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Abstract

This paper documents the results of a study to determine the effects of selected vegetation-management treatments in loblolly pine. Vegetation in precommercially thinned, 6-year-old stands was subjected to five biennial growing season burns in either early March, May, or July coupled with hand felling of residual woody stems. Using a randomized complete block design, we compared the vegetation-management treatments to an unthinned, unburned and unweeded check. By stand age 17, intensive vegetation management increased pine diameter growth by 2 centimeters (a = .004) and volume growth by 0.04 cubic meters (m^3) per tree (a = .02) when compared to the check. However, this was a small biological gain in growth. Among the burned treatments, five burns in early March reduced average pine total height by 0.8 m (a = .004), diameter at breast height by 1.5 cm (a = .03), and volume per tree by 0.04 m^3 (a = .06) compared to burning in early May or July. Vegetation management significantly reduced the height of hardwood trees and shrubs (a = .0001), but the number of trees and shrubs per hectare was not significantly affected. Vegetation management significantly increased total herbaceous plant production (*a* = ,003). Pinehill bluestem was not on the check plots, but it was the most productive herbaceous species on the vegetation-management treatments, composing 49 percent of the average total annual production of 457 kilograms per hectare.

Keywords: American beautyberry, blackberry, greenbrier, loblolly pine. pinehill bluestem, prescribed burning, sweetgum, vegetation management.

Introduction

Natural fires have established and maintained extensive fire-dependent forests throughout the world, and humans have used fire to alter these forests for millennia (Brown and Davis 1973, Robbins and Myers 1989, Spurr and Barnes 1973). Fire continues to be extensively used in the Southeastern United States to manage the 54-million-hectare (ha) loblolly pine (*Pinus taeda* L.)-shortleaf pine (*P. echinata* Mill.)-hardwood forest type, which extends almost continuously from eastern Texas to northeastern Virginia in a 240- to 480-kilometer (km) belt (Wolters and Wilhite 1974). Bluestems (*Andropogon* spp. and *Schizachyrium* spp.) are common grasses in openings. Legumes and many composites are also common but ordinarily produce little herbage. Overstocked pine stands and an absence of fire result in a reduction in understory native herbaceous plant biomass.

Many forest managers maintain herbaceous plant communities within forest stands. Burning pine forests during the growing season generally produces more intense fines than burning during the dormant season, which more effectively reduces hardwood vegetation and hopefully increases herbaceous plant production (Chen and others 1975, Grelen 1976, Lotti 1956, Robbins and Myers 1989). However, the use of fire at certain times of the year can differentially influence development of seedling and sapling pines (Grelen 1975, 1983).

The objective of this 1 l-year study was to determine how biennial burning in March, May, or July, coupled with cutting and removal of residual woody stems, influenced pine growth, native hardwoods, and herbaceous plant production in precommercially thinned loblolly pine stands.

Materials and Methods

Study Area

The study is within the loblolly pine-shot-deaf pine-hardwood forest type on the humid, temperate, subtropical, outer Coastal Plain, mixed-forest ecoregion of the Southern United States (McNab and Avers 1994). It is located within boundaries of the Kisatchie National Forest in central Louisiana about 45 km north of Alexandria at an average elevation of 53 meters (m). The site crosses a gradient from Metcalf very fine sandy loam to Cadeville very fine sandy loam soils (Kilpatrick and others 1986). The Metcalf is a fine-silty, siliceous, thermic Aquic Glossudalf on nearly level, somewhat poorly drained ridge crests. The Cadeville is a fine, mixed, thermic Albaquic Hapludalf on the moderately sloping (0 to 5 percent), well-drained side slopes. At age 50, the site index for loblolly pines ranges from 24 m on the Cadeville soil to 28 m on the Metcalf soil.

Such soils are best suited for timber production, and loblolly pine is the recommended species for forest management.

The area's climate is humid subtropical with mean January and July temperatures of 8 and 28 "C, respectively (Louisiana Office of State Climatology 1993). **Annual** precipitation averages 1490 millimeters (mm) with 820 mm during the **200+** day growing season, which normally begins around March 1 and ends in October because of dry weather.

Within the general forest, a**19-ha** stand of mature loblolly and shortleaf pines was **clearcut** harvested in 1976. The herbaceous plant production was about 80 kilograms (kg) per hectare and was mostly **longleaf** uniola (***Chasmanthium sessiliflorum*** **[Poir.]** Yates) with only scattered bluestems and forbs. The residual vegetation and debris were pushed down and crushed with a rolling drum chopper pulled by a crawler tractor. **In** early 1977 after broadcast burning, the site was planted with 1-O loblolly pine seedlings at about 1,700 seedlings per hectare.

Within 2 years, the surviving planted seedlings were indistinguishable from thousands of natural pine seedlings that originated from the mature pine stands surrounding the **19-ha** clearing. The volunteers *were* almost entirely loblolly pines, although some shortleaf pines were scattered throughout the plantation. By the fifth year, pine stocking was 7,450 trees per hectare; and heights ranged from < 30 centimeters (cm) to about 5 m.

Treatments

In February 1982 just before the sixth growing season, approximately 3 ha of the site were fenced to exclude cattle. Twelve plots were laid out, each one separated by a 3-m-wide fire line. Individual plots were 30.5 m^2 or 0.093 ha.

An evenly dispersed, overstocked stand of loblolly pine saplings was divided into three blocks of four plots each. The pine population was not well distributed in the site's remaining area and, therefore, was not included in the study. Blocking was based on surface soil drainage. Four treatments were randomly assigned to plots within each block as follows:

Treatment I-Check: No treatment was applied.

Treatment 2-March burns: Beginning in 1982, plots were prescribed burned biennially on or as near March 1 as weather and fuel conditions permitted. After the 1982 growing season, the **6-year-old** loblolly saplings were precommercially thinned to 1,730 well-spaced dominant and codominant trees per hectare. All hardwood trees, shrubs, and blackberry (***Rubus*** spp.) with living stems at least l-m tall were severed near the root collar and removed from the plots in May 1982, 1984, 1985, 1987, 1989, and 1991.

Treatment 3-May burns: Plots were prescribed burned biennially on or as near May 1 as weather and fuel conditions permitted. Otherwise, management practices were the same as treatment 2.

Treatment &July burns: Plots were prescribed burned biennially on or as near July 1 as weather and fuel conditions permitted. Otherwise, management practices were the same as treatment 2.

On treatments **2, 3,** and 4, fire efficacy was sometimes reduced because the effort to burn as near to the **first** day of the month as possible meant that fuel bed conditions were not always optimal. Nonetheless, all burns were completed. This necessitated the removal of all **nonpine** woody vegetation over l-m tall not killed by fire in treatments 2, 3, and 4.

Measurements and Data Analysis

After precommercial thinning, 25 of the best saplings on each plot (269 trees per hectare) were tagged for remeasurement purposes. Twenty-five of the best saplings were also selected on the unthinned and unburned check plots. Selected trees were at least 5 m from the plot edge. During the study, < 1 percent of the selected pines died. Total height was first measured in January 1983 after the sixth growing season from planting. Total height and diameter at breast height were last measured in March 1994 after the 1 7^{th} growing season. The diameter at breast height and height data collected in March 1994 were used to calculate total outside-bark-stem volume above a **15-cm** stump (Baldwin and Feduccia 1987).

Total current-year herbaceous production (oven-dried at 80 **°C)** was determined in February 1994 by clipping the aboveground foliage on twelve **0.22-**m^2 subplots laid out in a **3-** by 4-grid pattern within the central**0.04-ha** area of each whole plot. The herbaceous plant samples were collected 22, 20, and 18 months after the last bums on treatments **2, 3,** and 4, respectively. Waiting for more than a full year before sampling gave the herbaceous vegetation enough time to recover on all plots so valid treatment comparisons were possible.

The samples were subdivided into six **taxa:** (1) **pinehill bluestem (*S.*** *scoparium var.* ***divergens*** [Hack.] Gould); (2) other bluestems (mostly *A.* ***virginicus*** L., A. ***elliottii*** Chapm., *A. ternarius* Michx., *A. gerardii* Vitmar, and S. *tenerum* Nees); (3) longleaf uniola; (4) other grasses (mostly *Panicum virgatum* L., *Sorghastrum avenaceum* [Michx.] Nash., *Dichanthelium* spp., *Eragrostis* spp., and *Aristida* spp.); (5) grass-like plants (*Carex* spp., *Cyperus* spp., *Eleocharis* spp., *Juncus* spp., and *Rhynchospora* spp.); and (6) forbs (mostly *Helianthus angustifolius* L.).

Also on each plot, small trees, shrubs, blackberry, and vines were counted, and heights and crown covers were estimated in March 1994 at five 40-m^2 subplots laid out in an "X" pattern within the central 0.04-ha area of each whole plot. The brush was last severed in 199 l, so it had at least 1 year of regrowth before the final burns and 18 to 22 months to recover from the fires before the final measurements were taken to facilitate comparisons of height and crown spread among the burning treatments.

Loblolly pine total height, diameter at breast height, and volume per tree at stand age 17 were compared using analyses of covariance for a randomized complete block design with the three blocks as replicates, four treatments, and total height after six growing seasons as the covariate. Also, because there were no covariates, total herbaceous production, herbaceous production by taxa, and understory woody plant stocking, total height, and crown cover were compared using analyses of variance for a randomized complete block design. Treatment comparisons were made with single-degree-of-freedom contrasts to answer the following three questions:

- *Treatment 1 versus treatments 2, 3, and 4.* Do precommercial thinning and woody vegetation control by both burning and cutting influence pine development, herbaceous plant production, and understory woody vegetation?
- *Treatment 2 versus treatments 3 and 4. Does* burning in March influence pine development, herbaceous plant production, and understory woody vegetation differently than burning later in the growing season?
- *Treatment 3 versus treatment 4. Does* midspring burning influence pine development, herbaceous plant production, and understory woody vegetation differently than burning in the summer?

Selecting the α Level

Inherent variability within research blocks can be reduced by careful plot selection. Still, the problem of accepting a false null hypothesis is a major concern in field studies because natural variation is always an issue regardless of the care taken to reduce it (Peterman 1990, Thomas 1997). Little of the usable portion of the study area was left after the plots were established, so increasing error degrees-of-freedom by adding replications was not a solution. Given past experience with similar studies and the fact that there were only three blocks, an a level of 0.10 was intuitively chosen at the beginning of the study in 1982.

A power analysis was done with pine data collected in March 1994 (Thomas 1997) (table 1). A power of ≥ 0.80

Table l-Analysis of the probability of failing to reject the null hypothesis when the null hypothesis is false (power of the test), based on measurements taken in March 1994 of 17-year-old loblolly pine

Types of analysis and measurement variables	Power of the test		
	a=.05	a=.10	a=.15
Analysis of variance			
D.b.h. (cm)	0.743	0.877	0.933
Total height(m)	.255	.402	.510
Volume per tree (m^3 per stem)	.507	.683	.782
Analysis of covariance"			
D.b.h. (cm)	.909	.975	.991
Total height (m)	.832	,939	.973
Volume per tree (m^3 per stem)	.630	.802	.883

[a] Total height of pine trees at age 6 years was used as the covariate.

was desired and was achieved for **all** three experimental variables (total height, diameter at breast height, and volume per tree) at an a level of 0.10 when pretreatment 1982 height data were used as the covariate. If the treatment means were analyzed without including the 1982 heights as a covariate, a desired power value was not achieved for all experimental variables, even at an a level of 0.15. Therefore, the power analysis validated the intuitive selection of 0.10 as the α level if an analysis of covariance was to be used for the variables. The same a level was also used in the herbaceous and woody plant analyses.

However, there are problems with doing a posteriori power analysis. It may be useful only for interpreting results that have already failed to reject the null hypothesis at lower α levels (Peterman 1990). It simply may be a way of restating the test's statistical significance (Thomas 1997).

Results

Loblolly Pines

The diameter at breast height and volume of the 25 selected dominant and codominant pines were significantly less on the check than on the vegetation-management treatments (table 2), largely because vegetation-management plots had been precommercially thinned and the nonpine woody plants not killed by fire were severed. The gain between stand ages 6 and 17 averaged 2 cm in diameter at breast height and 0.04 m^3 per tree. The variable total pine height was not significantly diierent between the check and vegetation-management treatments at age 17.

On the March-burned plots, trees were significantly shorter, with smaller diameters and less volume per tree than the average for plots burned in May and July (table 2). The biennial May burns also significantly increased both height and diameter growth over what was found on plots burned in July.

Other Woody Vegetation

The March-burned plots had significantly more trees, shrubs, and blackberry than was the average stocking on plots burned in May and July (table 3). Plots burned in July had a similar number of stems per hectare as the checks. Average height and crown cover on plots treated with fire were significantly less than on the check plots. The average height of woody vegetation was significantly less on the plots burned in July than on those burned in May.

Table 2-Least square means for total height, diameter at breast height, and volume of 17-year-old loblolly pine

Treatments	Covariate[a]	Least square means		
		Total height	D.b.h.	Total stem volume
	m	m	*cm*	*m^3*
Treatment 1, check	5.05	14.0	19	0.22
Treatment 2, March burns	5.07	13.6	20	.24
Treatment 3, May burns	4.59	14.6	22	.29
Treatment 4, July burns	5.15	14.2	21	.26
Covariate α levels		0.0119	0.089 1	.1669
Linear contrasts		α levels		
Treatment 1 vs. treatments 2+3+4	—	0.5 104	0.0042	0.02 11
Treatment 2 vs. treatments 3+4	—	.0041	.0290	.0584
Treatment 3 vs. treatment 4	—	.1028	.1044	.2799

[a] Total height of pines at age 6 years was used as the covariate.

Table 3—Stocking, average height, and crown cover of hardwood trees, shrubs, and blackberry and vine stocking in 17-year-old loblolly pine stands

					a levels		
Taxa	Check (Treatment 1)	March burn (Treatment 2)	May bum (Treatment 3)	July burn (Treatment 4)	Treatment 1 vs. 2+3+4	Treatment 2 vs. 3+4	Treatment 3 vs. 4
All trees, shrubs, and blackberry							
Stems per hectare	8,560	29,300	20,988	8,971	0.1185	0.0704	0.1616
Average height(m)	2.3	0.6	0.7	0.3	.0001	.7562	.0422
Crown cover(m)	1.0	.3	.3	.2	.0001	.5093	.3339
Sweetgum							
Stems per hectare	1,152	247	7,490	1,728	.3522	.5086	.1088
Average height(m)	4.5	.9	1.1	.6	.0281	.8635	.6313
Crown cover(m)	1.4	.3	.4	.2	.0031	.8646	.3464
American beautyberry							
Stems per hectare	1,399	4,691	2.551	3,374	.6012	.3642	.6948
Average height(m)	1.5	.9	.8	.4	.0134	.0495	.0311
Crown cover (m)	0.9	.4	.5	.2	.0261	.4165	.0833
Blackberry							
Stems per hectare	412	15,720	8,230	2,057	.2344	.1835	.4708
Average height(m)	0.2	.5	.5	.2	.3221	.3552	.1612
Crown cover(m)	0.2	.2	.2	.2	.5416	.1910	1.0000
Vines							
Stems per hectare	10,123	7,572	4,691	2,716	.6047	.9600	.3342

Plant species differ in their response to vegetation management (**Haywood** 1995). in terms of distribution across the study site and the number of stems present, the most abundant tree and shrub species were **sweetgum** (***Liquidambar styraciflua*** L.) and American beautyberry (***Callicarpa americana*** L.). Compared to the checks, vegetation management significantly reduced the height and crown cover of sweetgum. Plots burned in May had the most **sweetgum** stems, and the difference in number on plots burned in May and July was significant, at a = . **11** (table 3). Vegetation management did not significantly affect the stocking of American beautyberry, probably because of the large variation in stocking between plots within treatments.

Blackberry was most common on plots burned in March, but the large variation in stocking between plots within treatments resulted in nonsignificant findings in the analyses of variance (table 3). The stocking of vines was not significantly affected by treatment, although the check plots were better stocked than the three vegetation-management treatments. Greenbrier (***Smilax*** spp.) was the most abundant vine **taxon.**

Herbaceous Vegetation

Vegetation management resulted in significantly greater total current-year herbaceous plant production in these **17-year-**old pine stands (table 4). **Pinehill bluestem** was not found on the check plots. However, it was the most productive species on the vegetation-management treatments, composing 49 percent of the total current-year production (457 kg per hectare average). **Longleaf** uniola was the only grass commonly found on the check plots, but **longleaf** uniola was still less productive on the checks than on the vegetation-management treatments, as were the grass-like plants and forbs (data not shown).

There were no statistically significant differences in herbaceous plant productivity among the three vegetation-management treatments. However, burning in May strongly increased the productivity of the other-grasses group, compared to burning in July (data not shown); and burning in July reduced total herbaceous plant productivity, compared to the other burned treatments (table 4).

Discussion

Loblolly Pine

Intensive vegetation management by precommercial thinning, **biennial** prescribed burning, and severing of woody plants influenced loblolly pine growth between stand ages 6 and 17, but the differences were not biologically important. Also, total height growth might be a better variable for

Table 4—Least square means for current-year herbaceous plant productivity in 17-year-old loblolly pine stands

Treatments	Total yield	Pinehill bluestem
	- - - - - - - - Kg per ha - - - - - -	
Treatment 1, check	16	0
Treatment 2, March burns	534	339
Treatment 3, May burns	518	215
Treatment 4, July burns	318	114
Linear contrasts	- - - - - - - - α levels - - - - -	
Treatment 1 vs. treatment 2+3+4	0.0028	0.0622
Treatment 2 vs. treatment 3+4	.2727	.1424
Treatment 3 vs. treatment 4	.1219	.4292

comparing the unthinned and unweeded checks to the vegetation-management treatments because height growth is less sensitive to stocking than diameter growth, and total height was unaffected by management.

These results were similar to those from another study, where prescribed burning in young pine stands reduced the number of trees < 2 m tall without affecting taller saplings (Haywood 1995). In that study, burning was associated with an increase in average diameter and volume because the bums provided some precommercial thinning effect.

There were differences in the growth of pines between the March, May, and July dates of burning. Grelen (1975, 1983) also reported that periodic prescribed burning in May increased survival and early growth of longleaf pine (*P. palustris* Mill.) seedlings over survival and growth following March burning.

The degree of scorching, leaf consumption, and mortality sustained by burned vegetation is influenced by the amount and condition of insulating tissues, as well as the intensity and duration of the burn (Greene and Shilling 1987). Living conifer tissues tolerate 55 °C temperatures for 60 seconds, and loblolly pine tissues die immediately if heated to 65 °C (Baker 1929, Chapman 1942). Because the temperature of plant tissues is influenced by ambient air temperature and the cooling effect of transpiration, hot and dry conditions result in higher plant-tissue temperatures, greater stress, and reduced ability to tolerate high temperatures generated by prescribed burning.

Diurnal weather conditions were not measured, and the phenological stage of new pine growth was not observed. However, while vegetation responses to any single bum were not important in this study, the long-term cumulative effect of repeated burning on tree growth, which is analogous to the effect of the climate on cumulative growth, was important.

We argue that burning early in the growing season generally exposes new plant tissues with little insulation to injurious or lethal temperatures that may curtail growth because the new growth does not have the insulative tissues and girth of older stems (Greene and Shilling 1987). May bums normally follow the first flush of shoot growth. More developed young plant tissues and good growing conditions might help pines tolerate exposure to high temperatures in May. July, however, is normally the hottest month of the year, with an average daily temperature of 28 °C and monthly rainfall of 123 mm (Louisiana Office of State Climatology 1993). Drier, hotter conditions would be less favorable for plant tissues exposed to fiie (Haywood 1995). It follows, then, that early May is generally the best time to use prescribed fiie on the west Gulf Coastal Plain, as reported by Grelen (1975, 1983).

Other Vegetation

Initially, prescribed burning and the severing of woody undergrowth should result in more, though smaller stems, than are found under untreated pine stands because the tops are killed while root systems are mostly unaffected (Cain 1985, Cain and Mann 1980, Silker 1961). Hence, it was expected that vegetation management would reduce the size of a woody undergrowth of abundant sweetgum, American beautyberry, blackberry, and greenbrier.

Also, Chen and others (1975) reported that annual or biennial burning in July more effectively controls woody undergrowth than burning in the dormant season. Woody plant vigor and stem count should eventually decrease if fire is used often in the summer (Lotti 1956). When comparing the use of fiie in March, May, and July, our findings did not completely support these other studies. Although plots burned in March had fewer stems than those burned later in the year, the significant decrease in woody plant height associated with burning in July was probably due to the strong effect of fire on American beautyberry. Still, summer burning may be useful in loblolly pine forests when preparing stands for regeneration harvesting (Lotti 1956).

Pinehill bluestem was the most common herbaceous plant in the burned pine stands. These results agree with Wolters and Wilhite (1974) that a high proportion of pinehill bluestem in the herbaceous plant community indicates a well-managed understory on upland pine sites in the loblolly pine-shortleaf pine-hardwood forest type, and that further changes in management practices may not be necessary for restoration of herbaceous plant communities.

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