Twenty Years of Prescribed Burning Influence the Development of Direct-Seeded Longleaf Pine on a Wet Pine Site in Louisiana

James D. Haywood *and* **Harold E. Grelen** *(retired), USDA Forest Service, Southern Research Station, Pineville, LA 71360.*

ABSTRACT: *Prescribed burning treatments were applied over a 20 yr period in a completely randomized field study to determine the effects of various fire regimes on vegetation in a direct seeded stand of longleafpine (*Pinus palustris *Mill.). Seeding was done in November 1968. The study area was broadcast-burned about 16 months after seeding. The initial research treatments were applied in 1973, and as many as 12 research bums were applied through 1993. Pines were measured in March 1995. Prescribed burning resulted in a greater stocking of longleaf pine (an average of 598 trees/ac) on treated plots than on unburned plots (30 trees/ac). However, on the burned treatments, longleaf pines were significantly smaller (2.5 ft^3/tree of stemwood} than were the unburned trees (3.7 ft^3/tree of stemwood). Half of the treated plots were burned in early March, and the other half were burned in early May. Seasons of burning did not significantly influence longleaf pine stocking. However, use of fire in May resulted in significantly greater basal area (100 ft^2/ac) and stemwood production (1,921 ft^3/ac) than burning in March (59 ft^2/ac and 909 ft^3/ac). Fire effectively kept natural loblolly pine (*P. taeda *L.) seedlingsfrom reaching sapling size, but loblolly saplings and poles dominated the unburned plots (710 trees/ac). When all pines were considered on all treatments, stocking ranged from 467 to 740 trees/ac, but stocking was not significantly different among treatments. The unburned plots had significantly greater total basal area (149 ft^2/ac) andstemwoodproductivity (2,918 ft^3/ac) than the burned treatments (82 ft^2/ac and 1,459 ft^3/ac). Likewise, hardwoods that were at least 1 in. dbh were more common on unbumedplots (327 stems/ac) than on burned treatments (58 stems/ac). South. J. Appl. For. 24(2):86–92.*

The reestablishment and recovery of longleaf pine (*Pinus palustris* Mill.) on lands historically stocked by this species concerns public land managers in the southern United States. Longleaf pine is a fire subclimax type, and generally, prescribed burning is considered a necessary management practice for preparing sites for regeneration (Boyer 1993a, Croker and Boyer 1975, Smith 1961, Wahlenberg 1946). The management of longleaf pine regeneration can be difficult partly because it develops little above ground for the first 3 to 6 yr (or longer under adverse conditions) as the root system develops (p. 81-84, Harlow and Harrar 1969). The bunch of needles at the surface resembles a clump of grass, hence the term "grass stage" to describe the juvenile period of growth. Grass stage longleaf seedlings are susceptible to encroachment by aggressive underbrush and seedlings of other pine species, smothering by dead grass, and brown-spot needle blight, caused by ***Mycosphaerella dearessii*** Barr. (Boyer 1975, Croker and Boyer 1975, Wahlenberg 1946). Prescribed burning during this period can be used to relieve the longleaf seedlings from these stresses, and once the seedlings have a well-developed root collar (at least 1 in. diameter), they are able to emerge from the grass stage.

Many forest managers maintain herbaceous plant communities within forest stands. Periodic burning of southern pine forests regardless of season can help control hardwoods and hopefully increase herbaceous plant production (Glitzenstein et al. 1995, Grelen 1976, 1983, Robbins and Myers 1989). Although periodic burning later in the growing season may more effectively reduce hardwood vegetation than periodic burning near the beginning of the growing season (Chen et al. 1975, Grelen 1975, Lotti 1956, Lotti et al. 1960, Robbins and Myers 1989), the effects of a single bum can be transitory with no lasting effect associated with season (Haywood 1995, Olson and Platt 1995).

However, prescribed fire is not a panacea for managing stands of longleaf pine and their understory plant communities. Fire can destroy seedlings in and emerging from the grass stage, and later, the use of fire can adversely affect stand growth and yield and soil productivity (Boyer and Miller 1994, Grace and Platt 1995, Wahlenberg 1946). Use of fire at certain times of the year can differentially influence development of seedling and sapling pines (Grelen 1975, 1983).

NOTE: James D. Haywoodis the corresponding author, and he can be reached at (318) 473-7226; Fax: (318) 473-7273; E-mail: dhaywood@fs.fed.us.
Manuscript received January 8, 1999, accepted October 6, 1999.

Research on the seasonal effects of fire was reported by Grelen (1975) for a site that was better drained than the one we describe here. The objective of this long-term research study was to determine how different schedules of prescribed burning in March or May influenced pines, hardwoods, and understory plant production in a direct-seeded longleaf pine stand on a wet pine site. Unburned conditions were also evaluated. The first 7 yr of research were reported by Grelen (1983).

Materials and Methods

Study Area

The study area is within the humid, temperate, lower coastal plain and flatwoods province of the Southeastern United States (McNab and Avers 1994). It is located within boundaries of the Kisatchie National Forest in central Louisiana about 19 miles south-southwest of Alexandria (approx. 92°30'W long,, 31°N lat.) at an average elevation of 170 ft.

The soil, Kolin silt loam (fine-silty, siliceous, thermic, Glossaquic Paleudalfs), is moderately well drained with a 1 to 5% slope (Kerr et al. 1980). It has low natural fertility. Water perches above a clayey lower subsoil in winter and early spring. Harms (1996) classes this area as a wet pine site because the soil is seasonally wet during winter and often droughty during the late growing season. Kerr et al. (1980) consider this soil to be suitable for both pine and hardwood management.

The area's climate is subtropical with mean January and July temperatures of 47" and 82°F, respectively (Louisiana Office of State Climatology 1995). Annual precipitation averages 55 in. with more than 30 in. during the 250 day growing season, which is from March 10 to November 15 (the spring and fall dates with a 50% probability of a frost).

The 5 ac study area lies within a quarter-mile of two hardwood-pine intermittent drainages. The original stand of pines and hardwoods was clearcut in the 1920s. A cover of perennial grasses with scattered pines and hardwoods was maintained by periodic burning for open-range grazing (Grelen 1983). The area was direct-seeded to longleafpine in November 1968 and was burned in early 1970. When this study began in 1973, grass-stage longleafseedlings were abundant. Some, along with the older seedlings, were the progenies of occasional seed trees. All overstory pines and hardwoods on the study area were girdled to reduce shade and root competition to form an even-aged stand of longleaf pine regeneration. However, scattered loblolly pine (P. *taeda* L.) and longleaf pine outside of the study area and loblolly pine within the drainages continued to be natural seed sources.

The herbaceous understory, predominantly bluestems (*Andropogon* spp.), provided fuel for the burning treatments. Southern bayberry (*Myrica cerifera* L.) was the dominant shrub, and seedling blackgum (*Nyssa sylvatica* Marsh.), sweetgum (*Liquidambar styraciflua* L.), and oaks (*Quercus* spp.) were the most common hardwoods (Grelen 1983). Loblolly pine seedlings were abundant, and the natural seeding of loblolly pine onto sites regenerated to longleaf pine continues to be a serious hindrance to the management of longleaf pine in central Louisiana to this day.

Treatments

In late 1972, the 5 ac study area was fenced to exclude livestock. Eighteen contiguous plots were laid out, each one separated by a 10-ft-wide fireline. Individual plots were 104 by 104 ft or 0.25 ac. The 15 best drained plots, each having well-distributed longleaf pine regeneration, were used in this research. Five treatments, replicated 3 times, were randomly assigned to the 15 plots as follows:

1. **Unburned (1970 to present).** Direct seeded in November 1968, control burned 16 months later in 1970, overstory hardwood and pine trees were felled in early 1973 to form an even-aged stand of longleaf pine regeneration, but there was no treatment thereafter.
2. **Biennial March burns.** Plots were initially treated as the unburned plots were treated; but beginning in 1973, these plots were prescribed burned biennially on or as near March 1 as weather and fuel conditions permitted. Burning continued through 1993, for a total of 11 research bums over a 20 yr period.
3. **Annual-triennial March burns.** Plots were initially treated as the unburned plots were treated; but from 1973 through 1980, these plots were prescribed burned annually on or as near 1 March as weather and fuel conditions permitted. Because of a lack of fine fuel accumulation on an annual basis, the annual bums ceased, and triennial bums were begun in 1983 on or as near March 1 as possible. Burning continued through 1992, for a total of 12 research bums over a 19 yr period.
4. **Biennial May burns.** Plots were initially treated as the unburned plots were treated; but beginning in 1973, these plots were prescribed burned biennially on or as near May 1 as weather and fuel conditions permitted. Burning continued through 1993, for a total of 11 research burns over a 20 yr period.
5. **Annual-triennial May burns.** Plots were initially treated as the unburned plots were treated; but from 1973 through 1980, these plots were prescribed burned annually on or as near May 1 as weather and fuel conditions permitted. Because of a lack of fine fuel accumulation on an annual basis, the annual bums ceased, and triennial bums were begun in 1983 on or as near May 1 as possible. Burning continued through 1992, for a total of 12 research bums over a 19 yr period.

Plots were burned with backfires and strip headfires, and all bums were completed as planned. Because dates rather than burning conditions were prescribed, and cumulative effects of decades of burning were measured rather than the effect of a single bum, no fuel or daily weather data were recorded, We concerned ourselves with the long-term cumulative effects of repeated burning on plant development-which is analogous to the effects of the climate on cumulative growth-rather than transitory vegetation responses to a single bum (Olson and Platt 1995).

Measurements aud Data Analysis

In March 1995, total height and dbh of all pine trees (longleaf and loblolly) at least 1 in. dbh (saplings and poles) were measured in the central 0.1 ac of each whole plot. These data were used to calculate total inside-bark stem volume. Stemwood volumes for loblolly pine were calculated from a0.5 ft stump height (Baldwin and Feduccia 1987). For longleaf pine at least 5 in. dbh, stemwood volumes were calculated from a 0.4 ft stump height, and for longleaf pine less than 5 in. dbh, stemwood volumes were calculated from a 0.1 ft stump height (Baldwin and Saucier 1983). These measurements were made 22 to 24 months after the last biennial burns, and 34 to 36 months after the last annual-triennial bums.

In February 1996, total height and dbh of all hardwood trees and shrubs with a central stem at least 1 in. dbh were measured in the central 0.1 ac of each whole plot. These measurements were made 33 to 35 months after the last biennial bums and 45 to 47 months after the last annual-triennial bums.

In October 1996, understory vegetation (herbaceous plus woody plants less than 1 in. dbh) was inventoried and a total biomass sample was collected and oven-dried at 176°F. The inventory and samples were taken on nine 2.4 ft^2 subplots that were laid out in a 3 x 3 grid pattern within the central 0.1 ac of each whole plot. The inventory and samples were taken 41 to 43 months after the last biennial bums and 53 to 55 months after the last annual-triennial bums. Delaying before data were collected gave the understory vegetation enough time to recover on all plots so valid treatment comparisons could be made. However, this delay meant the samples were collected well after the next bum would have been made, and the productivity estimates are probably higher than would be expected had the burning treatments continued.

Plot means were compared using analyses of variance for a completely randomized design with three replications of each of the five treatments (a = 0.05). Variables analyzed were number of stems and basal area per acre, total height, and dbh for only longleaf pine, longleaf plus loblolly pine, or hardwood trees and shrubs; stemwood volume per tree and per acre for only longleaf pine or longleaf plus loblolly pine; and understory biomass production. Treatment comparisons were made with single-degree-of-freedom contrasts to answer the following questions:

1. Treatment 1 versus treatments 2, 3, 4, and 5; i.e., were there differences between the unburned plots and the averages for the four burning treatments?
2. Treatments 2 and 3 versus treatments 4 and 5; i.e., were results following long-term burning in March different from burning in May?
3. Treatments 2 and 4 versus treatments 3 and 5; i.e., were results following the biennial burning schedule different from those following the annual-triennial burning schedule?
4. Treatments 2 and 5 versus treatments 3 and 4; i.e., were there interactions between seasons of burning (March or May) and burning schedules (biennial or annual-triennial)?

Results

Pines

Total height and dbh of longleaf pine saplings and poles were significantly greater on the unburned plots (5 1 ft and 5.7 in.) than the average for the four burned treatments (34 ft and 4.6 in.) (Table 1). However, longleaf pine stocking was significantly less on the unburned plots (30 trees/ac) than on the four burned treatments (598 trees/ac). Consequently, despite their larger stature, longleaf pines on the unburned plots had less basal area and stemwood (6 ft^2/ac and 115 ft^3/ac) than the four burned treatments (79 ft^2/ac and 1,394 ft^3/ac).

Seasons of burning and burning schedules interacted significantly to affect total height of longleaf pine. Average height was greatest after 11 biennial May bums but least after 11 biennial March burns (Table 1). Grelen (1975) also reported that biennial burning in May resulted in larger

Table 1. Least square means and linear contrasts among prescribed burning treatments for several tree and stand characteristics of only the direct-seeded longleaf pine in a pine stand in Louisiana.

Treatments	Total height (ft)	Dbh (in.)	Stemwood (ft^3/tree)	Stocking (trees/ac)	Basal area (ft^2/ac)	Stemwood production (ft^3/ac)
Unburned (trt. 1)	51	5.7	3.70	30	5.5	115
Biennial March burns (trt. 2)	28	3.9	1.65	467	39.6	587
Annual-triennial March bums (trt. 3)	33	4.3	1.73	693	78.3	1,188
Biennial May bums (trt. 4)	41	5.4	3.70	517	93.0	1,820
Annual-triennial May burns (trt. 5)	36	4.7	2.89	717	106.3	1,980
Linear contrasts			(α levels)			
Unburned versus burning treatments*	0.0001	0.0172	0.0178	0.0326	0.0041	0.0066
March bums versus May burns†	0.0001	0.0062	0.0007	0.8343	0.0212	0.005 1
Biennial burns versus annual-triennial burns††	0.8584	0.6274	0.2798	0.2418	0.1092	0.2007
Interaction between seasons of burning and burning schedules§	0.0011	0.1002	0.1915	0.9393	0.4065	0.4448

* Trt. 1 vs. trt. 2+3+4+5.
† Trt. 2+3 vs. trt. 4+5.
†† Trt. 2+4 vs. trt. 3+5.
§ Trt. 2+5 vs. trt. 3+4.

longleaf pine saplings than biennial burning in either March or July.

There were also differences between the two burning seasons regardless of the burning schedules. Longleaf pines on the two May-burn treatments averaged greater dbh (5 in.) and stemwood per tree (3.3 ft^3/tree) and more basal area (100 ft^2/ac) and stemwood per acre (1,900 ft^3/ac) than longleaf pines on the two March-bum treatments (4 in., 1.7 ft^3/tree, 59 ft^2/ac, and 887 ft^3/ac) (Table 1).

Natural loblolly seedlings, originating from parent trees near the study area, were not repressed on the unburned plots, yielding 7 10 loblolly saplings and poles per acre 26 growing seasons after direct seeding to longleaf pine (Tables 1 and 2). On the treatment plots, use of fire effectively controlled the loblolly pine regeneration. None of the loblolly pines reached sapling size on the two March-bum treatments, but an average of 13 loblolly pines per acre were sapling size or larger on the two May-bum treatments. When both pine species were included in the analysis, stocking ranged from 467 to 740 trees/ac, and there was no statistical difference among all five treatments (Table 2).

Consequently, the unburned plots were the most productive when both pine species were included in the analyses (Table 2). The unburned plots had 149 ft^2/ac of basal area and 29 17 ft^3/ac of stemwood compared to an average of 82 ft^2/ac of basal area and 1,438 ft^3/ac of stemwood for the four burned treatments. When comparisons were made among the bum treatments, the statistical outcomes were the same when both pine species were considered as when only longleaf was considered-i.e., the two May-bum treatments (104 ft^2/ac and 1,988 ft^3/ac) were more productive, on average, than the two March-bum treatments (59 ft^2/ac and 887 ft^3/ac) with no significant differences between burning schedules.

Other Vegetation

Plant species differ in their response to vegetation management. In terms of distribution across the unburned plots, the most common species of woody plants at least 1 in. dbh were sweetgum, red maple (*Acerrubrum* L.), American holly (*Ilexopaca* Ait.), yaupon (*Z. vomitoria* Ait.), and possumhaw (*I. decidua* Walt.). Therefore, a shift in species composition occurred after burning ceased. Only sweetgum remained as a common larger hardwood, while the original southern bayberry, blackgum, and oaks were replaced by red maple, American holly, yaupon, and possumhaw as the more common larger hardwoods 26 yr later.

On the four burned treatments, the most common species was blackjack oak (*Q. marilandica* Muenchh.). Blackjack oak is known to tolerate fire (Grelen 1976).

Compared to the unburned plots, use of fire significantly reduced stocking and stand basal area per acre of hardwood trees and shrubs at least 1 in. dbh (Table 3). Hardwood stocking and basal area were 327 stems/ac and 13 ft^2/ac on the unburned plots and averaged 58 stems/ac and 2 ft^2/ac on the four burned treatments. However, the differences in mean total height and dbh were not significant, averaging 16 ft and 2 in. on the four burned treatments and 23 ft and 2 in. on the unburned plots. Among the burned treatments themselves, there were no statistically significant differences in total height, dbh, stocking, and basal area.

In terms of distribution across the four burned treatments, the most common grass taxa were broomsedge (*Andropogon virginicus* L.), arrowfeather threeawn (*Aristida purpurascens* Poir.), low panicums (*Dichanthelium* spp.), tall panicums (*Panicum* spp.), and paspalums (*Paspalum* spp.). The most common grasslike taxon was beakrush (*Rhynchospora* spp.). The most common forb taxa were the composites bushy aster (*Asterdumosus* L.), eupatoriums (*Eupatorium* spp.), goldasters (*Heterotheca* spp.), swamp sunflower (*Helianthus angustifolius* L.), rough coneflower (*Rudbeckia grandiflora* Sweet DC *var. alismaefolia* [T.&G.] Cronq.), slender rosinweed (*Silphium gracile* A. Gray), Texas ironweed (*Vernonia texana* [A. Gray] Small); the legumes downy milkpea (*Galactia volubilis* [L.] Britton) and pencilflower (*Stylosanthes biflora* [L.] BSP); and downy lobelia (*Lobelia puberula* Michx.), water-hyssop (*Mecardonia acuminata* [Walt.] Small), Maryland beautyberry (*Rhexia mariana* L.), and Hyssop skullcap (*Scutellaria integrifolia* L.). Blackberry

Table 2. Both the direct-seeded longleaf and natural loblolly pines in a pine stand in Louisiana.

Treatments	Total height (ft)	Dbh (in)	Stemwood (ft^3/tree)	Stocking (trees/ac)	Basal area (ft^2/ac)	Stemwood production (ft^3/ac)
Unburned (nt. 1)	46	5.8	4.09	740	149.0	2,917
Biennial March bums (trt. 2)*	28	3.9	1.65	467	39.6	587
Annual-triennial March bums (trt. 3)*	33	4.3	1.73	693	78.3	1,188
Biennial May burns (trt. 4)	41	5.6	3.96	533	101.4	1,987
Annual-triennial May burns (m. 5)	35	4.7	2.84	727	107.2	1,990
Linear contrasts			(α levels)			
Unburned versus burning treatments+	0.0001	0.0069	0.0090	0.476 1	0.0008	0.0004
March bums versus May burns††	0.0002	0.0079	0.0025	0.7655	0.0054	0.0015
Biennial bums versus annual-triennial bums*	0.7014	0.4747	0.2545	0.2269	0.1135	0.2622
Interaction between seasons of burning and burning schedules++	0.0028	0.0867	0.1910	0.9206	0.2287	0.2678

* There were no loblolly pines at least 1 in. dbh on plots burned in March.
† Trt. 1 vs. trt. 2+3+4+5.
†† Trt. 2+3 vs. trt. 4+5.
§ Trt. 2+4 vs. trt. 3+5.
‖ Tn. 2+5 vs. trt. 3+4.

Table 3. Least square means and linar contrasts among prescribed burning treatments for several tree and stand characteristics of the hardwood trees and shrubs at least 1 in. dbh in a pine stand in Louisiana.

Treatments	Total height (ft)	Dbh (in.)	Stocking (stems/ac)	Basal area (ft²/ac)
Unburned (trt. 1)	23	1.8	327	12.9
Biennial March burns (trt. 2)	13	2.4	10	0.3
Annual–triennial March burns (trt. 3)	14	2.2	97	1.9
Biennial May burns (trt. 4)	16	1.8	70	1.0
Annual–triennial May burns (trt. 5)	21	2.3	53	3.2
Linear contrasts	(α levels)			
Unburned versus burning treatments*	0.0681	0.6266	0.0001	0.0130
March burns versus May burns†	0.1849	0.8120	0.8051	0.8029
Biennial burns versus annual–triennial burns††	0.4630	0.8649	0.3204	0.6309
Interaction between seasons of burning and burning schedules§	0.5547	0.7096	0.1610	0.9314

* Trt. 1 vs. trt. 2+3+4+5.
† Trt. 2+3 vs. trt. 4+5.
†† Trt. 2+4 vs. trt. 3+5.
§ Trt. 2+5 vs. trt. 3+4.

(*Rubus* spp.) was widely distributed, and the most common understory woody plants were Carolina jessamine (Gelsemium *sempervirens* [L.] Ait. f.), southern bayberry, loblolly pine, greenbriar (*Smilax* spp.), and Elliott's blueberry *(Vuccinium corymbosum* L.). Understory plants were not widely distributed on the unburned plots.

Control burning can be used to manage herbaceous and small woody plants (Grelen and Epps 1967). Productivity of the understory vegetation averaged 706 lb/ac on the four burned treatments but was less than 1 lb/ac on the unburned plots, partly because dense shade and an accumulation of litter smothered the understory vegetation. However, the difference in understory vegetation productivity between the unburned plots and the four burned treatments was not statistically significant (a = 0.12). Logically this makes no sense, but the inability to detect treatment differences in this instance was probably because large differences in sample size between the unburned and four burned treatments and the variation of sample size within treatments created too much variance.

The three linear contrasts that involve only the burning treatments yield better statistical results. The biennial burning schedule produced a significantly greater yield (1,150 lb/ac) than the annual-triennial burning schedule (261 lb/ac) (Table 4). This outcome was largely due to the comparatively high yields where the biennial burning was done in March (1,8 10 lb/ac). The plots biennially burned in March also had the shortest pines and the least basal area of the five treatments (Table 2). The inverse relationship between longleaf pine basal area and herbage yield is well known (Grelen and Lohrey 1978).

Discussion

The long-term use of fire effectively kept loblolly pine from reaching sapling size, and longleaf pine became the most common tree species. Fire maintained a well-developed understory of herbaceous and woody plants, but some hardwoods were able to reach sapling size.

When fire was excluded, natural loblolly pine seedlings eventually dominated the stand, and longleaf pine was a secondary species. Hardwood trees and shrubs formed a midstory. The deep shade and accumulation of litter nearly eliminated understory vegetation.

Total height of longleafpine might be the best variable for comparing treatments because longleaf pine was the only tree species found on all plots and height growth is less sensitive to stocking than diameter growth. Based on total height, longleaf pines on the unburned plots were more productive than longleaf pines subjected to repeated prescribed bums. The adverse effect of fire on longleaf pine growth and yield has also been reported by Boyer and Miller (1994) and Wahlenberg (1946).

Height growth might be an excellent variable for comparing treatments, but stemwood productivity is still the most important trait to many managers. Mean dbh and stemwood volume of longleaf saplings and poles were greater on the unburned plots than on the four burned treatments. When loblolly pines were included in the analysis, unburned plots had the greatest pine basal area and stemwood production per acre, although unburned plots also had the greatest cover of hardwood competitors.

Table 4. Least square means and linear contrasts among prescribed burning treatments for the productivity of understory vegetation (herbaceous plus woody plants less than 1 in. dbh) in a pine stand in Louisiana.

Treatments	Oven-dried yield (lb/ac)
Unburned (trt. 1)	< 1
Biennial March burns (trt. 2)	1,810
Annual–triennial March burns (trt. 3)	219
Biennial May burns (trt. 4)	491
Annual–triennial May burns (trt. 5)	303
Linear contrasts	(α levels)
Unburned versus burning treatments*	0.1196
March burns versus May burns†	0.1270
Biennial burns versus annual–triennial burns††	0.0375
Interaction between seasons of burning and burning schedules§	0.0876

* Trt. 1 vs. trt. 2+3+4+5.
† Trt. 2+3 vs. trt. 4+5.
†† Trt. 2+4 vs. trt. 3+5.
§ Trt. 2+5 vs. trt. 3+4.

There may be several reasons for these results. For example, burning began in 1970 when the longleaf pines were in the grass stage. Sublethal fire injury to the longleaf pine stem and root system, or fire-related losses in soil productivity, could have adversely influenced tree development over the next 25 yr (Boyer and Miller 1994, Wahlenberg 1946). On the other hand, longleaf pine had greater competition from woody plants on the unburned plots than on the four burned treatments. This competition may have eliminated all but the fastest growing longleaf pine seedlings on the unburned plots, so average stem sizes would be expected to be greater on the unburned plots than on the four burned treatments. Furthermore, fire prevented loblolly pine from reaching sapling or pole size, although loblolly pine was the most common tree on the unburned plots. Since loblolly pine is noted for its rapid growth from seedling to pole size (Schultz 1997), this favored total stemwood production on the unburned plots.

Among the four burned treatments, biennial burning in May resulted in the tallest longleaf, while biennial burning in March resulted in the shortest longleaf saplings and poles. These results are similar to Grelen's (1975) findings. New longleaf pine seedling growth in March is usually a silvery "candle" (Grelen 1983). By May, the candle is surrounded by an insulating sheath of elongating needles. Thus, the growing point is better protected in May than in March. It follows, then, that early May is generally a better time than March to use prescribed fire in the West Gulf Coastal Plain for long-term longleaf pine development.

Glitzenstein et al. (1995) found no effect of burning season on development and survival of longleaf pine on a sandy flatwoods in Florida. However, they noted that their work reported on how fire affected longleaf pine 2 cm dbh or larger, whereas burning began when Grelen's trees were still in the grass stage; thus the difference in tree size between the two studies may partly explain the difference in results. Also, periodic burning seems to result in greater hardwood control in the Atlantic and East Gulf Coastal Plain (Lotti 1956, Lotti et al. 1960, Waldrop and Lloyd 1991) than in the Central Gulf Coastal Plain (Boyer 1993b). Therefore there may simply be regional differences in tree responses to burning associated with unidentified variables-such as soil type, seasonal rainfall and temperature patterns, indigenous species, etc.

Nevertheless, the land manager faces a quandary. To grow longleaf, rapidly growing and competitive natural loblolly pine regeneration has to be controlled. Prescribed fire is an effective means for doing this. However, use of fire may slow the growth of longleaf regeneration. When managers are challenged to meet a variety of complex desired conditions for multiple resource objectives-such as the maintenance of understory herbaceous and woody vegetation for wildlife habitat and protection of rare or endangered species-sacrificing growth to obtain the desired forest cover may be an acceptable outcome.

Another option is using herbicides, perhaps directly applied to hardwood vegetation and unwanted herbaceous plants, as a supplement treatment. Herbicides can help control vegetation that is too large in stature to control with prescribed burning or that fire will not control. Weeding with hand tools or machinery is another option, but vigorous sprouting often results. Where managers must restore certain plant communities as quickly as possible, supplemental treatments may have to be used because the effects of a single prescribed bum are often transitory and a series of bums must be completed before lasting changes in understory plant communities can be obtained (Haywood 1995, Olson and Platt 1995). Regardless of how the manager proceeds, tradeoffs have to be made in using prescribed fire or other treatments for maintaining or restoring longleaf pine forest ecosystems.

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