REGENERATING SHORTLEAF PINE IN CLEARCUTS IN THE MISSOURI OZARK HIGHLANDS

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Abstract—A shortleaf pine (*Pinus echinata* Mill.) regeneration study was established by the Missouri Department of Conservation in 1986 at the Current River Conservation Area. The objective of the study was to compare natural to artificial regeneration methods, and site preparation prescribed burning to bulldozing for shortleaf pine establishment and growth. Eighteen years after establishment, the control treatment (natural regeneration) had only 94 stems/ha, the burn treatment had 727 stems/ha, and the doze treatment had 1,680 stems/ha. Mean volume growth per tree was greatest in the doze treatment (53.7 dm^3) followed by the burn treatment (34.1 dm^3) with the control having the least volume growth (22.3 dm^3). Hardwood competition was greatest in the control treatment (3,132 stems/ha) followed by the burn treatment (2,470 stems/ha) and least in the doze treatment (1,210 stems/ha). The results suggest that (1) survival and growth of shortleaf pine increases with increase in site preparation intensity, (2) natural regeneration may not achieve stocking goals and adequate growth, and (3) prescribed burning is a viable site preparation method.

INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill.) dominated southern Missouri, but today it only occupies <10 percent of its original range. Sites formerly occupied by shortleaf pine have many hardwood species, many of which are not as well adapted as shortleaf pine to the dry, nutrient-poor, and eroded sites. These less adapted hardwood species are experiencing problems with oak decline associated with red oak borers and Armillaria root rot. The decline and mortality is affecting mostly black oak (*Quercus velutina* Lam.) and scarlet oak (*Q. coccinea* Münchh.). It is estimated that 200 000 ha of forest is affected by severe oak decline on the Mark Twain National Forest (Law and others 2004). Restoring shortleaf pine on former pine and oak-pine sites is a long-term strategy for mitigating chronic oak decline (Law and others 2004). Shortleaf pine restoration is being achieved through natural or artificial regeneration. Natural regeneration is sometimes preferred because it has lower establishment and capitalization costs than artificial regeneration (Vesikallic 1981). When harvesting does not coincide with a good seed crop or where few seed trees exist, artificial regeneration may be preferred. A good seed crop occurs once every 5 to 7 years in shortleaf pine (Brinkman and Rogers 1967). The uncertainty regarding predicting good shortleaf pine seed crops limits the success of natural regeneration. Artificial regeneration also provides an opportunity to improve productivity by planting improved shortleaf pine seedlings, and it is a more precise method than natural regeneration for obtaining stocking goals. Although both natural and artificial regeneration methods are currently used for restoring shortleaf pine in the Missouri Ozarks, there is lack of information on their comparative effectiveness.

Adequate site preparation is critical for germination of seeds, and survival and growth of shortleaf pine seedlings. For successful germination and establishment, the heavy hardwood leaf litter, forbs, woody vegetation, and grass should be eliminated or reduced. Common site preparation methods include prescribed burning, and mechanical and chemical treatments. Prescribed burning or mechanical disturbances are effective site preparation methods because they remove the dense leaf litter, grass, and vegetation, and expose seed to the mineral soil. Chemical methods on the other hand do not expose mineral soil but are effective in reducing or eliminating competing vegetation. In Oklahoma at least three times as many seedlings emerged on burned sites than on unburned sites (Boggs and Wittwer 1993). In contrast, Yocom and Lawson (1977) found that prescribed burning provided little additional seedbed benefit in sites disturbed by logging in Arkansas. In the Missouri Ozarks, cultivation after removal of litter was a superior site preparation method compared to burning or raking (Liming 1945). These contrasting results point to the need for more information on effectiveness of the different site preparation methods. Progress in restoring shortleaf pine will probably be greatly accelerated when information on the efficacy of the regeneration and site preparation methods are made available to resource managers.

The objective of the study was to compare natural to artificial regeneration methods, and site preparation prescribed burning to bulldozing for shortleaf pine establishment and growth. We also evaluated the effectiveness of the different treatments on controlling hardwood competition.

MATERIALS AND METHODS

Study Site

The study is located in compartment 15 on the Current River Conservation Area of the Missouri Department of Conservation (fig. 1). The Current River Conservation Area is located in Reynolds and Shannon Counties located in southeast Missouri. The conservation area is approximately 11 300 ha of forest land. The study sites are located completely within the Current River and Black River Oak/

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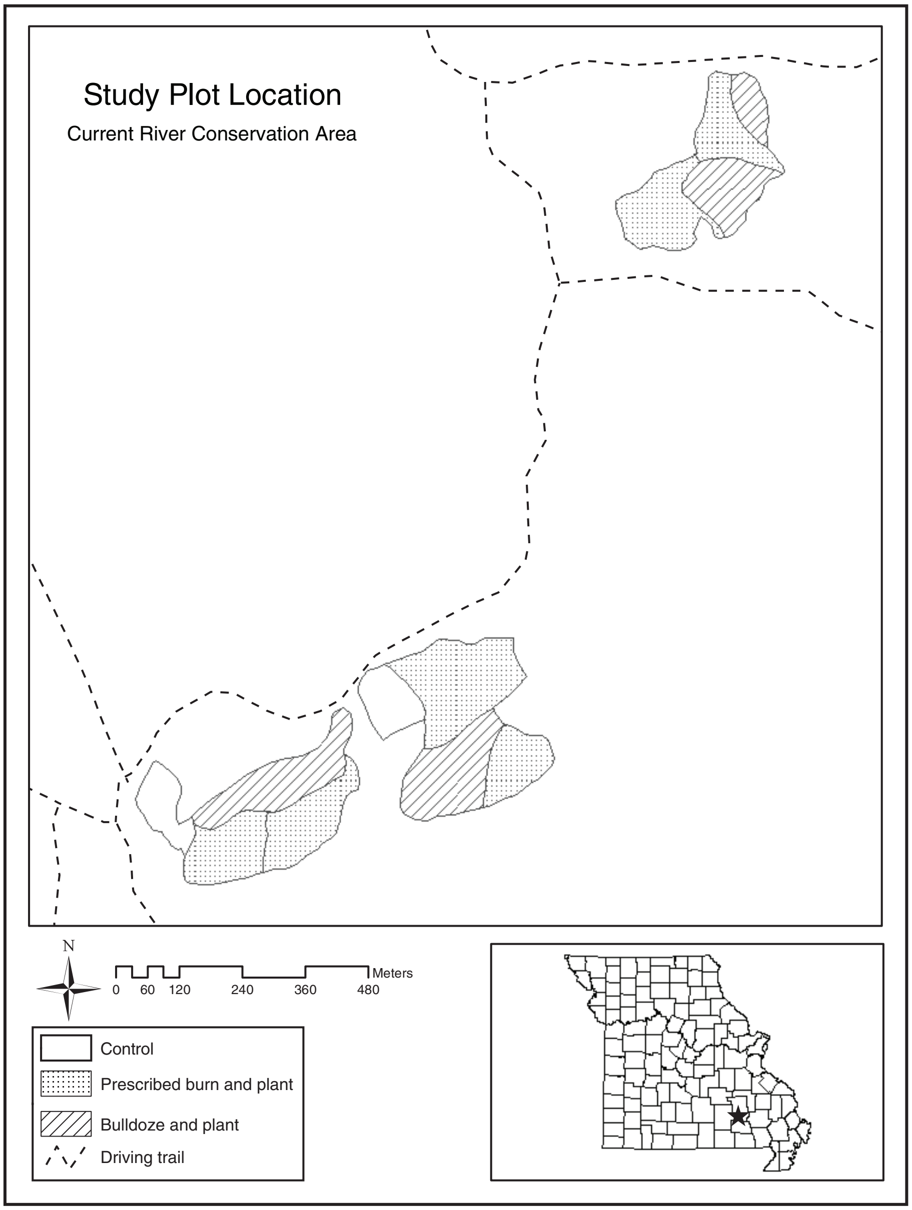

Figure 1—Location of study site.

Pine Woodland/Forest Hills Land Type Association (Nigh and Schroeder 2002). These land types are characterized by hilly landscapes with narrow ridges, narrow valleys, and steep slopes with 46 to 76 m of local relief. The ridges and upper slopes are formed from the Roubidoux Formation whereas the lower hillslopes and valleys cut into the Gasconade Formation. Historically, this area was dominated by shortleaf pine and shortleaf pine-oak woodland complexes.

Compartment 15 had several pockets of oak decline during the mid-1980s. Timber was salvaged from these pockets between December 1984 and May 1985. The timber harvest was advertised and sold as three sale units, measuring 10, 18, and 25 ha. Each sale unit was composed of 4 to 11 stands. On several stands in two larger sale units an attempt was made to regenerate shortleaf pine using different regeneration and site preparation methods.

Site Preparation, Planting, and Assessment

Treatments included burn, doze, and control. The burn treatment included complete overstory removal followed by a spring burn. The doze treatments consisted of complete removal of the overstory followed by stump and slash removal using a bulldozer. After the burn and doze treatments were applied, the stands were handplanted with unimproved 1-0 shortleaf pine bare-root seedlings at a spacing of 2.4 by 2.4 m in spring 1986. The control treatment consisted of complete removal of the overstory, and no planting or site preparation was carried out. Layout of the stands is shown in figure 1. Groups of stands were allocated in blocks by spatial proximity.

The blocking allowed for replication of the three treatments in space. Three blocks were identified, one block located in the north with two treatments represented (burn and doze) and two blocks located in the south with all three treatments represented in each block (fig. 1).

Two random plots were established in each treatment within a block in July 2004. Each plot was 10 by 10 m. The number of trees, species, height, and diameter at breast height (d.b.h.) of all trees in a plot were measured. Height was measured using height poles and d.b.h. (cm) was measured using diameter tapes. Conical volume (V, dm^3 per tree) was calculated for all trees using the equation:

$$V = \frac{1}{3}\pi\left(\frac{D}{2}\right)^2 H$$

where
D = d.b.h. (dm)
H = height (dm)

Statistical Analysis

Plot means were used for all analyses. Using the PROC GLM procedure in SAS version 9.1 (SAS Institute Inc., Cary, NC), analysis of variance (ANOVA) was used to test for significant differences among blocks and treatments for height, diameter, and volume. Stocking was analyzed using chi-square test. All analyses were carried out at the $P \leq 0.1$ probability level.

RESULTS

Stocking and Growth

Eighteen years after applying the treatments, naturally regenerated shortleaf pine in the control treatment had an average density of only 94 stems/ha, a significantly lower density ($P < 0.001$) than in the burn treatment (727 stems/ha) and doze treatment (1,680 stems/ha) (fig. 2). Survival in the doze treatment was significantly higher than in the burn treatment ($P < 0.001$).

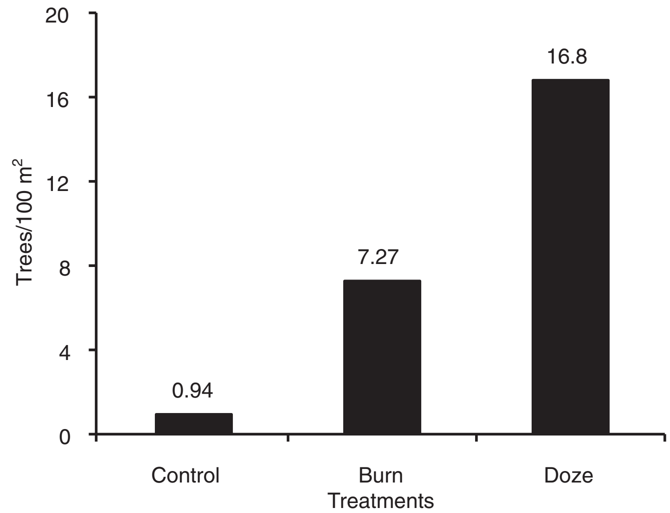

Figure 2—Stocking of shortleaf pine trees 18 years after establishment. Control = no site preparation and no planting, burn = prescribed burn and plant, and doze = bulldoze and plant.

Bulldozing increased height growth by 27.3 percent, diameter by 27.5 percent, and volume by 140.8 percent over the control treatment (table 1). Bulldozing increased height growth by 20.1 percent, diameter by 18.1 percent, and volume by 57.4 percent over the burn treatment. Although the burn treatment increased height by 6.0 percent, diameter by 7.9 percent, and volume by 89.6 percent over the control, the increases were not statistically significant.

Table 1—Treatment effects on height, diameter, and volume at 18 years for a shortleaf pine clearcut study

Regeneration technique[a]	Height	D.b.h.	Volume
	m	*cm*	*dm*^{3}
Control	7.5	10.0	22.3
Burn	7.9	10.8	34.1
Doze	9.5	12.8	53.7
MSE	1.35	3.02	250.85
Treatment contrasts	-------------------------	*P-value*	-------------------------
Control vs. burn	0.595	0.357	0.283
Control vs. doze	0.043	0.038	0.025
Burn vs. doze	0.027	0.063	0.050

[a] Control = no site preparation and no planting; burn = prescribed burn and plant; doze = bulldoze and plant; MSE = mean square error.

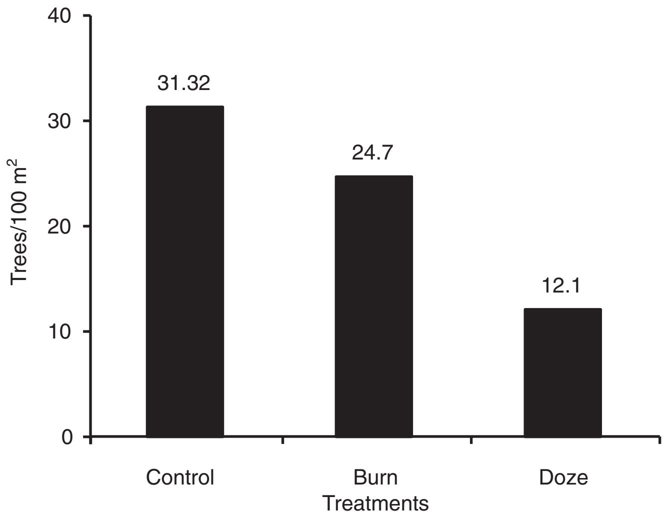

Figure 3—Density of hardwoods 18 years after establishment. Control = no site preparation and no planting, burn = prescribed burn and plant, and doze = bulldoze and plant.

Hardwood Competition

The control treatment had a significantly higher density of hardwood competitors than the burn treatment (27 percent higher, $P = 0.092$) and a significantly higher density of hardwood competitors than the doze treatment (150 percent higher, $P < 0.001$) (fig. 3). Density of naturally regenerated hardwoods was significantly higher in the burn treatment than in the doze treatment (100 percent higher, $P < 0.001$). Hardwoods were taller in the control treatment (6.28 m) than in the burn (5.96 m) and doze treatments (5.88 m). Hardwoods in the doze treatment were smaller in diameter (4.86 cm) than those in the burn and control treatments (5.53 and 5.75 cm, respectively). Species richness within the 3 treatments was similar (10 to 11 hardwood species). The dominant oak species occurring across all treatments was white oak (*Q. alba* L.) followed by post oak (*Q. stellata* Wangenh.), scarlet oak, and black oak had the least average density.

DISCUSSION

Eighteen years after establishment, stocking of naturally regenerated shortleaf pine was low and inadequate to meet the minimum stocking goals for a shortleaf pine forest (1,000 stems per acre) or shortleaf pine-oak forest (500 stems/ha). The low density of naturally regenerated shortleaf pine trees was most likely due to harvesting not coinciding with a good seed crop. It may also be attributed to inadequate seedbed preparation, insufficient moisture for germination and seedling establishment, or excessive competition. Naturally regenerated loblolly pine (*P. taeda* L.) seedlings released from woody and herbaceous competition have been reported to have better survival and more vigor than those not released on a site in southern Arkansas (Cain and Barnett 1996). At our study site, stands naturally regenerated required followup release to increase vigor of shortleaf pine trees. Underplanting or direct seeding was necessary to increase the stocking of shortleaf pine in naturally regenerated stands. However, dozed and prescribed burned stands did not need any followup release or enrichment planting because both treatments achieved higher than the minimum desired stocking for pine-oak forest.

Although the doze treatment had better survival and less hardwood competitors than the burn treatment, the burn treatment was successful at achieving the desired stocking goals. Furthermore, growth achieved by the burn treatment was comparable to that achieved by the doze treatment. Thus, planting on sites prepared by prescribed burning appears to a viable method of restoring shortleaf pine. Gwaze and others (2006) found that prescribed burning was as effective as subsoiling as a site preparation method at a site in the Salem Ranger District, Mark Twain National Forest. Our results are not consistent with other studies in Florida where burning did not improve survival or growth of slash pine (*P. elliottii* Engelm.) 10 years after planting, but mechanical site preparation did (Outcalt 1983). The effectiveness of prescribed burning can be unpredictable due to varying amounts and types of fuel, slope and aspect, and unstable weather conditions.

The stocking of naturally regenerated shortleaf pine of 94 trees/ha (38 trees per acre) is below the minimum required for a fully stocked shortleaf pine stand or for a pine-oak mixed stand in Missouri. In Missouri a minimum of 400 or 200 shortleaf pine trees in a free-to-grow condition is required to fully stock a pine stand or pine-oak stand at 5 years. Thus, results from this study suggest that natural regeneration may not meet adequate stocking goals and seedlings regenerated by this method exhibit poor growth. Because natural regeneration continues to be important for restoring shortleaf pine in the Missouri Ozarks, and is desirable for landowners who prefer low-cost establishment methods, more effective techniques to establish and recruit naturally regenerated seedlings need to be identified. Also, methods for predicting seed yields need to be developed so that harvesting can be planned to coincide with a good seed crop. The study suggests that planting on sites prepared by prescribed burning is a viable method of restoring shortleaf pine.

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