SPROUTING CAPABILITY AND GROWTH OF ONE-YEAR-OLD SHORTLEAF PINE SEEDLINGS AFTER DIFFERENT TIMES OF BURNING AND CLIPPING

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Abstract—Shortleaf pine (*Pinus echinata* Mill.) is capable of sprouting after the stem is killed. The sprouting ability of shortleaf pine could be used to favor the species silviculturally for specific management objectives. Information is limited on burning effects at different periods of the growing season on shortleaf pine survival and growth. This study was located on the Cumberland Plateau region of east Tennessee and was conducted on one-year-old seedlings. Replicated treatments analyzed as a randomized block design included: clipping in March, burning in April, burning in July, burning in November, and an untreated control. Results indicate that after one full growing season after the treatment year, survival and growth of shortleaf pine sprouts did not differ among the three burning times (treatments) although differences were observed between burning and clipping and burning and control (unburned) treatments. Sprout number was statistically different among treatments with maximum burn temperatures as a covariate.

INTRODUCTION

The wide range of soil and moisture conditions on which shortleaf pine (*Pinus echinata* Mill.) can flourish makes it a ubiquitous species across the southeastern and eastern United States. Shortleaf pine is found in 22 States covering over 440,000 square miles (Lawson 1990). The species can form almost pure stands on shallow, well-drained upland soils in areas such as the Ouachita Mountains of Arkansas. Shortleaf pine typically becomes a more minor tree species component with increasing site productivity. The species' rooting habit, low demand for soil nutrients, and sprouting capability enable it to flourish on a wide variety of sites (Fowells 1965, Guldin 1986). Initial seedling height growth is typically slow due to the formation of a large taproot, but the taproot gives shortleaf pine a distinct advantage on poor sites over other species. Sprouting maintains the species on sites with frequent disturbances where other species unable to sprout may decline over time (Lawson 1990). These characteristics perpetuate shortleaf pine on poorer sites and make it a transitional successional species on more productive sites.

Shortleaf pine has the ability to sprout during the seedling or sapling developmental stages, and stems approaching 6 to 8 inches diameter at breast height (dbh) (Fowells 1965, Lawson 1990, Little and Somes 1956). The species' sprouting ability decreases with increasing age and size, similar to other tree species that can sprout. Sprouts initiate from axillary dormant buds located at or just above a unique physiological feature known as the basal crook. The basal crook typically develops within two to three months following germination. When shoot growth begins, the stem grows horizontally for a time and then turns vertically at a point slightly above the cotyledons just before it reaches the soil surface, forming a horizontal crook (Stone and Stone 1954). Seedlings growing in full sun typically grow more developed basal crooks than those growing in full or partial shade (Guldin 1986, Lilly and others 2010, Little and Mergen 1966). Detrimental agents such as fire, herbivory, or injury cause a sprouting response in vigorous, young trees. As many as sixty sprouts may initiate on a damaged seedling, but typically only one to three sprouts will reach maturity if no further disturbances occur (Mattoon 1915).

Landscape-wide factors such as urbanization, fire suppression, cessation of free-roaming livestock grazing, Southern pine beetle outbreaks, paucity of young shortleaf pine age classes, and loblolly pine (*P. taeda* L.) preponderance have all combined in the last few decades to diminish shortleaf pine populations (Birch and others 1986, Coffey 2012, Moser and others 2007). The shortleaf pine resource declined by 52 percent across its range from the early 1980s to 2010 (Oswalt 2012). Restoration efforts of shortleaf pine ecosystems were initiated by the U.S. Forest Service in the Ouachita Mountains in the early 1990s, but other national forests, government agencies, and private landowners have shown interest in restoring shortleaf pine ecosystems in recent years (Atkinson 2010, Bukenhofer and others 1994). Knowledge of shortleaf pine sprouting capability and propensity provides insight to the management methods associated with restoration activities, especially prescribed burning. Ecosystem restoration frequently involves disturbances such as burning intended to favor shortleaf pine over other species and reintroduce fire dependent species into those systems.

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Few studies (e.g. Campbell 1985, Cain and Shelton 2000, Lilly and others 2012, Shelton and Cain 2002), especially in the eastern portion of the species' range outside of Arkansas, have examined when disturbances such as stem clipping and burning can be applied to young seedlings during the growing season to produce the largest and greatest number of sprouts.

The objectives of this study were to determine the optimum timing for shortleaf pine survival and the sprouting response among four treatments: clipping during the early growing season or burning at three separate periods of the growing season. We compared seedling survival, height of the dominant sprout, and the number of sprouts produced among treatments one full growing season after the year treatments were applied.

METHODS

The study was conducted on the Cumberland Forest, a unit of the University of Tennessee's Forest Resources Research and Education Center (FRREC). The Cumberland Forest is located on the Walden Ridge subregion of the Cumberland Plateau (Smalley 1982). The study site was a previously maintained field with soils consisting of fine-loamy, siliceous, semi-active, mesic Typic Hapludults on 5-12 percent slopes from the Lonewood series. Shortleaf pine has a site index of 70 feet at base age 50 years for these soils (U.S. Department of Agriculture Natural Resources Conservation Service 2012). Shortleaf pine seedlings (1-0 stock) were purchased from the Tennessee Division of Forestry Nursery at Delano, TN, which used Tennessee seed sources. Seedlings were planted on February 25, 2011 and averaged 11 inches tall at planting.

The study was established on a 5,796 square foot section (69 feet by 84 feet) of the field. Three blocks were established that consisted of 15 plots each. Each rectangular plot measured 4 feet by 9 feet and contained 50 seedlings planted on a 1 foot by 1 foot spacing with 6-foot buffers on each side of the plot. Within each block, each treatment was applied once to a plot. All seedlings within a plot from each block were clipped in late March of 2011, closely followed by burning of one plot from each block on April 14, 2011. Mid-growing-season burns were completed on July 14, 2011 and late growing-season/early dormant-season burns on November 10, 2011. One control plot from each block that received no treatments was used in the analysis as well.

One inconsistency with the experimental procedures was that the July burn plots were burned twice within a few days of each other using the same methodology because of poor ignition and incomplete burn coverage on the first attempt, which may have affected some of the survival, height growth and sprouting results. Some seedlings in these plots burned twice, while others were burned once.

Clipped seedlings were cut 1 to 2 inches above ground level. In addition, all root collar sprouts that may have already existed on the stem were cut to ensure uniform starting heights and sprouting conditions. Prior to conducting burns, herbaceous plants and grasses were cut to ground level within plots, and a 1.5 percent solution of glyphosate herbicide (Cornerstone Plus®) was applied to reduce the effects of these fuels on the burns. The fuel source used for the burns was eastern white pine (*Pinus strobus* L.) needles gathered from nearby plantations. Needles were gathered and sifted to remove larger limbs and twigs. The needles were then allowed to dry on a tarp in full sunlight for at least two hours prior to burning to reduce fuel moisture to levels low enough for the needles to carry a fire. Needles were distributed evenly within plots using 5-gallon buckets to ensure equal fuel volumes within plots.

Burns were established in a ring pattern around plots using drip torches. The temperature and duration of each burn was measured and recorded for each plot. Burn temperatures were recorded every 15 seconds until complete flame-out using a Kintrex® Digital Infrared Thermometer. The thermometer sat on a pole 4 feet from the center of a plot, which was the midpoint between the fifth and sixth tree of the third column. The center was used as the measurement point due to the likelihood of hotter interior temperatures than along the edges. The pole measured 3 feet 8 inches tall, and including the height of the thermometer handle, the thermometer rested approximately 70 inches away from plot center. Fire weather data (relative humidity, ambient air temperature, and wind speed) were recorded prior to conducting each of the burns.

Survival percentage, height of the dominant sprout, and number of sprouts were the three measurements completed following treatments. Measurements were recorded in January 2013, one full growing season after treatments were applied to the first-year seedlings. Analysis of variance was used to test for differences among treatments. Data were analyzed as a randomized complete block experimental design using the PROC MIXED procedure in SAS 9.3 (SAS Institute Inc., 2012). Least square means were separated using Fisher's protected least significant difference test with a significance level set at $P = 0.05$. Burn temperature and duration data were included as covariates in the analysis to determine if they had a significant effect on the dependent variables. Mean burn temperature, total burn duration, maximum burn temperature, median burn temperature, and the sum of all temperature readings were all tested as covariates using a significance level of $P=0.05$.

RESULTS

All seedlings that received burn treatments were topkilled. Significant differences in seedling survival occurred among the five treatments (P=0.04). Survival rates were greatest with the control treatment and the clip treatment, which both had a 75.3 percent survival rate (fig. 1). The average survival rates among the three burning times were not statistically different, ranging from 38.7 to 48.7 percent. The clip and control treatments were significantly different from the April and July burn treatments, but similar to the November burn treatment (fig. 1).

The six variables used in covariate analysis did not affect treatment means for dominant sprout height of shortleaf pine seedlings. Significant differences in dominant sprout height occurred among the five treatments (P<0.001). Seedlings averaged 11 inches tall at planting, and the controls, which had the tallest mean height, averaged 48.5 inches after one growing season (fig. 2). The clip treatment seedlings averaged 26.1 inches. This treatment was statistically different from the three burn treatments and the control. There were no statistical differences among the three burn treatments as indicated by their letter groupings, even though numerically, seedlings in the July burn treatment were shorter on average (15.4 inches) than seedlings burned in April (19.2 inches) and November (19.7 inches).

The number of sprouts produced by each seedling was significantly affected by the maximum burn temperature covariate. Maximum burn temperatures ranged from 512 degrees Fahrenheit in one of the March burn plots to greater than 932 degrees Fahrenheit in one of the November burn plots. There were significant differences among treatments with the covariate included (P=0.0089). Differences in the adjusted (for the covariate) and unadjusted (without the covariate) means and standard errors are presented in table 1. The July burn produced the fewest number of sprouts (4.2), while the April burn (7.0) yielded nearly three more sprouts per seedling on average. The November burn produced the most sprouts of any treatment (11.0). The mean number of sprouts produced in the clip treatment (6.0) was statistically similar (letter groupings) to the April burn and not significantly different from the number of sprouts produced by the July burn. The control treatment produced the fewest sprouts (1.3), and this treatment was significantly different from the other treatments (table 1).

DISCUSSION

Several studies have observed poor survival rates after summer burns as compared to dormant season or early growing season burns in shortleaf pine seedlings of various ages (Cain and Shelton 2000, Grossmann and Kuser 1988, Shelton and Cain 2002) similar to those in this study. The low survival rate of seedlings burned in April was likely a partial result of poor root/soil contact and seedlings not being fully established after their February planting (Grossnickle 2005, Rietveld 1989). Another study with 6-year-old seedlings reported similar survival percentages for an April burn that was assessed one full growing season after the treatment year (Lilly and others 2012). Although some seedlings in the July burn plots were burned twice, survival percentages were not statistically different from the April or November burn plots. More fully established seedlings should attain large enough size for the root collar, develop thicker bark, and produce larger basal crooks, which may increase survival percentages after burning (Little and Somes 1956). Although the survival percentages for the November burn was similar to the two earlier burns, others have observed that as seedling size increases, survival percentage increases (Lilly and others 2012, Mattoon 1915).

The control and clip treatments had the same survival percentage (75.3 percent). The high survival of the clipped seedlings differed from another study in Arkansas that found a survival rate of 48 percent for four-year-old seedlings that were clipped at a similar height above ground level (Campbell 1985). The control seedlings had a somewhat lower one-year survival rate (75 versus greater than 80 percent) than the expected survival rate of shortleaf pine seedlings that are outplanted in Arkansas National Forests by the U.S. Forest Service (Mexal 1992).

The clipped seedlings grew taller than the burned seedlings, as expected. The lack of heat damage to the basal crook and the dormant buds just above the basal crook near the soil line result in a greater likelihood for clipped seedlings to grow taller (Cain and Shelton 2000, Lilly and others 2012, Little and Somes 1956). Because there were no significant differences among the burn treatments, data from seedlings older than one year old may be necessary to detect statistical differences in height growth using these same treatments. The three burn treatments had about a 60 percent or less height reduction as compared to the controls. A similar study in Arkansas found that one-year-old seedlings burned during January were 82 percent shorter than the controls measured one growing season after burns were applied (Cain and Shelton 2000). Height growth following the clip treatment and the burn treatments in this study was in the 1- to 3-foot range expected for this species throughout most of its range when typical weather patterns occur during the growing season (Lawson 1990, Williston 1951).

Although the height of shortleaf pine sprouts in burned plots was about 60 percent less than that in unburned control plots, burning combined with the sprouting ability of shortleaf pine could allow shortleaf pine to be more competitive with other species during the regeneration process. This outcome is reinforced in a site preparation study to create mixed pine-hardwood stands by Mullins and others (1997) when planting loblolly pine following a complete hardwood harvest. The planted loblolly pine seedlings only survived and developed when burning and/or herbicides were used to hinder initial hardwood growth. Those pine seedlings planted in harvested areas without site preparation had poor survival because they were overwhelmed by the hardwood sprout growth. The site preparation burn was conducted following the harvest and before the pine planting. Shortleaf pine probably would have similar growth properties as loblolly pine during establishment. An added advantage is the sprouting ability of shortleaf pine. A burning regime after planting could put shortleaf pine sprouts on a more even footing with sprouting hardwoods. Mixtures of pine (shortleaf) and oak were probably initiated and maintained with a fire regime before fire suppression began in the early 1900s (Brose and others 2001, Elliott and Vose 2005).

The mean number of sprouts per tree produced after burn treatments was less with the maximum temperature covariate included for the April and July burns, whereas the seedlings burned in November produced more sprouts with this covariate included. This is likely a result of the seedlings being better established in November following the February planting. All burning treatments produced more sprouts than clipping except for the July burn. This result is different from a study in New Jersey by Grossmann and Kuser (1988), who found more sprouts on six- to eight-year-old seedlings after spring clippings. The discrepancies in this result could be due to differences in burn intensity or duration, which was not outlined in the New Jersey study. Lilly and others (2012) found more sprouts on average (8.8 +/- 0.7 to 7.51 +/- 0.7 unadjusted) following an April burn applied to six-year-old seedlings. This finding agrees with the axiom that sprouting ability increases with size until a certain size threshold is reached. As expected, the controls produced few sprouts in comparison to the clip and the burn treatments, which has been outlined in previous work by others (e.g., Guldin 1986, Mattoon 1915). Managers interested in obtaining more or fewer sprouts in young shortleaf pine regeneration following burns may want to carefully consider the timing of burning to influence sprouting. Fewer sprouts would likely be more attractive in most situations due to increased vigor. One to three sprouts typically differentiate themselves from the rest and achieve larger size classes (Mattoon 1915).

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Table 1—Mean number of sprouts produced after one full growing season adjusted for the significant covariate maximum burn temperature and means unadjusted for the covariate

	Maximum covariate			Unadjusted means		
	P=0.0089 F=6.99			P=0.0118 F=27.4		
Treatment	Mean	SE	LG[a]	Mean	SE	LG
BA	7.01	0.706	B[b]	7.51	0.706	AB
BJ	4.25	0.666	C	4.81	0.663	B
BN	11.09	0.721	A	10.06	0.647	A
CL	—	—	—	6	0.591	B
CO	—	—	—	1.33	0.588	C

[a]LG denotes statistical letter grouping.

[b]Means within each column not followed by the same letter differ significantly at P = 0.05.

Note: BA is the burn in April of 2011, BJ is the burn in July of 2011, BN is the burn in November of 2011, CL is the clip in March of 2011, and CO is the control that received no treatment.

Note: cells with dashes had no maximum burn temperature covariates because these treatment areas were unburned.

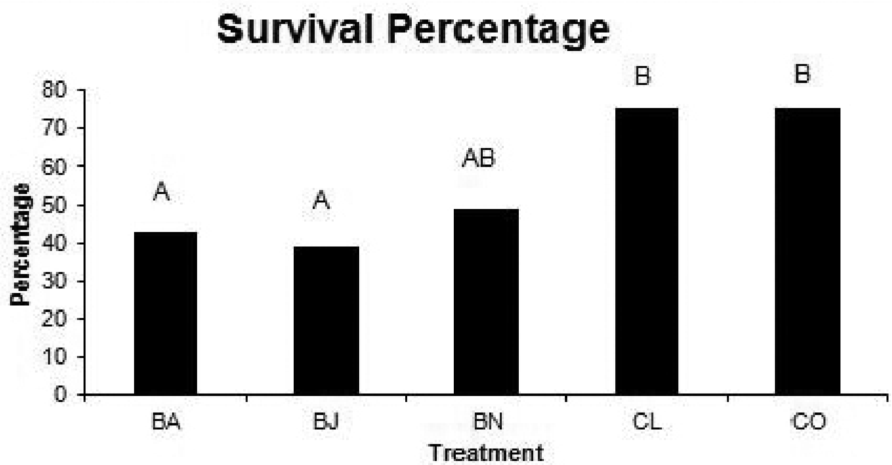

Figure 1—Mean survival percentage by treatment one growing season following treatment. Columns with different letters differ significantly at P = 0.05. BA is the burn in April of 2011, BJ is the burn in July of 2011, BN is the burn in November of 2011, CL is the clip in March of 2011, and CO is the control that received no treatment.

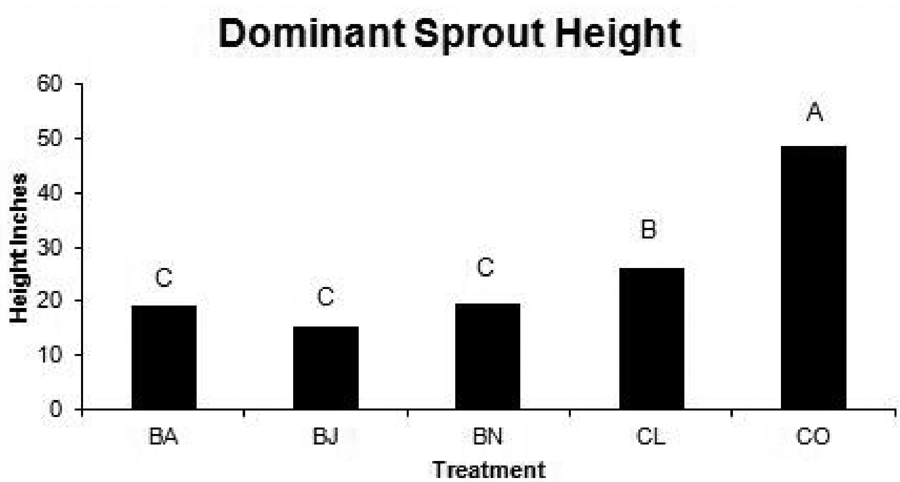

Figure 2—Mean dominant sprout height by treatment one growing season following treatment application. Columns with different letters differ significantly at P = 0.05. BA is the burn in April of 2011, BJ is the burn in July of 2011, BN is the burn in November of 2011, CL is the clip in March of 2011, and CO is the control that received no treatment.