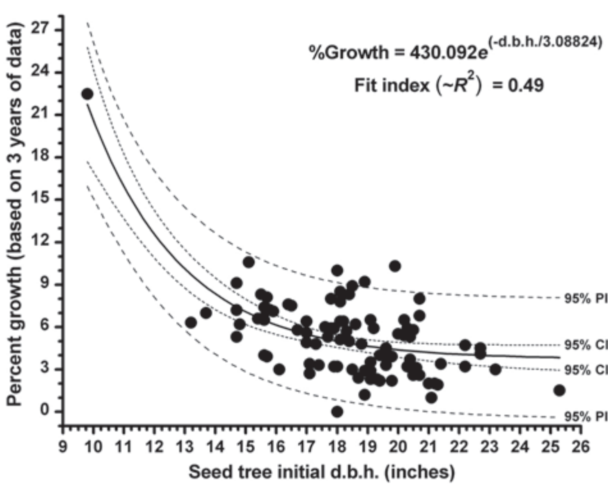

Figure 3—Annualized growth performance, measured as a percentage increase in board foot volume (Doyle) from initial d.b.h., for loblolly and shortleaf pine seed trees used in this study. 95 percent PI = 95 percent prediction interval, 95 percent CI = 95 percent confidence interval.

that pine stands to be regenerated with a seed tree cut be thinned several years prior to boost tree vigor and crown density. Unfortunately, no observations were made on crown density for the current study, making it impossible to verify if this contributed to any of the growth differences.

Overwood Silvicultural Lessons

Seed tree management provides many options for a landowner, depending on their silvicultural objectives, stand conditions, and site quality (Wahlenberg 1960). For a 40- to 45-year-old pine-dominated stand, we suggest landowners leave approximately 1,000 to 1,200 board feet (Doyle rule) per acre in quality seed trees (stems of at least 12 inches d.b.h. and of good form, with healthy crowns and abundant evidence of cones), and assume their volume can increase 6 to 8 percent per year. Hence, on a fairly typical site in southern AR and northern LA, the overwood will have increased to about 1,500 board feet per acre after 5 to 7 years (assuming no seed tree mortality). This level of cut is considered operable by most local logging crews, and should help to ensure that the overwood can be removed when desired.

It is possible to adjust the number and longevity of the seed trees following the regeneration harvest. For instance, in a 40- to 45-year-old stand, one can leave more overwood (perhaps starting at 1,500 board feet in 10 to 15 seed trees per acre) and then do a removal cut at three years. Under this circumstance, the landowner would want to be sure to cut the seed trees sooner, rather than later, because this quantity of overstory will likely provide too much competition with the pine regeneration as the new stand develops. In an older stand (for instance, more than 55 years) with larger seed trees, it is probably desirable to leave significantly fewer pines (as few as five or six per acre) to minimize how much timber value is risked in the overwood. This stand should also prove operable soon after the regeneration harvest, or can be left for considerably longer. However, I would caution against leaving too few seed trees, because attrition due to mortality is inevitable, and keeping at least some residual seed trees will greatly improve stand merchantability down the road.

Many foresters prefer early removal because it tends to minimize logging-related seedling mortality and the loss of economic value following to the death of seed trees. However, it is also possible to remove the overwood considerably later (12 to 20 years after the regeneration cut). In this study, the relatively large size of the seed trees (most are 90 to 100 feet tall) and their low density allows them to be retained for a long time. Unless clustered, the crowns of widely distributed seed trees are high enough above the forest floor so as to not provide serious competition for most of the younger trees. Even the loss of a limited amount of pine regeneration will have a negligible impact on the future crop trees because of the generally high stocking levels following seed tree cuts. It is important to note that even large diameter seed trees are capable of strong growth following the regeneration harvest, so unacceptably low growth performance by the overwood is not a major concern. For locations where seed crop failure, arson, or other forest health problems (for example, prolonged drought) can threaten newly established pine seedlings, the longer retention of the overwood also acts as a buffer against complete loss (Lotti 1953).

Assuming mortality is limited, waiting to remove the seed trees can also significantly bolster the sawtimber yield of the stand, and may turn what would have otherwise been a precommercial thinning into a commercial one. Grano (1961) reported on some seed tree harvests on the CEF that did not have the overwood cut following the regeneration harvest. In these stands, approximately 13 seed trees at least 10 inches in diameter per acre were retained. After 21 years, the stand was thinned for the first time, and over 6,800 board feet (International 1/4 inch rule) per acre of sawtimber was harvested, primarily from the old seed trees. Using techniques and equipment consistent with that period of time, less than 14 percent of the regeneration on these sites was lost to logging damage, even though 31 to 42 square feet per acre of pine greater than 10 inches d.b.h. were felled (Grano 1961). Modern mechanized operations may produce more damage, but if fewer seed trees are reserved and done in conjunction with a planned thinning, these losses can be controlled, especially if using directional felling and the tops are removed prior to skidding.

CONCLUSIONS

This study highlights some of the promises and challenges to using seed tree methods to manage loblolly and shortleaf pine stands in the Upper West Gulf Coastal Plain. Though stand-level growth was limited due to mortality, individual seed tree growth rates were strong. In general, the smallest diameter seed trees grew the fastest (in terms of percent volume) and represented the lowest risk of mortality-based volume loss. Given that seed production is rarely limiting in mixed loblolly/shortleaf pine stands, the silviculturist needs to weigh the risk of seed tree loss with the potential for future growth. Fortunately, the good regeneration that typically follows seed tree harvests, coupled with the commercial potential of the overwood, allows for many different options to be evaluated at the landowner's discretion, rather than forcing a particular decision because of the economic pressures of high establishment and maintenance costs.

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LITERATURE CITED

Baker, J.B. 1982. Natural regeneration of loblolly/shortleaf pine. In: [editor unknown]. Low cost alternatives for regeneration of southern pines. Athens, GA: Georgia Center for Continuing Education: 31-50.

Bragg, D.C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Journal of the Torrey Botanical Society. 129: 261-288.

Cain, M.D.; Shelton, M.G. 2000. Revisiting the relationship between common weather variables and loblolly-shortleaf pine seed crops in natural stands. New Forests. 19: 187-204.

Cain, M.D.; Shelton, M.G. 2001a. Natural loblolly and shortleaf pine productivity through 53 years of management under four reproduction cutting methods. Southern Journal of Applied Forestry. 25: 7-16.

Cain, M.D.; Shelton, M.G. 2001b. Twenty years of natural loblolly and shortleaf pine seed production on the Crossett Experimental Forest in southeastern Arkansas. Southern Journal of Applied Forestry. 25: 40-45.

Chapman, H.H. 1913. Prolonging the cut of southern pine. I. Possibilities of a second cut. Yale University Forestry School Bulletin. 2: 1-22.

Conner, R.C.; Hartsell, A.J. 2002. Forest area and conditions. In: Wear, D.N.; Greis, J.G., eds. Southern forest resource assessment. Gen. Tech. Rep. SRS-53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 357-402.

Darling, O.H.; Bragg, D.C. 2008. The early mills, railroads, and logging camps of the Crossett Lumber Company. Arkansas Historical Quarterly. 67: 107-140.

Farrar, R.M.; Murphy, P.A.; Willett, R.L. 1984. Tables for estimating growth and yield of uneven-aged stands of loblolly-shortleaf pine on average sites in the West Gulf area. Bulletin 874. Fayetteville, AR: Arkansas Agricultural Experiment Station. 21 p.

Gill, H.V.; Avery, D.C.; Larance, F.C.; Fultz, C.L. 1979. Soil survey of Ashley County, Arkansas. Washington, D.C.: U.S. Department of Agriculture, Soil Conservation Service and Forest Service. 92 p.

Grano, C.X. 1949. Is litter a barrier to the initial establishment of shortleaf and loblolly pine reproduction? Journal of Forestry. 47: 544-548.

Grano, C.X. 1954. Re-establishment of shortleaf-loblolly pine under four cutting methods. Journal of Forestry. 52: 132-133.

Grano, C.X. 1957. Growth of loblolly pine seed trees in relation to crown density. Journal of Forestry. 55: 852.

Grano, C.X. 1961. Shortleaf-loblolly reproduction losses moderate, following seed tree felling. Journal of Forestry. 59: 24-25.

Lotti, T. 1953. Good seed trees pay off. Southern Lumberman. 187(2336): 43-44.

Patterson, D.W.; Doruska, P.F.; Posey, T. 2004. Weight and bulk density of loblolly pine plywood logs in southeast Arkansas. Forest Products Journal. 54: 145-148.

Reynolds, R.R. 1980. The Crossett story: the beginning of forestry in southern Arkansas and northern Louisiana. Gen. Tech. Rep. SO-32. New Orleans, LA: U.S. Department of Agriculture, Forest Service. 40 p.

Schultz, R.P. 1997. Loblolly pine: the ecology and culture of loblolly pine (*Pinus taeda* L.). Agricultural Handbook 713. Washington, DC: U.S. Department of Agriculture, Forest Service. 493 p.

Shelton, M.G.; Cain, M.D. 1999. Structure and short-term dynamics of the tree component of a mature pine-oak forest in southeastern Arkansas. Journal of the Torrey Botanical Society. 126: 32-48.

Wahlenberg, W.G. 1960. Loblolly pine: its use, ecology, regeneration, protection, growth and management. Durham, NC: Duke University, School of Forestry. 603 p.

Williston, H.L. 1987. Southern pine management primer. New York, NY: Vantage Press. 167 p.