# DELAYED PRESCRIBED BURNING IN A SEEDLING AND SAPLING LONGLEAF PINE PLANTATION IN LOUISIANA

**James D. Haywood**[1]

**Abstract**—To examine the effects of delaying prescribed burning for several years, I initiated five treatments in a 5- to 6-year-old longleaf pine stand: a check of no control; biennial hardwood control by directed chemical application; and biennial burning in either early March, May, or July. After the initial burns, longleaf pine survival decreased from 82 percent in February 1999 to 67 percent in November 2000. Mortality was highest among the smallest pine trees. Total pine heights in November 2000, adjusted for initial heights in February 1999, averaged 11.9, 11.5, 10.9, 11.4, and 11.3 ft on the five treatments, respectively. Total height was significantly greater on the check treatment than the average of the other four treatments, and March burning had the most adverse effect on height growth.

## INTRODUCTION

Longleaf pine (*Pinus palustris* Mill.) forests once constituted a major ecosystem in the Southern United States stretching from southeastern Virginia to central Florida and west into east Texas (Outcalt and Sheffield 1996). These forests covered a wide range of site conditions from wet pine flatwoods to dry mountain slopes, but intensive exploitation reduced the extent of old-growth longleaf forests to only 3.2 million ac by 1993.

The continued loss of longleaf pine forests has endangered or threatened nearly 200 associated taxa of vascular plants and several vertebrate species (Brockway and others 1998). Protecting the remaining longleaf pine forests and restoring longleaf pine plant communities within their historical ranges are paramount in saving these threatened species from extinction. The reintroduction of longleaf pine generally involves the use of fire for preparing sites for regeneration, and prescribed burning usually continues from seedling establishment through stand maturity (Boyer 1993, Croker and Boyer 1975, Haywood and Grelen 2000, Wahlenberg 1946).

Newly established longleaf seedlings may develop little aboveground for several years as the root system develops (Harlow and Harrar 1969). The bunch of needles at the surface resembles a clump of grass, hence the term grass stage describes the juvenile period of growth. Once the seedlings have developed a root collar of about 1 in., they are able to emerge from the grass stage.

Because aboveground growth of longleaf seedlings is slow in newly established stands, a burning program helps keep competing woody vegetation from overtopping and crowding the longleaf pine regeneration, removes dead grass that smothers young seedlings, and reduces the occurrence of brown-spot needle blight caused by *Mycosphaerella dearnessii* Barr. (Croker and Boyer 1975, Wahlenberg 1946).

However, prescribed burns are not always executed on schedule because of adverse weather conditions and lack of resources. A delay of several years can allow fine fuels to accumulate, and this accumulation increases the likelihood of more intense burns when the burning program begins. Delayed burning is, therefore, more likely to destroy seedling and sapling longleaf pines than if fuel loads are kept in check. If fire is not used or is delayed too long, competing woody plants [especially loblolly pine (*P. taeda* L.)] have to be controlled by cutting or directed applications of herbicides on many sites (Haywood 2000). If not, a mixed overstory will eventually develop of loblolly, longleaf, and hardwoods, with a midstory of trees and shrubs that shades out most of the understory vegetation (Haywood and Grelen 2000). To examine the effects of delaying prescribed burning for several years, I initiated this study in a seedling and sapling-size stand of planted longleaf pine.

## STUDY AREA

The study area is on the Longleaf Tract, Palustris Experimental Forest, Kisatchie National Forest, in central Louisiana about 19 mi south-southwest of Alexandria (approximate longitude 92°30' W., latitude 31° N.) at an average elevation of 170 ft. Harms (1996) classes the naturally infertile Beauregard-Malbis silt-loam soil complex as a wet pine site because it is seasonally wet during winter although often droughty during summer. Haywood (2000) describes the soils and subtropical climate.

The original forest stand was clearcut harvested in the mid-1980s. The unmerchantable stems and new growth were sheared and windrowed in 1991. A low cover of herbaceous and scattered woody vegetation developed after windrowing, and it was rotary mowed in July and August 1992.

[1] Research Forester, Southern Research Station, Alexandria Forestry Center, 2500 Shreveport Highway, Pineville, LA 71360-5500.

*Citation for proceedings:* Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

## METHODS

### Study Establishment

Initially, I established research plots in a randomized complete block split-plot design and removed them in December 1992 (Haywood 2000). Each of the 15 whole plots (5 blocks by 3 main plot treatments) measured 84 by 84 ft (0.16 ac) and contained 14 rows of 14 seedlings arranged in 6-by-6 ft spacing. I divided the center 100 seedlings equally into 2 subplots, and randomly assigned year-of-planting to each of the 50-seedling subplots. One subplot was planted in February 1993 and the other subplot was planted in January 1994. For each year-of-planting, I used the same Mississippi seed source. My crew hand planted the 42-week-old container longleaf seedlings with a punch of the correct size for the root plug. In both years the soil was wet, and we encountered no planting problems.

To determine the effects of herbaceous vegetation management practices on growth of newly planted longleaf pine seedlings, I assigned 3 treatments to the 15 whole plots (Haywood 2000). These treatments were (1) no herbaceous plant control after planting, (2) two annual applications of hexazinone herbicide [3-cyclohexyl-6-(dimethylamino)-1-methyl-1,3,5-triazine-2,4(1H,3H)-dione], and (3) mulching. Despite treatment, on all plots hardwood and loblolly pine brush overtopped and crowded the planted longleaf seedlings. We manually severed the brush in 1997 and sprayed the new growth with triclopyr (3,5,6-trichloro-2-pyridinyloxyacetic acid) herbicide in 1998. The most commonly treated plant was waxmyrtle (Myrica cerifera L.).

### New Study Design

After completing the initial vegetation management research and reporting the findings (Haywood 2000), I initiated this new phase of research to address delayed prescribed burning. This shift was possible because in the original design, the block, seedling age (subplot), and treatment-by-age interaction effects were not significant (a = 0.05). Therefore, I reconfigured the design, and the three original treatments—check, herbicide application, and mulching—became the blocks. Blocking was justified because of significant differences in longleaf pine total height among the original treatments (Haywood 2000).

I randomly assigned five treatments within the three blocks, or replicates (Steel and Torrie 1980). In the first (check) there was no more woody plant control after 1998. In the second (herbicide) beginning in 1999 there was biennial control of woody vegetation over 2 ft tall with a directed application of herbicide (triclopyr) in May; we did not treat blackberry (*Rubus* spp.) and woody vines. In the third, fourth, and fifth treatments, I conducted biennial burning in early March, May, or July, respectively.

### Confirmation of the New Study Design

I analyzed pretreatment survival and tree height data taken in February 1999 using the original analysis of variance for a split-plot randomized complete block design model (Steel and Torrie 1980). However, this time I used the new treatments (check, herbicide, March burn, May burn, and July burn) as the main plot effects (table 1). I included tree age and treatment-by-age interaction terms in the analysis, and there were no significant age effects or treatment-by-age interactions in the pretreatment analyses (a = 0.05). Thus, the plots were sufficiently uniform to continue with the new research, and I ignored the age of seedlings in future analyses.

### Burning Samples and Technique

Before setting fires, I collected a combustible fine fuel sample on five randomly located 2.4-$ft^2$ fuel-monitoring plots. I again collected fuel samples 1 week after the burns to determine fuel consumption on a dry-weight basis. I calculated Byram's fire intensity for each burn (Haywood 1995).

All burns were strip-head fires set with drip torches and were monitored to determine their intensity (Haywood 1995). First, we set a backfire along the downwind side of the plot. After the line was secure, we lit the strips about 24 ft apart and allowed them to burn together.

### Measurements

Before initiating new treatments, I measured longleaf pine total height in February 1999 to use as a covariate in future analyses. I measured posttreatment total height and diameter at breast height in October 1999 and November 2000, 4 to 7 and 17 to 20 months after the initial set of treatments, respectively.

### Data Analysis

The model was a randomized complete block design with three blocks as replicates (Steel and Torrie 1980), and I analyzed two groups of longleaf pine—all pine trees or just those out of the grass stage (pines over 0.4 ft tall). In this first analysis, dependent variables were pretreatment pine survival and total height measured in February 1999 and pretreatment survival and heights adjusted for mortality through November 2000. If I found significant treatment differences (a = 0.05), I used Duncan's Multiple Range Tests to determine mean separations.

In subsequent analyses of posttreatment total height and diameter measurements, I used the pretreatment heights as a covariate in the study design (Steel and Torrie 1980). I did not use pretreatment diameters as covariates because not all trees were at least 4.5 ft tall in February 1999.

I used linear contrasts to determine differences among treatments to address several hypotheses associated with delayed burning based partly on Haywood and Grelen (2000). First, suspension of woody plant control will eventually be detrimental to longleaf pine trees: treatment 1 versus treatments 2 through 5. Second, biennial burning and woody plant control with herbicides will have similar effects: treatment 2 versus treatments 3 through 5. Third, burning in May will have similar growth effects as burning in March or July: treatment 4 versus treatments 3 and 5, and fourth, March and July burning will have similar effects: treatment 3 versus treatment 5.

**Table 1—Confirmation of the new study design; the 5- and 6-year-old longleaf pine were measured in February 1999 before the initiation of treatments[a]**

| Treatment effects | All longleaf pine | | | Longleaf out of the grass stage | | |
|---|---|---|---|---|---|---|
| | Survival | Height | Disease | Pines out of grass stage | Height | Disease |
| | *Pct* | *Ft* | - - - - - - *Percent* - - - - - - | | *Ft* | *Pct* |
| Treatments | | | | | | |
| 1. Check | 86 | 6.3 | 10 | 82 | 6.6 | 10 |
| 2. Herbicide | 86 | 5.0 | 12 | 79 | 5.3 | 11 |
| 3. March burn | 79 | 5.5 | 7 | 74 | 5.8 | 6 |
| 4. May burn | 83 | 5.3 | 11 | 79 | 5.6 | 11 |
| 5. July burn | 84 | 4.3 | 15 | 76 | 4.6 | 16 |
| Prob>F-value | .205 | .388 | .221 | .243 | .405 | .104 |
| Age | | | | | | |
| 5-year-old trees | 83 | 4.9 | 11 | 77 | 5.2 | 10 |
| 6-year-old trees | 84 | 5.7 | 11 | 79 | 6.0 | 11 |
| Prob>F-value | .786 | .212 | .937 | .730 | .190 | .497 |
| Treatment-by-age interactions | | | | | | |
| 5-year-old trees | | | | | | |
| 1. Check | 87 | 5.7 | 11 | 83 | 6.0 | 10 |
| 2. Herbicide | 85 | 4.8 | 14 | 79 | 5.1 | 12 |
| 3. March burn | 82 | 5.1 | 7 | 76 | 5.5 | 7 |
| 4. May burn | 82 | 4.5 | 10 | 76 | 4.8 | 10 |
| 5. July burn | 79 | 4.4 | 13 | 74 | 4.7 | 12 |
| 6-year-old trees | | | | | | |
| 1. Check | 85 | 7.0 | 9 | 81 | 7.2 | 9 |
| 2. Herbicide | 87 | 5.2 | 11 | 80 | 5.6 | 9 |
| 3. March burn | 76 | 6.0 | 7 | 73 | 6.2 | 6 |
| 4. May burn | 85 | 6.1 | 12 | 81 | 6.3 | 11 |
| 5. July burn | 88 | 4.2 | 18 | 79 | 4.6 | 20 |
| Prob>F-value | .205 | .894 | .782 | .655 | .934 | .523 |

[a] There were no significant treatment or age differences or treatment-by-age interactions before treatments began (a = 0.05).

## RESULTS

### Burning Effects

I conducted the first set of burns in a 6-year-old grass-dominated rough. Grasses dominated the rough because woody competitors were controlled on all plots before the study began (table 2). Fire intensities ranged from 84 to 199 British thermal units (Btu) per foot, which were well above the recommended maximum intensity of 50 Btus per foot (Haywood 1995).

### Treatment Effects

Tree mortality was low on the check and herbicide treated plots, decreasing on average from 86 percent in February 1999 to 81 percent in November 2000 (table 3). The dead longleaf pines averaged < 1 ft tall; so, initial heights of living trees increased from 5.7 to 6.1 ft once I dropped dead trees from the data set.

Prescribed burning, regardless of date, reduced longleaf pine survival, which decreased from an average of 82 percent in February 1999 to an average of 67 percent in November 2000 on the three burned treatments (table 3). The dead trees averaged < 2 ft tall. Thus before burning, the longleaf pines averaged 5.0 ft tall, and after I dropped these dead trees from the data set, the surviving pines averaged 5.9 ft tall in the pretreatment measurement (table 3).

In February 1999, percentage of pines out of the grass stage (pines over 0.4 ft tall) averaged 96 percent and ranged from 94 percent on the March-burn plots to 97 percent on the check and herbicide plots (table 3). Although these were the tallest trees, fire had the same adverse

**Table 2—Parameters and intensities for the three 1999 prescribed burns conducted in a 6-year-old grass rough in 1999**

| Treatments | Burning date | Diurnal temperature range | Wind speed | Average fuel load[a] | Range in fire intensity | Average fire intensity[b] |
|---|---|---|---|---|---|---|
| | | *°F* | *Mph* | *Lbs/ac* | - - - - *Btu per foot* - - - - | |
| March burn | March 2 | 56 – 73 | 4 | 3,305 | 92 – 124 | 111 |
| May burn | May 14 | 56 – 86 | 2 | 5,360 | 84 – 109 | 99 |
| July burn | July 8 | 70 – 91 | 3 | 3,908 | 116 – 199 | 170 |

[a] Oven-dried weights.
[b] Average fire intensities were from two to over three times the recommended maximum intensity of 50 Btus per foot (Haywood 1995).

effect on survival as for all pines partly because longleaf pines are still highly vulnerable to fire damage and mortality until the seedlings are 4 to 6 ft tall (Bruce 1951). Longleaf pines out of the grass stage averaged 5.3 ft tall before burning, and after I dropped the dead trees from the data set, the remaining pines averaged 6.0 ft tall on the three burned treatments.

In October 1999 and 4 to 7 months after treatment, height of all longleaf pines was significantly greater on the checks (8.8 ft) than the average for the other four treatments (8.3 ft), and height was significantly greater on the herbicide plots (8.5 ft) than the average for the three burned treatments (8.2 ft) (table 3). Tree height was significantly greater on the July-burn plots than on the March-burn plots. Diameter of longleaf pines did not significantly differ among treatments, although diameter at breast height on the herbicide plots (1.5 in.) was greater than the average for the three burned treatments (1.4 in.) at probability > F-value (P) = 0.07. I found a similar pattern of treatment responses for longleaf pines out of the grass stage.

In November 2000 and 17 to 20 months after treatment, height of all longleaf pines was still significantly greater on the checks (11.9 ft) than the average for the other four treatments (11.3 ft) (table 3). None of the other treatment contrasts were significant, although the July-burn trees (11.5 ft) were taller than the March-burn trees (10.9 ft) at P = 0.07. Diameter did not significantly differ among treatments, although the checks (2.0 in.) had a greater diameter at breast height than the average for the other four treatments (1.9 in.) at P = 0.06. I found a similar pattern of treatment responses for longleaf pines out of the grass stage.

## DISCUSSION

The rapidity that loblolly pine and hardwood brush develops in new longleaf pine plantations is a serious problem that managers must address either with fire, herbicides, or a combination of treatments (Haywood and Grelen 2000). However, neither herbicides nor fire are panaceas for managing longleaf pine stands. Fire can destroy seedlings in and emerging from the grass stage, and later the use of fire can adversely affect stand growth and yield (Boyer and Miller 1994, Bruce 1951, Harlow and Harrar 1969, Wahlenberg 1946). Misapplied herbicides can injure desirable plants and contaminate soil and water resources.

Overall, the fire intensities for the three 1999 burns were unacceptably high partly because the delay in burning allowed fine fuels to accumulate over the previous 6 years. Still, delaying the first burn also allowed many of the longleaf seedlings to reach a stature where they could better tolerate heat injury (Bruce 1951, Greene and Shilling 1987, Haywood 1995). Therefore, mortality was mostly among the smallest seedlings that were of little consequence toward future stand development.

Originally we considered that delayed burning would avoid the documented, detrimental effect that repeated March burning has on longleaf pine seedling and sapling growth (Haywood and Grelen 2000). Although mortality was largely among the smallest pine trees, the untreated checks still had greater height growth than the treated plots, and March was still the most detrimental time to burn. This suggests that the application of fire or herbicide had sublethal effects on the trees that were not as obvious as the heat-related death of the smallest trees.

Longleaf pine remains very susceptible to heat-related injury until the seedlings are about 6 ft tall (Bruce 1951). Trees on the burned plots averaged about 6 ft tall at the beginning of the study, and probably most did not have the stature to avoid injury especially at the high fire intensities experienced (table 2). Also, a larger proportion of a smaller tree is exposed to a misapplication of directed herbicide than is a larger tree, and smaller trees are less obvious and therefore more often accidentally sprayed than larger trees. Regardless, neither delaying the first burn nor application of herbicide benefited these 5- and 6-year-old longleaf pines.

**Table 3—Survival and growth responses of longleaf pine to the initial series of treatments under the new study design[a]**

| | Pretreatment | | Post-treatment | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Pines surviving in February 1999 | | | | October 1999 | | November 2000 | |
| Treatment effects | Living pines | Covariate height | Survival | Covariate height | LSM[b] height | LSM D.b.h. | LSM height | LSM D.b.h. |
| | *Percent* | *Ft* | *Percent* | *- - - - - - - Ft - - - - - -* | | *In.* | *Ft* | *In.* |
| All longleaf | | | | | | | | |
| 1. Check | 86 | 6.3 | 81a[c] | 6.8 | 8.8 | 1.47 | 11.9 | 2.01 |
| 2. Herbicide | 86 | 5.0 | 81a | 5.3 | 8.5 | 1.46 | 11.5 | 1.97 |
| 3. March burn | 79 | 5.5 | 69b | 6.1 | 7.7 | 1.30 | 10.9 | 1.85 |
| 4. May burn | 83 | 5.3 | 67b | 6.3 | 8.3 | 1.35 | 11.4 | 1.92 |
| 5. July burn | 84 | 4.3 | 66b | 5.2 | 8.6 | 1.38 | 11.3 | 1.91 |
| Prob>F-value | .205 | .389 | .006 | .695 | .001 | .128 | .024 | .141 |
| Contrasts[d] | | | | | | | | |
| Trt 1 vs trt 2–5 | | | | | .002 | .106 | .012 | .067 |
| Trt 2 vs trt 3–5 | | | | | .026 | .064 | .106 | .159 |
| Trt 4 vs trt 3+5 | | | | | .217 | .895 | .217 | .371 |
| Trt 3 vs trt 5 | | | | | .001 | .281 | .074 | .340 |
| Longleaf out of the grass stage | | | | | | | | |
| 1. Check | 97[e] | 6.6 | 80a[c] | 6.8 | 9.0 | 1.50 | 12.1 | 2.05 |
| 2. Herbicide | 97 | 5.3 | 79a | 5.4 | 8.7 | 1.49 | 11.8 | 2.01 |
| 3. March burn | 94 | 5.8 | 66b | 6.4 | 7.9 | 1.33 | 11.2 | 1.91 |
| 4. May burn | 96 | 5.6 | 66b | 6.4 | 8.5 | 1.38 | 11.6 | 1.96 |
| 5. July burn | 96 | 4.6 | 65b | 5.3 | 8.7 | 1.41 | 11.5 | 1.94 |
| Prob>F-value | .590 | .405 | .005 | .682 | .002 | .134 | .056 | .275 |
| Contrasts[d] | | | | | | | | |
| Trt 1 vs trt 2–5 | | | | | .004 | .108 | .022 | .112 |
| Trt 2 vs trt 3–5 | | | | | .035 | .064 | .144 | .211 |
| Trt 4 vs trt 3+5 | | | | | .277 | .898 | .308 | .492 |
| Trt 3 vs trt 5 | | | | | .001 | .308 | .215 | .633 |

[a] Seedling age was ignored but the seedlings were in the sixth or seventh growing season after planting when first treated.
[b] LSM = Least-squares means are adjusted to make them the best estimates of what they would have been if all the covariate means had been the same (Steel and Torrie 1980).
[c] By longleaf pine group and for pine survival, means followed by the same letter are not significantly different based on Duncan's Multiple Range Tests (a = 0.05).
[d] The linear contrasts compared (vs) preselected combinations of the preceding treatments (trt), and the Prob>F-value are reported for each contrast.
[e] Percentage of the living pines out of the grass stage when the study began.

## LITERATURE CITED

**Boyer, William D.** 1993. Long-term development of regeneration under longleaf pine seedtree and shelterwood stands. Southern Journal of Applied Forestry. 17(1): 10–15.

**Boyer, William D.; Miller, James H.** 1994. Effect of burning and brush treatments on nutrient and soil physical properties in young longleaf pine stands. Forest Ecology and Management. 70: 311–318.

**Brockway, Dale G.; Outcalt, Kenneth W.; Wilkins, R. Neal.** 1998. Restoring longleaf pine wiregrass ecosystems: plant cover, diversity and biomass following low-rate hexazinone application on Florida sandhills. Forest Ecology and Management. 103: 159–175.

**Bruce, David.** 1951. Fire, site, and longleaf height growth. Journal of Forestry. 49(1): 25–27.

**Croker, Thomas C., Jr.; Boyer, William D.** 1975. Regenerating longleaf pine naturally. Res. Pap. SO–105. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 21 p.

**Greene, Thomas A.; Shilling, Charles L.** 1987. Predicting girdling probability for pine and hardwood saplings in low-intensity backfires. Forest Science. 33(4): 1010–1021.

**Harlow, William M.; Harrar, Ellwood S.** 1969. Textbook of dendrology. 5th ed. New York: McGraw-Hill Book Company. 512 p.

**Harms, William R.** 1996. An old-growth definition for wet pine forests, woodlands, and savannas. Gen. Tech. Rep. SRS–2. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 7 p.

**Haywood, James D.** 1995. Prescribed burning and hexazinone herbicide as release treatments in a sapling hardwood-loblolly pine stand. New Forests. 10: 39–53.

**Haywood, James D.** 2000. Mulch and hexazinone herbicide shorten the time longleaf pine seedlings are in the grass stage and increase height growth. New Forests. 19: 279–290.

**Haywood, James D.; Grelen, Harold A.** 2000. Twenty years of prescribed burning influence the development of direct-seeded longleaf pine on a wet pine site in Louisiana. Southern Journal of Applied Forestry. 24(2): 86–92.

**Outcalt, Kenneth W.; Sheffield, Raymond M.** 1996. The longleaf pine forest: trends and current conditions. Resour. Bull. SRS–9. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 23 p.

**Steel, Robert G.D.; Torrie, James H.** 1980. Principles and procedures of statistics. 2d ed. New York: McGraw-Hill Book Company. 633 p.

**Wahlenberg, W.G.** 1946. Longleaf pine its use, ecology, regeneration, protection, growth, and management. Washington, DC: Charles Lathrop Pack Forestry Foundation; U.S. Department of Agriculture, Forest Service. 429 p.

.