A 16-YEAR EVALUATION OF EFFECTS OF RIPPING ON SHORTLEAF PINE ON A MISSOURI OZARKS SITE

David Gwaze, Carl Hauser, and Mark Johanson[1]

Abstract—A shortleaf pine (*Pinus echinata* Mill.) ripping study was established by the Missouri Department of Conservation in March 1988 at the Logan Creek Conservation Area. The objective of the study was to evaluate the effects of ripping on survival, height, diameter, volume, crown spread, and free-to-grow status of planted shortleaf pine seedlings. Ripping improved survival by 4 percent during the first 3 growing seasons, and at age 16 the improvement in survival was 7.1 percent. It improved crown spread by 13.6 percent and free-to-grow status by 3.8 percent after 2 growing seasons. Ripping improved height, diameter, and volume by 14.2, 14.0, and 41.2 percent, respectively, after 2 growing seasons. However, at age 16, ripping had no effect on height, and it reduced diameter and volume by 5.3 percent and 10.2 percent, respectively. The results suggest that benefits of ripping are minor and short-term.

INTRODUCTION

Restoration of shortleaf pine (*Pinus echinata* Mill.) in its former natural range can be accomplished through natural and/or artificial regeneration. Artificial regeneration is preferred where (1) no seed trees exist, (2) harvesting does not coincide with a good seed crop, (3) more precise stocking goals are required, and (4) genetic composition of the new forest needs to be altered to achieve certain management objectives (e.g. better production, greater genetic diversity, etc.). In the Missouri Ozarks, most of the forests have been high graded and good seed crops are difficult to predict, making artificial regeneration attractive. Furthermore, genetically improved seed is available, providing an opportunity to improve forest productivity.

Artificial regeneration of shortleaf pine in the Missouri Ozarks presents numerous challenges. Summer droughts are common, soils are rocky and contain hardpans, and hardwood vegetation competes with the planted seedlings. Some form of site preparation is essential for successfully establishing shortleaf pine on these sites. Ripping or subsoiling is an alternative mechanical site preparation method for regenerating shortleaf pine on these harsh sites. Ripping has been reported to improve survival and growth of planted shortleaf pine by breaking up the hardpans or impervious subsoil layers and thus encouraging deeper root development and increased root growth area (Wittwer and others 1986). It has also been reported to reduce hardwood competition around the seedling during the first few years after planting, eliminating the need for follow-up release treatment from competing hardwoods (Wittwer and others 1986). Ripping provides a catchment area for any precipitation and allows the seedling's roots to extend further into the soil profile where more moisture may be available. The result is an increase in moisture for the seedling, and ultimately, improved survival and growth. Ripping has also been used as a site preparation method in the U.S.A. (e.g. Wittwer and others 1986) and in other countries such as New Zealand (Guild 1971) and Australia (Lacey and others 2001). There are few reports that quantify ripping benefits on shortleaf pine in the U.S.A. In Georgia, ripping increased height growth by 17 percent, root-collar diameter by 15 percent, and tree volume by 38 percent 5 years after planting (Berry 1979). In Arkansas, ripping improved survival by 20 to 25 percent, and competition from weeds and other vegetation was reduced (McClure 1984). In Missouri, ripping increased height growth by 53.8 percent after 5 growing seasons at Mark Twain National Forest (McClure 1989).

Interest in ripping for shortleaf regeneration in Missouri was stimulated by the excellent results in Arkansas (McClure 1984). Ripping was started in Missouri in 1984 at the Mark Twain National Forest, Salem District. The Missouri Department of Conservation (MDC) and Mark Twain National Forest began the trial use of ripping for shortleaf pine site preparation in the late 1980s. By the early 1990s, about 300 acres of public land were ripped and planted with shortleaf pine trees. Initial results in Missouri indicated that increased growth and survival might be expected using this practice (McClure 1989), but benefits of ripping at mature ages had not been quantified. In 1987, a project was initiated to evaluate the efficacy of ripping as a site preparation method in Missouri Ozarks. The objectives were to determine the effects of ripping on survival, height, diameter, volume, crown spread, and free-to-grow status of planted shortleaf pine seedlings.

MATERIALS AND METHODS

Study Site

The study site is located on Logan Creek Conservation Area in the Ozark Highlands of Reynolds County, MO (NE ¼ of Sec 7, T. 30 N., R. 1 W.; fig. 1). The study site is classified by the ecological classification system for Missouri (ECS) within the Current River Pine-Oak Woodland Dissected Plain Landtype Association (LTA) (Nigh and Schroeder 2002). This LTA is located along the periphery of the Current River Valley and is characterized by a moderately dissected upland plain associated with the Roubidoux Formation. Relief over large areas is generally < 100 feet. Historically, this area was dominated by pine and pine-oak woodland complexes. Sinkholes and other karst features are common within this LTA.

The study location is on a ridge and upper west facing slope of up to 10 percent. Soils on the ridge tops are Captina series

[1] Resource Scientist, Missouri Department of Conservation, Columbia, MO 65201; Former Silviculturist, Missouri Department of Conservation, Jefferson City, MO 65102; and Resource Science Assistant, Missouri Department of Conservation, Ellington, MO 63638, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2006. Proceedings of the 13th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–92. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 640 p.

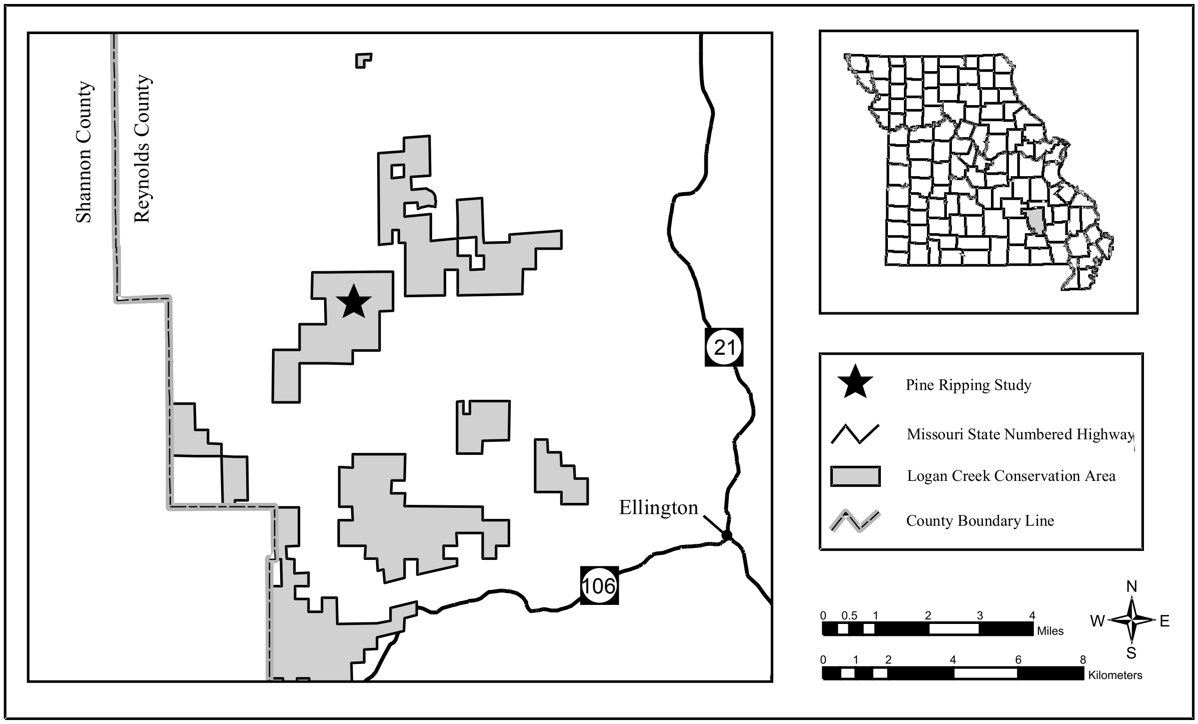

Figure 1—Location of ripping study.

which characteristically have a fragipan at a depth around 18 inches. Clarksville soils are generally found on the side slopes. The original stand, dominated by black oak (*Quercus velutina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), white oak (*Q. alba* L.), and shortleaf pine (*Pinus echinata*), was destroyed by a tornado in 1985. A salvage harvest was done prior to initiating this study.

Site Preparation, Planting, and Assessment

The site was bulldozed, and remaining stems and debris were windrowed on the contour. Ripping was done with a bulldozer and two-toothed ripper during winter of 1987. Genetically improved 1-0 shortleaf pine seedlings were planted on a spacing of 7 x 7 feet in March 1988. Total height (HT), crown spread, basal diameter (BD) at 1 inch above ground, and survival were measured December 1988 and September 1989. All assessments were repeated in September 1990, except for basal diameter. Height and crown spread were measured with a meter stick, and basal diameter was measured with an electronic caliper. Vegetation was considered competing with shortleaf pine seedlings if a leaf or branch of competing vegetation was located within an imaginary inverted cone of 45° each side of vertical above the terminal bud or competing vegetation covered the pine's terminal leader. Otherwise, the shortleaf pine seedlings were judged as free-to-grow. The study was re-measured at age 16 in April 2004 for height using a clinometer and for diameter at breast height (d.b.h.), using a diameter tape. Volume at ages 1 and 2 were estimated using a volume index: HT x BD^2. Volume at 16 years was estimated using volume of a cone:

$$\text{volume (dm}^3\text{)} = HT \bullet dbh^2 \bullet 0.02618 \qquad (1)$$

Study Design and Statistical Analysis

A randomized block design was used, with 2 treatments in a total of 10 blocks (fig. 2). The treatments were: (1) ripping to a depth of 46 to 61 cms (18 to 24 inches) on a 2.14 m (seven foot) spacing, and (2) control, with no ripping. Ripping was done to break up the fragipan and to remove competing vegetation. Each plot was 4 rows x 10 seedlings with a buffer of 2 rows on each side and 2 seedlings on each end. Because of varying space between windrows and the need to avoid residual stumps, not all plots resulted in 40 measured seedlings per plot. The actual number varied from 37 to 66 measured seedlings per plot, with only 2 plots with less than 40.

Plot means were used for all analyses. Analyses were carried out for survival, height, diameter, volume, crown spread, and free-to-grow status for each age separately. Using the PROC GLM procedure in SAS, analyses of variance (ANOVAs) were used to test for significant differences among blocks and

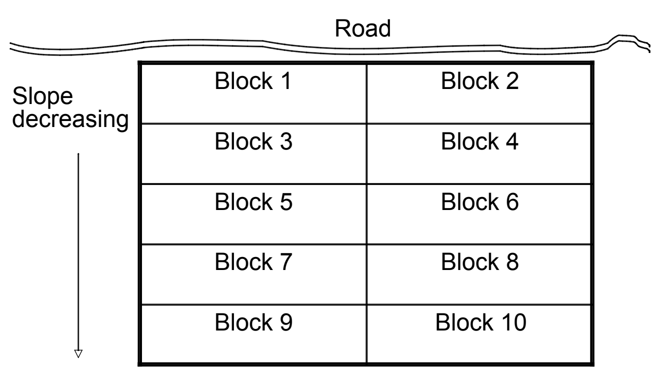

Figure 2—Schematic diagram of the field layout. The ripping and control treatments were randomly assigned to each block.

treatments for height, diameter, volume, and crown spread. The following linear model was used for the analysis:

$$Y_{ij} = \mu + B_i + T_j + e_{ij} \qquad (2)$$

where

$Y_{ij} =$ the observation on the j^{th} treatment in the i^{th} block

μ = the population mean

B_i = the random variable for block

T_j = the fixed effect of treatment (ripping and control)

e_{ij} = the error term. Survival and free-to-grow were analyzed using chi-squared test.

RESULTS AND DISCUSSION

Survival

Seedlings in the ripping treatment had significantly higher survival than those in the control treatment at all ages ($P < 0.05$). Survival at ages 1 to 3 was above 90 percent for both treatments (fig. 3). At age 16, survival in the control treatment dropped to 84.2 percent while that in ripping treatments remained above 90 percent (survival = 90.2 percent). The differences between ripping and control treatments were probably not operationally meaningful as survival of 84.2 percent after 16 growing seasons is well within acceptable limits for the region. The high survival rates for both treatments were a surprise given that the region experienced a dry summer in 1988. Results from this study are consistent with other studies in the U.S.A. which showed that ripping improved survival of shortleaf pine (Berry 1979, McClure 1989).

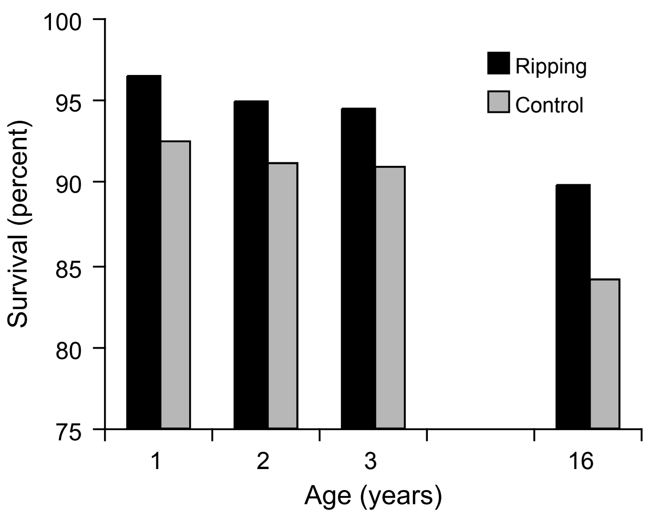

Figure 3—Mean survival of two treatments at four ages.

Growth at Ages 1 to 3

Seedlings in the ripping treatment had significantly greater height, diameter, volume, and crown spread than those in the control treatment for all ages, except height after the first growing season (table 1). Ripping increased crown spread, height, basal diameter, and volume by 13.6, 14.1, 14.0, and 41.2 percent, respectively, after 2 growing seasons (table 1). Although root systems were not assessed, a larger basal diameter should be correlated with larger root systems. After 3 growing seasons, height growth in the ripping treatment was 146.9 cm and that in the control treatment was 130.8 cm, an increase of 12.3 percent (table 1). The advantage of ripping appears to decline with age for crown spread, and the trend is less clear for height.

The increased growth in the ripping treatment may have been the result of improved soil physical properties and/or improved soil-water extraction. Ripping may have resulted in increased water infiltration from snowmelt, which may have increased soil moisture within the ripped treatment during planting in comparison to the control treatment.

There appeared to be a greater advantage of ripping near the ridge, and the advantage diminished down the slope (fig. 4). Ripping improved volume by 161.2 percent and 132.9 percent in the 2 blocks (1 and 2) located near the ridge, respectively. The response to ripping near the ridge might be expected, because the Captina soils are found on the ridges and Clarksville soils on the side slopes. The Captina soils are deep, moderately well-drained soils with a fragipan at 18 to 24 inches.

Table 1—Treatment effects on height, diameter, volume and crown spread at 1 to 3 and 16 years for a shortleaf pine ripping study

	Age	Ripping	Control	Increase[a]	P-value
	years			*%*	
Height (cm)	1	25.1	22.7	10.6	0.065
Height (cm)	2	73.5	64.4	14.1	0.020
Height (cm)	3	146.9	130.8	12.3	0.010
Height (m)	16	10.7	10.6	1.3	0.360
Basal diameter (mm)	1	4.8	4.4	9.1	0.010
Basal diameter (mm)	2	13.0	11.4	14.0	0.019
Diameter (cm)	16	14.9	15.8	-5.3	0.005
Volume (cm^3)	1	6.8	5.0	36.0	0.021
Volume (cm^3)	2	148.7	105.3	41.2	0.018
Volume (dm^3)	16	66.7	74.3	-10.2	0.016
Crown spread (cm)	1	14.3	11.4	25.4	0.004
Crown spread (cm)	2	44.2	38.8	13.6	0.028
Crown spread (cm)	3	75.4	67.6	11.7	0.007

[a] Increase due to ripping

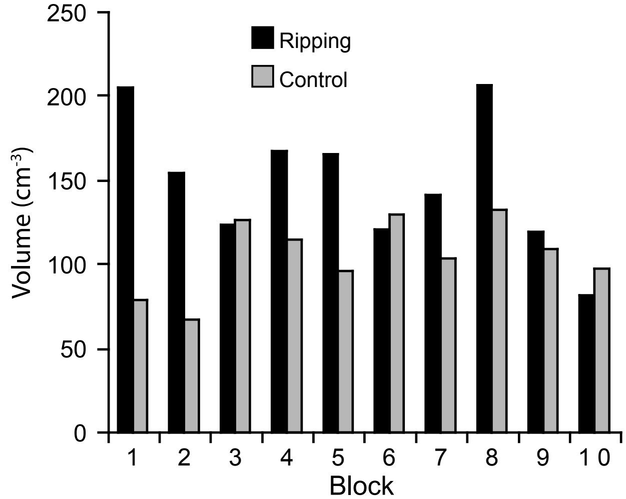

Figure 4—Volume growth for two treatments across the different blocks after the two growing seasaons.

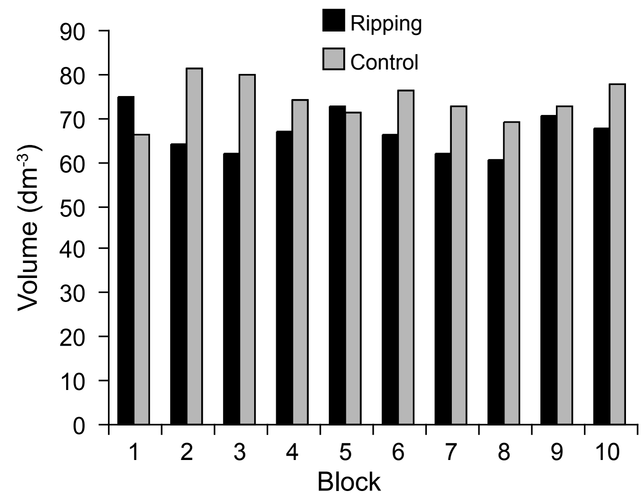

Figure 5—Volume growth for 2 treatments across the different blocks at age 16.

This study appears to indicate that ripping in the absence of a fragipan, such as in the mid-slopes, is of little benefit to growth.

Early results from this study are consistent with findings from other research on ripping effects on survival and growth of shortleaf pine in the U.S.A. In Missouri, a ripping study at Salem District of Mark Twain National Forest showed that shortleaf pine trees planted in a burned and ripped site were 53.8 percent taller than controls after 5 years (McClure 1989). Also, Berry (1979) reported that volume of shortleaf pine was improved 38 percent by ripping at 5 years of age in a Piedmont site in Georgia. In Oklahoma, ripping increased basal diameter of loblolly pine by 20 percent after 2 growing seasons (Wittwer and others 1986). In contrast, early results from studies at 5 years or younger in Australia revealed that ripping had no significant effect on growth of *Pinus elliottii* (Francis and others 1984) or of *Eucalyptus*, *Melaleuca*, and *Callitris* species (Knight and others 1998). These differences probably reflect different soil physical properties or different requirements for the species involved.

Growth at Age 16

There was no significant difference between height of trees in the ripping and the control treatments at 16 years of age, but trees in the ripping treatment had significantly lower diameter and volume than those in the control treatment (table 1). While ripping increased volume by 41.2 percent after 2 growing seasons, the trees in the control treatment caught up; at 16 years the trees in the control treatment averaged 10.2 percent more volume and 5.3 percent greater diameter than trees in the ripping treatment. Trees in the ripping treatment had lower average volume than those in the control treatment in all blocks except block 1 (fig. 5). Thus, the advantage of ripping near the ridge was still maintained at age 16 years in block 1 but not in block 2.

Results at 16 years indicate that, while ripping at this site was beneficial at young ages, it was not at older ages. Therefore, early assessments may not be reliable for measuring the benefits of ripping at older ages. It is important to verify the effects of ripping over time, especially on studies where inferences about benefits of ripping were based on early growth assessments. It may be that the fragipan re-forms, the ripping depth was not sufficient to break the fragipan, or that there are other limiting factors below the fragipan that restrict tree growth in the ripping treatment. It is difficult to relate the results to soil properties, because information on soil properties is absent. More research is required to understand the relationship between soil properties and effect of ripping. There is need for addition research on effect of ripping on different soils and the need to find the most appropriate ripping depth for each particular soil type.

The success of ripping as a site preparation method depends on the long-term benefits of ripping out-weighing the costs. The costs of ripping should be offset by the savings in planting time and improved survival and growth generated by ripping. The study showed that ripping benefited trees in the short-term. Trees in control treatments had a slower start, but they eventually out-performed the trees in the ripping treatment at 16 years at this site.

Competition

There was no significant difference in free-to-grow status between trees in the ripping treatment and those in the control treatment after the first and third growing seasons; but free-to-grow seedlings were significantly higher in ripping treatment than in the control treatment after the second growing season (fig. 6, $P = 0.024$).

The number of surviving seedlings in the free-to-grow status was > 93 percent in both treatments across all the 3 first growing seasons. The lack of competition was consistent with high survival during the first three growing seasons. Although seedlings in the ripping treatment have a statistically significant better competitive advantage in the second growing season, the competitive advantage is too small to be of practical significance (< 4 percent).

In Missouri, herbicide release was normally applied during the 1980s at 3 to 5 years to maintain a minimum of 400 shortleaf pine seedlings per acre in a free-to-grow condition. According to McClure (1984), the biggest advantage of ripping is that

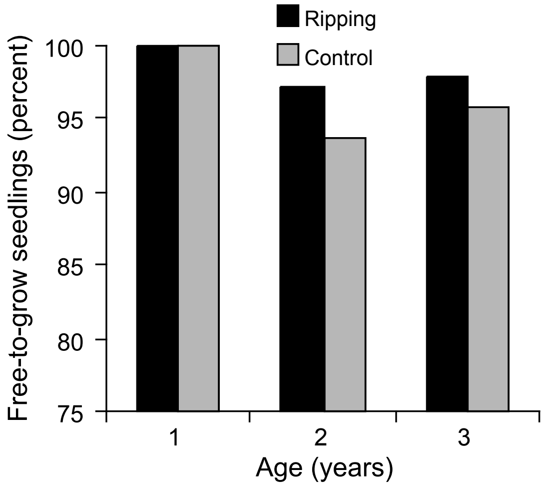

Figure 6—Free-to-grow seedlings for two treatments at three ages.

release herbicide will not be needed. This study does not support this assertion. Prior burning or bulldozing is a prerequisite for controlling slash and vegetation before ripping. Fire or bulldozing would remove slash that would otherwise collect under the draw bar, forcing it out of the ground. In the absence of slash, the operator can avoid stumps and large rocks. Herbicides are restricted on federal lands. Thus, fire or bulldozing used alone or in combination with ripping are the only site preparation methods likely to negate the use of herbicide. Our study shows that herbicide release is not required after 3 years on both the ripped and control treatments. The study indicates that there were 871 and 851 seedlings per acre in free-to grow status after 3 growing seasons in rip and control treatments, respectively. Thus release herbicide will not be needed on the control treatments (bull dozed and not ripped). Because the number of seedlings in free-to-grow status is high in both treatments, fewer seedlings need to be planted to achieve 400 free-to-grow seedlings. Given the number of free-to-grow seedlings after 3 growing seasons, only 409 and 418 seedlings need to be planted in ripped and non-ripped sites, respectively, to achieve the 400 free-to-grow seedlings at this site. Such low planting densities could be recommended when artificially regenerating shortleaf pine to achieve a pine-oak mix in which pine would still be dominant.

CONCLUSION

Restoration of shortleaf pine depends on an effective low-cost site preparation method. The results presented here provide baseline data for future studies that will investigate effects of different site preparation methods on survival and growth of shortleaf pine in Missouri. This study has shown that conclusions regarding advantages of ripping based on evaluation at a young age do not reflect results at more mature ages. This study showed that while ripping was beneficial at ages 3 and younger, it was not at age 16.

ACKNOWLEDGMENTS

The work reported was supported by the Missouri Department of Conservation. The authors acknowledge the contributions of many members of the Missouri Department of Conservation, particularly staff at Ellington Office who have been involved in the establishment, maintenance, measurement of the study.

LITERATURE CITED

Berry, C.R. 1979. Subsoiling improves growth of pine on a Georgia Piedmont site. Res. Note SE-284. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 3 p.

Francis, P.J.; Bacon, G.J.; Gordon, P. 1984. Effects of ripping and nitrogen fertilizer on the growth and windfirmness of slash pine on a shallow soil on the Queensland coastal lowlands. Australian Forestry. 47 (2): 90-94.

Guild, D.W. 1971. Windrowing and ripping, a comparative study with other site preparation techniques. New Zealand Journal of Forestry. 16: 88-97.

Knight, A.J.P.; Beale, P.E.; Dalton, G.S. 1998. Direct seeding of native trees and shrubs in low rainfall areas and on non-wetting sands in South Australia. Agroforestry Systems. 39: 225-239.

Lacey, S.T.; Brennan, P.D.; Parekh, J. 2001. Deep may not be meaningful: Cost and effectiveness of various ripping tine configurations in a plantation cultivation trial in eastern Australia. New Forests. 21(3): 231-248.

McClure, L. 1984. Mechanical site preparation. In: Artificial reforestation of shortleaf pine: a Missouri seminar. Salem, MO: U.S. Department of Agriculture, Forest Service, Mark Twain National Forest: 50-60.

McClure, L. 1989. Alternatives for stand in management area 4.1: analysis and choice in forest project level planning. Salem, MO: U.S. Department of Agriculture, Forest Service, Mark Twain National Forest. 52 p.

Nigh, T.A.; Schroeder, W.A. 2002. Atlas of Missouri ecoregions. Jefferson City, MO: Missouri Department of Conservation. 212 p.

Wittwer, R.F.; Dougherty, P.M.; Cosby, D. 1986. Effects of ripping and herbicide site preparation treatments on loblolly pine seedling growth and survival. Southern Journal of Applied Forestry. 10: 253-257.