# Does Prescribed Burning Have a Place in Regenerating Uneven-Aged Loblolly-Shortleaf Pine Stands?

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**ABSTRACT:** *Before the 1981 growing season, a study was installed in southeastern Arkansas to examine the effects of three dormant-season burn intervals (low, moderate, and highfrequency) and an unburned treatment on natural regeneration in uneven-aged stands of loblolly and shortleaf pines (*Pinus taeda *and* P. echinata, *respectively). Merchantable pine basal areas were maintained by harvesting on a 5 or 6 yr cutting cycle. When the study began, hardwoods greater than I in. dbh were injected with herbicide on all plots. During the next 19 yr, there were eight high frequency, four moderate frequency, and three low frequency prescribed burns. In 1991, the unburned plots received a single, broadcast-herbicide treatment. Single-tree selection harvests were conducted in 1982, 1987, 1992, and 1997. Through 1999 (I 9 yr), herbicides applied at IO yr intervals were more effective than dormant-season burns for enhancing the growth of submerchantable pines. Although recurring winter burns tended to stop the progression of both pines and hardwoods from seedling to sapling size classes, the data suggest that properly timed dormant-season burns might be used to secure natural pine regeneration in selection management. South. J. Appl. For. 26(3): 117–123.*

**Key** *Words: Pinus taeda, P. echinata,* crown scorch, quadrat stocking, selection silviculture, stand density.

Loblolly *(Pinus taeda)* and shortleaf *(P. echinata)* pines have been successfully managed in uneven-aged stands using the selection system for more than 6 decades (Baker et al. 1996). In uneven-aged management, some trees are harvested regularly as individuals or in groups, with total volume cut at any one time being roughly equal to the growth that has occurred since the last harvest (Reynolds 1959). Guidelines for uneven-aged silviculture call for postharvest basal areas of 45 to 60 $ft^2$/ac, maximum diameters of 14 to 22 in., and a q-factor of 1.2 for 1 in. dbh classes (Baker et al. 1996). The q-factor is the ratio of the number of trees in any given diameter class to the number in the next larger class. Criteria for successful regeneration in uneven-aged pine stands involve regulating the stocking and structure of the merchantable portion of the stand with careful logging and periodically controlling nonpine vegetation (Shelton and Cain 2000). Control of nonpine vegetation is required because these competitors inhibit the establishment of pine regeneration from seeds and retard the growth of established seedlings and saplings (Cain 1985, 1991b, 1992, Shelton and Cain 2000).

Historically, selective herbicides have been the option of choice for controlling nonpine competition in uneven-aged management of loblolly and shortleaf pines (Murphy et al. 1991). Although other competition control techniques may have application in selection silviculture, little information is available concerning their use. For example, prescribed fire has been rigorously excluded from uneven-aged stands because of the perception that fires are likely to destroy most of the submerchantable pine component (Farrar 1984); yet there had been no long-term investigation of prescribed fires in uneven-aged stands to address that concern. In 1980, the present study was installed with the objective of determining the effects of three dormant-season prescribed burning intervals on the establishment and growth of natural pine regeneration and on understory hardwood development in uneven-aged loblolly-shortleaf pine stands that were managed using single-tree selection.

## Methods

### Study Area

The study was located in southeastern Arkansas, at 33°02′ N mean latitude and 91°56′ W mean longitude. Elevation is about 130 ft, with nearly level topography. Soils are predominantly Bude and Providence silt loams (Glossaquic and Typic Fragiudalfs, respectively) with an impervious layer at 18 to 40 in. that impedes internal drainage (USDA 1979). Site

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index is 85 to 90 ft at 50 yr for loblolly pine. Annual precipitation averages 55 in. with seasonal extremes being wet winters and dry autumns.

### Stand History and Plot Layout

The study contained three 40 ac compartments that had been managed using single-tree selection from the late 1930s to the late 1960s, with complete exclusion of fire. Hardwoods were periodically controlled by girdling in early years of selection management and later by stem injection and mist-blowing of herbicides. From 1970 until 1980, there was no harvesting of pines or control of competing vegetation. When the study was installed in 1980, basal area of merchantable-sized pines (>3.5 in. dbh) ranged from 80 to 125 $ft^2$/ac.

In 1980, density of the submerchantablecomponent (stems <3.6 in. dbh) averaged 30 trees/ac for pines and 5,000 rootstocks/ac for hardwoods. In regulated uneven-aged loblolly-shortleaf pine stands, submerchantable pine density should average at least 100 stems/ac (Cain 199 la). Individual compartments were divided into 16 plots containing 2.5 ac each (330 ft by 330 ft) with 1.6 ac (264 ft by 264 ft) interior measurement plots. After study installation in 1980, all pines of merchantable size were inventoried by 1 in. dbh classes on a plot-by-plot basis for computation of basal area.

### Treatments

Four contiguous 2.5 ac basal area plots comprised a 10 ac burn treatment. On each 40 ac compartment (replication), one of three burn intervals-high, moderate, and low frequency—and an unburned treatment were randomly assigned to each of the 10 ac treatment areas. Within each burn treatment, residual merchantable pine basal areas of 40, 60, 80, and 100 $ft^2$/ac were assigned to the 2.5 ac plots at random. Basal areas were maintained by cutting and removing merchantable pines on a 5 or 6 yr cycle by the single-tree selection system.

All plots, except the unburned treatment, were initially prescribe-burned in mid-January 198 1. Subsequent treatments included seven high frequency, three moderate frequency, and two low frequency burns (Table I). In summer 198 1, residual hardwoods that were 1 in. or larger in dbh, including those on unburned plots, were basally injected with the herbicide[1] Tordon® 101R.

The initial selection cut was made in summer 1982. Trees were marked for harvest in accordance with the basal area–maximumdiameter-quotient (BD*q*) technique (Farrar 1984). Subsequent cycle cuts were conducted in autumn 1987, winter 1992, and winter 1997, using the same BD*q* criteria that were developed for the 1982 harvest.

Providing for competition control at least every 10 yr has long been recommended as a standard practice in uneven-aged management to ensure adequate pine regeneration (Reynolds et al. 1984). As such, the unburned plots in the present investigation were treated with a foliar broadcast application of Arsenal@ AC herbicide (0.375 lb ai/ac) plus Accord@ herbicide (1.5 lb ai/ac) in September 1991. Broadcast sprayers were mounted on articulated rubber-tired skidders, and the herbicides were dispersed in 30-ft-wide swaths.

Since basal areas of 40, 80, and 100 $ft^2$/ac are not recommended in uneven-aged management of loblolly and shortleaf pines (Baker et al. 1996), only the 60 $ft^2$/ac basal-area treatment was retained during the last 9 yr of the investigation. All bum treatments that were applied during the last 9 yr are documented in Table 2. Earlier burns were reported by Cain (1993a). While the bums were in progress, flame lengths were visually estimated and recorded by fireline personnel to the nearest 1.0 ft. Weather information was recorded using National Weather Service instrumentation located within 1 .0 mile of the study sites.

## Measurements and Data Analysis

For pretreatment and 10 yr assessments, density and quadrat stocking data for submerchantable pines and hardwood rootstocks were collected from 100 nonpermanent 1 milacre (0.001 ac) quadrats that were systematically spaced across each 1.6 ac interior plot. Hardwood rootstocks were comprised of either single or multiple stems (clumps) that obviously arose from the same root system. Stem counts were limited to pines and hardwoods of submerchantable size (<3.6 in. dbh). Submerchantable stems were categorized as seedlings (stems <0.6 in. dbh) or saplings (stems 0.6 in. to 3.5 in. dbh). In 1989, after the low frequency burn cycle, 240 submerchantable-sized pines were selected for obtaining

**Table 1. Chronological management activity in an investigation of prescribed dormant-season burns in uneven-aged stands of loblolly-shortleaf pines.**

| Year of management activity | Date of management activity by burn intervals | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unburned control | | High frequency | | | Moderate frequency | | | Low frequency | | |
| | Herbicide | Harvest | Herbicide | Burn | Harvest | Herbicide | Bum | Harvest | Herbicide | Burn | Harvest |
| 1981 | Summer | | Summer | January | | Summer | January | | Summer | January | |
| 1982 | | Summer | | | Summer | | | Summer | | | Summer |
| 1984 | | | | January | | | | | | | |
| 1987 | | November | | Jan-Feb | November | | Jan-Feb | November | | | November |
| 1989 | | | | December | | | | | | December | |
| 1990–1991 | (December 1990–January 1991, 10th-yr inventory) | | | | | | | | | | |
| 1991 | September | | | | | | | | | | |
| 1992 | | Nov-Dee | | February | Nov-Dee | | February | Nov-Dee | | February | Nov-Dee |
| 1993 | | | | November | | | | | | | |
| 1997 | | Nov-Dee | | October | Nov-Dee | | October | Nov-Dee | | | Nov-Dee |
| 1998 | | | | October | | | | | | | |
| 1999-2000 | (December 1999–January 2000, Final inventory) | | | | | | | | | | |

Table 2. **Fuel and weather conditions during prescribed winter burns (1992-98) in uneven-aged loblolly-shortleaf pine stands in southeastern Arkansas.**

| | Burn freauencv | | | | | |
|---|---|---|---|---|---|---|
| Fuel and weather variables | High, moderate, and low | | High | High | Moderate | High |
| Date of burn (month/day/yr) | 02103192 | 02110-11/92 | 11/29–30/93 | 10106197 | 10120197 | 10127198 |
| Days since last precipitation | 3 | 4-5 | 2-3 | 11 | 6 | 7 |
| Time of burning (hours CST) | 1400-1700 | 1300-1700 | 1300-1530 | 1100–1600 | 1200-1700 | 1100–1630 |
| Air temperature (“F) | 60-68 | 62-70 | 62-66 | 91-93 | 80-83 | 74-83 |
| Relative humidity (%) | 20-30 | 15-50 | 30-35 | 36–40 | 48-54 | 25-38 |
| Wind direction | N | SE | SE and SW | NE and S | W | S |
| Wind speed (miles/hour) | 7 | 7 | 2-5 | 2 | | 2 |
| Fine fuel moisture* (%) | 8 | 8-25 | 11–13 | 13-17 | 15-38 | 13 |
| Mean fireline intensity' (Btu/ft-sec) | 45 | 106 | 45 | 88 | 47 | 41 |
| Range in fireline intensity (Btu/ft-sec) | 26-69 | 27–231 | 18–81 | 38–171 | 19-1 18 | 6-100 |
| Rate of spread (chains/hr) | 2-5 | 2-8 | 5 | 5-8 | 5-9 | 3–4 |
| Type of burn | (Back and flank fires) | | | | | |

* Determined from fuel moisture sticks at midday or from litter collected onsite at the time of burning.
† Fireline intensity $5.67L_f^{2\ 17}$, where $L_f$ Ocular estimates of flame length in feet (Byram 1959).

ocular estimates of crown scorch to nearest 10% by size class and were measured for height to 0.1 ft and diameter to 0.1 in. Surviving pines were reassessed 1 yr later to determine the relationship between crown scorch and growth trends in height and gld. Linear regressions were generated to determine the relationship of crown scorch to height and groundline (gld) growth of submerchantable pines that occurred during the year after burning.

For measurements after 19 yr, pine saplings were counted by 1 in. dbh classes within each of nine 0.01 ac subplots per interior 1.6 ac plot. Up to three dominant pine saplings per subplot were measured for gld to 0.1 in., height-to-live-crown and total height to 0.1 ft, and crown width at the widest axis and perpendicular to that axis to 0. I ft. Sapling hardwoods were identified by species and counted by 1 in. dbh classes. One-milacre circular quadrats were nested within each of the nine 0.01 ac subplots for determining density and quadrat stocking of seedling-sized pines and hardwoods. The dominant hardwood seedling rootstock on each milacre was identified by species. These milacres were also used to make ocular estimates of site disturbance from fire and percent ground cover from hardwoods, shrubs, and herbaceous vegetation. Milacres were assessed as being overtopped by merchantable-sized pines as an expression of their stocking.

Nineteen-year results were analyzed in accordance with a randomized complete block design. Each burn treatment (low, moderate, and high frequency) and the unburned control had three replications. Analysis of variance and orthogonal contrasts were used to evaluate treatment differences at the $\alpha = 0.05$ level. Percentage data were analyzed following arcsine proportion transformation.

## Results and Discussion

### Pine Regeneration

During the first 10 yr, submerchantable pine density declined from 890 to 255 stems/ac, and milacre stocking declined from 27% to 10% as merchantable pine basal area increased from 40 to 100 ft$^2$/ac, regardless of the burn frequency because loblolly and shortleaf pines are shade intolerant. Submerchantable pine density averaged higher on plots in the moderate frequency burn (1,057 stems/ac) as compared to the high frequency (21 1 stems/ac) or low frequency burns (88 stems/ac) and the unburned plots (502 stems/ac). The higher density was attributed to the fact that the moderate frequency burn coincided with site disturbance from the selection cutting cycle, and that combination improved seedbed conditions in advance of a natural pine seedcrop that averaged more than 1 ,000,000 potentially viable seeds/ac (Cain 199 1 b). Like density, milacre stocking of submerchantable pines was highest on plots of the moderate frequency burn (28%) as compared to stocking on unburned (18%), high frequency (1 1%), or low frequency (5%) plots.

With the exception of the low frequency burn after the first 10 yr, submerchantable pine density was adequate (i.e., 200 stems/ac) at all basal area levels and burn frequencies; however, differentiation of those stems within seedling and sapling size classes was not. Density of pine saplings averaged 28 trees/ac, which was only 6% of submerchantable pine density across all basal area levels and burn frequencies. Mean densities by burn frequencies ranged from 27 to 31 saplings/ac, which was less than half of what is desired in regulated uneven-aged stands (Reynolds 1959).

Pines of submerchantable size were most likely to survive the prescribed burns if crown scorch was less than 60% and if the trees were taller than 8.0 ft or larger than 1.5 in. gld at the time of burning. Regardless of size, pine regeneration with 100% crown scorch did not survive.

Eight weeks after a low frequency burn, crown scorch assessments on submerchantable-sized sample pines averaged 95% for seedlings less than 3.0 ft tall, 90% for seedlings 3.0 ft tall to 0.5 in. dbh, and 80% for pine saplings 0.6 to 3.5 in. dbh. During the year after burning, surviving pines that were 0.6 to 3.5 in. dbh exhibited a statistically significant decline in both height growth and gld growth as crown scorch increased (Figure 1).

After 19 yr, density of pine seedlings averaged 796 stems/ac across all treatments (Table 3). The high frequency burn plots had eight times more ($P = 0.04$) pine seedlings than the mean of the moderate and low frequency burn plots. Even though an excellent pine seedcrop (I ,500,000 sound seeds/ac) was disseminated on all plots in the winter of 1998-l 999, only the high frequency burn plots received a prescribed burn

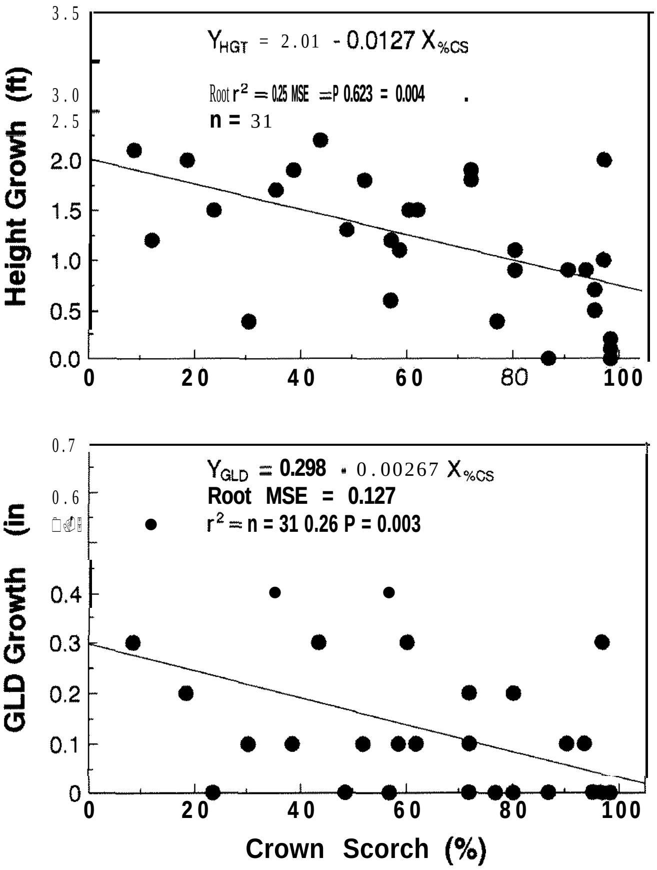


**Figure 1. Impact of crown scorch on height growth andgroundline diameter (gld) growth of loblolly pine saplings one growing season after a prescribed winter burn in uneven-aged loblolly-shortleaf pine stands in southeastern Arkansas.**

in October 1998, before pine seed dispersal. Immediately after the October 1998 prescribed burn, ocular estimates of burn coverage on permanent milacres averaged only 59% as compared to better than 90% following earlier burns. Inadequate burn coverage suggested that the seedbed was not well prepared for natural pine seeding that winter.

Milacre stocking of pine seedlings averaged only 20% across treatments (Table 3). Although milacre stocking of these seedlings ranged up to 44% on high frequency burn plots, differences among treatments were nonsignificant ($P > 0.05$). The rather low stocking of pine seedlings at 1 yr after the 1998 prescribed fire on high frequency burn plots was indicative of the variable burn coverage on those plots.

After 19 yr, the only treatment with adequate density and quadrat stocking of pine saplings was the unburned control, with saplings on all replications. Control plot density averaged 229 pine saplings/ac with 33% quadrat stocking. Differences among treatments were nonsignificant for density ($P > 0.05$), but stocking of pine saplings on unburned control plots was 28 percentage points higher ($P = 0.05$) than the mean of the other treatments (Table 3). On high and moderate frequency bum plots, two out of three replications had no pines of sapling size. Sapling-sized pines that were tagged for remeasurement on these plots were killed by the fires or logging disturbance. On low frequency burn plots, two ofthe three replications had pines of sapling size, but density averaged only 22 trees/ac. Acceptable stocking of submerchantable-sized pines should range from a minimum of 20% to an optimum of 50% in uneven-aged loblolly-shortleaf pine stands (Shelton and Cain 2000).

Data from sample pine saplings were insufficient for a comparison of treatments, and only unburned control plots had enough sample pines to describe trends. Of the 11 pine saplings present on control plots in 1991, four had grown to pulpwood size by 1999, four were still of sapling size, and three had died because of logging damage. Of the 13 pines that attained sapling size in 1992 and 1993, nine were still saplings in 1999, two had grown to pulpwood size, and two had died-one from logging and one from ice damage. There was a reduction in live-crown ratio for pine saplings on high intensity burn plots because of crown scorch. Recurring burns that result in crown scorch tend to have cumulative negative effects on pine growth (Cain 1993c).

When merchantable and submerchantable pines were combined, quadrat stocking across all treatments averaged 72% (Table 3). Control plots and high frequency burn plots had the highest pine stocking (78%), but there were no statistically significant differences among treatments ($P > 0.05$). When both merchantable and submerchantable pine stocking is assessed, Reynolds (1959) proposed that good stocking was achieved at 80% or better.

Nineteen years after the study was initiated, density and quadrat stocking of seedling-sized pines were adequate for perpetuating uneven-aged structure only on high intensity

**Table 3. Pine regeneration assessments in uneven-aged loblolly-shortleaf stands after 19 yr of prescribed burning in southeastern Arkansas.**

| Treatments and orthogonal contrasts | Pine seedlings Density (stems/ac) | Pine seedlings Stocking* (%) | Pine saplings Density (stems/ac) | Pine saplings Stocking* (%) | Pine stocking† (%) |
|---|---|---|---|---|---|
| 1. Check | 111 | 4 | 229 | 33 | 78 |
| 2. High | 2,518 | 44 | 4 | 4 | 78 |
| 3. Moderate | 333 | 18 | 4 | 4 | 67 |
| 4. Low | 222 | 15 | 22 | 7 | 67 |
| Mean square error | 1.54E06 | 0.0681 | 28803 | 0.0718 | 0.0106 |
| (Probabilities of a greater $F$ value for orthogonal contrasts) | | | | | |
| 1 vs. 2+3+4 | 0.312 | 0.088 | 0.100 | 0.047 | 0.260 |
| 2 vs. 3+4 | 0.043 | 0.080 | 0.941 | 0.775 | 0.166 |
| 3 vs. 4 | 0.916 | 0.864 | 0.898 | 0.623 | 0.880 |

* A quadrat was stocked if it contained at least one pine seedling or pine sapling.
† Quadrat stocking by pines of any size (submerchantable and merchantable).

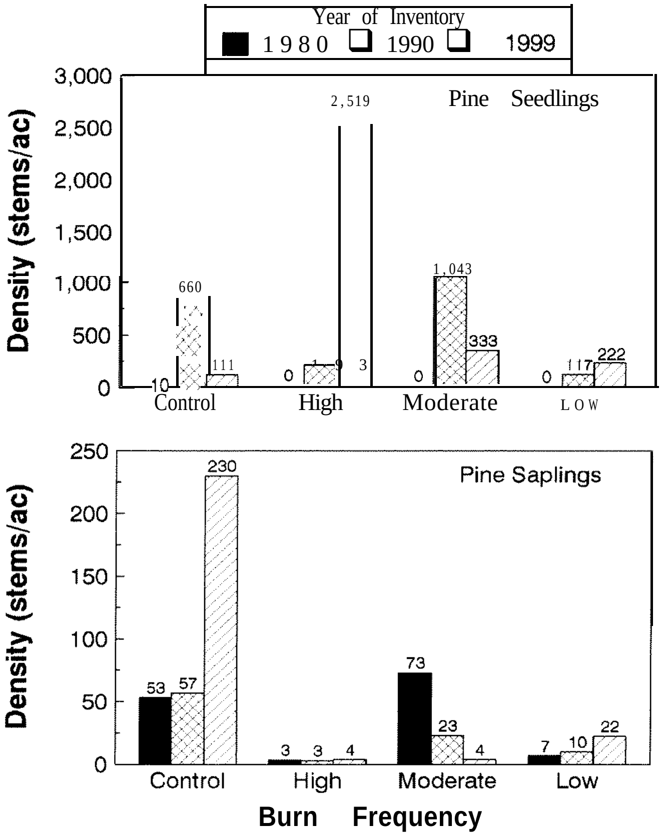


**Figure 2. Density of pine seedlings and saplings during 19 yr of prescribed dormant-season burns in uneven-aged loblolly-shortleaf pine stands in southeastern Arkansas.**

burn plots (Figure 2). So that adequate numbers of these pine seedlings attain sapling size, a herbicide treatment might be necessary to circumvent overtopping by hardwoods and herbaceous vegetation. For example, unburned control plots which were treated with selective herbicides 8 yr earlier had adequate density and stocking of pine saplings, while all three burn treatments were deficient in pines of sapling size (Figure 2).

### Competing Vegetation

Unlike pine regeneration, density of submerchantable-size hardwoods (4,555 rootstocks/ac) was not significantly influenced by merchantable pine basal area during the first IO yr of this study. Because of the time lag between burning and inventory, recurring fires at a high frequency tended to have fewer (P = 0.07) hardwoods (3,977 rootstockslac) than were recorded on plots in the moderate frequency burns (5,158 rootstockslac). After the first 10 yr, hardwood density on unburned control plots and low frequency burn plots fell between these extremes.

During the first 10 yr, seedling-size rootstocks were the most prevalent form of hardwood competition, accounting for 93% of all woody rootstocks. The moderate frequency burn treatment averaged 4,89 l seedling-size rootstocks/ac and that exceeded the mean density on the other burn treatments and unburned plots by 21%. Sapling-size hardwoods averaged 300 rootstocks/ac. Unburned plots had more hardwood saplings (7 16 stems/ac) than plots on the moderate (267 stems/ac), low (170 stems/ac), or high frequency (46 stems/ac) burns.

After 10 yr, quadrat stocking of all hardwood rootstocks averaged 94% with no difference among basal-area levels, but plots in the high frequency burns averaged 89% stocking of submerchantable-size hardwoods, and that was significantly less than on unburned plots (95%) or on plots in the moderate frequency burns (97%). All burn treatments resulted in fewer milacres stocked with sapling-size hardwoods when compared to unburned plots, which averaged 42%. Because of the time that had elapsed between the moderate frequency burn and the 10 yr inventory (Table 1), milacre stocking of hardwood saplings on plots in the high (3% ) and low frequency burns (1 1%) was less than on moderate frequency burn plots (20%).

After 19 yr of recurring prescribed burns, hardwoods of seedling size averaged 6,639 rootstockslac with no differences ($P > 0.05$) among treatments (Table 4). Similarly, milacre stocking of seedling-sized hardwoods was no different ($P > 0.05$) among treatments and averaged 97%.

Across all plots, red maple (*Acer rubrum*) was the predominant hardwood tree species of seedling size (<0.6 in. dbh), and American beautyberry (*Callicarpa americana*) was the predominant shrub. On unburned control plots, water oak (*Quercus nigra*) and sassafras (*Sassafras albidum*) exhibited higher relative dominance than red maple, and white

**Table 4. Hardwood and herbaceous vegetation assessments in uneven-aged loblolly-shortleaf pine stands after 19 yr of prescribed burning in southeastern Arkansas.**

| Treatments and orthogonal contrasts | Hardwood seedlings Density (rootstocksix) | Stocking* (%) | Hardwood saplings Density (stems/ac) | Stocking* | Ground cover Hardwoods | Shrubs | Herbaceous |
|---|---|---|---|---|---|---|---|
| | | | | | ....... (%) ---- | | ............ |
| I Check | 4.25') | 96 | 808 | 100 | 40 | 24 | 91 |
| 2. High | 6,741 | 96 | 59 | 26 | 22 | 25 | 87 |
| 3. Moderate | 7,778 | 96 | 430 | 78 | 40 | 39 | 89 |
| 4. Low | 7,778 | 100 | 1,370 | 100 | 56 | 36 | 72 |
| Mean square error | 6.90E06 | 0.0289 | 1.97805 | 0.0167 | 0.0186 | 0.027 | 0.0233 |
| | | (Probabilities of a greater $F$ value for orthogonal contrasts) ............ | | | | | |
| I vs. 2+3+4 | 0.1 19 | 0.750 | 0.550 | 0.001 | 0.892 | 0.438 | 0.258 |
| 2 vs. 3+4 | 0.596 | 0.654 | 0.037 | 0.001 | 0.025 | 0.224 | 0.508 |
| 3 vs. 4 | 1.000 | 0.445 | 0.041 | 0.004 | 0.186 | 0.814 | 0.1 17 |

* A quadrat was stocked if it contained at least one hardwood seedling or hardwood sapling.

oak (Q. *alba*) was the dominant tree species on low frequency burn plots. All of these species have a competitive advantage over naturally regenerating pines because of their ability to produce multiple stems from the same rootstock after a disturbance such as fire. Height growth of these root collar sprouts can exceed 2 ft during a single growing season (Cain 1993b).

Plots that had been prescribe-burned most often (high and moderate frequency burns) had the fewest hardwoods of sapling size (Table 4). Sapling hardwood density on high frequency burn plots averaged nine times fewer ($P = 0.04$) stems than the mean of moderate and low frequency burn plots, and moderate frequency burn plots averaged seven times fewer ($P = 0.04$) stems than low frequency burn plots.

Because of the length of time since treatment, quadrat stocking of hardwood saplings averaged 100% on unburned control plots and on low frequency burn plots (Table 4). Compared to the mean of the moderate and low frequency burn treatments, high frequency burns resulted in a 63 percentage points reduction ($P < 0.01$) in stocked quadrats. Also, the moderate frequency burns reduced ($P < 0.01$) stocking of sapling hardwoods by 22 percentage points versus the low frequency burns.

After 19 yr, the predominant hardwoods of sapling size were sweetgum *(Liquidambar styraciflua)* and southern red oak (*Q. falcata*) with 11% and 10% of the total, respectively, but dominance varied within treatments. On control plots, American holly (*Ilex opaca*) and water oak (Q. *nigra*) were the dominant saplings, accounting for 44% of the total. On low frequency burn plots, willow oak (Q. *phellos*) had the greatest number of dominant saplings, with 26% of the total. High frequency burn plots had only seven species that achieved sapling size. In contrast, the number of hardwood species attaining dominant status averaged ten on control plots, and nine on moderate and low frequency burn plots. Ground cover from hardwoods was least ($P = 0.03$) on high frequency burn plots at 22% (Table 4). On other treatments, ground cover from these species ranged from 40 to 56%. Ground cover from shrubs was not reduced ($P > 0.05$) by any of the treatments and averaged 31%.

Ground cover from herbaceous vegetation averaged 72% or higher (Table 4), and there were no statistically significant differences among treatments ($P > 0.05$). Herbaccous species (grasses, forbs, vines, and semiwoody plants) are able to invade good sites within 1 yr of intensive disturbance, as evidenced by 87% ground cover on high frequency burn plots in autumn 1999, just one growing season after a prescribed burn treatment. Cover from woody and herbaceous vegetation that grows low to the ground is considered a positive stand attribute when managing for wildlife habitat in addition to pine timber production (Cain et al. 1998), but both forms of competition are detrimental to pine regeneration (Cain 1985, 1992).

Recurring dormant-season prescribed burns during 19 yr were effective in temporarily reducing the size of hardwood competitors but not their numbers (Figure 3). For example, on high frequency burn plots, seedling-sized hardwoods averaged 3,000 more rootstocks/ac in 1999 compared to 1980, even though the 1999 inventory was conducted just 14 months after a high frequency burn. Those same plots averaged more than 900 hardwood saplings/ac in 1980, but fewer than 60 in 1999. In contrast, low frequency burn plots had more hardwood saplings (>1,000/ac) than any other treatment in 1999, because eight growing seasons had passed since the last burn on those plots.

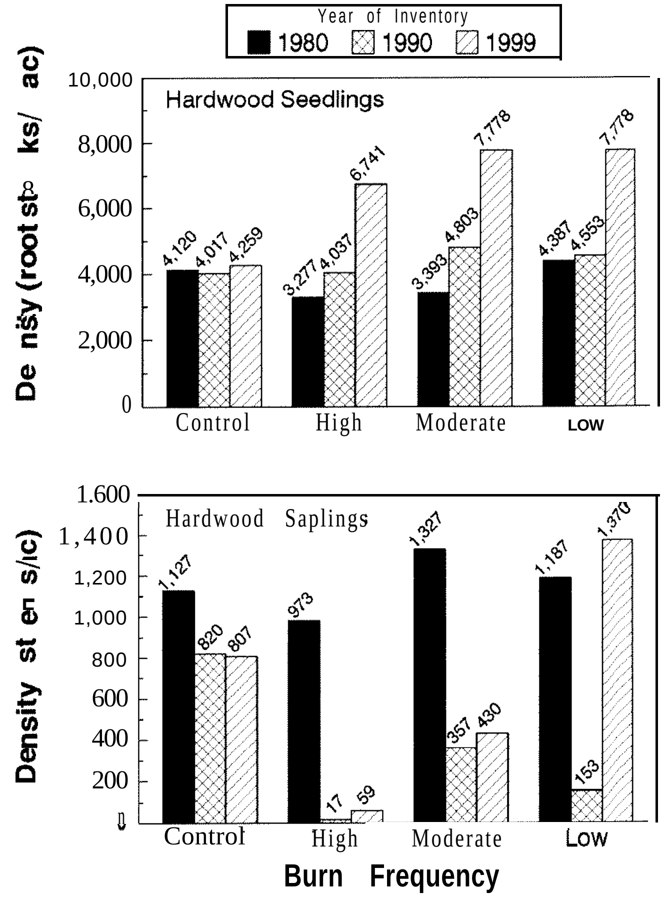


**Figure 3. Density of seedling- and sapling-sized hardwoods during 19 yr of prescribed dormant-season burns in uneven-aged loblolly-shortleaf pine stands in southeastern Arkansas.**

Because of rapid height growth and their propensity to produce multiple sprouts from a single rootstock, most hardwood species are able to achieve dominance over natural pine seedlings within 1 yr after the hardwoods are top-killed by dormant-season burning. To reduce hardwood density, repeat growing-season burns are needed (Grano 1970). Also, winter burns were not effective in reducing herbaceous competition because ground coverage from these species returned to preburn levels within one growing season after burning.

## Management Implications

When the management objective is the periodic establishment of pine regeneration in uneven-aged stands, variable loblolly and shortleaf pine seed crops will tend to confound the effects of rigid burning cycles. Consequently, fixed burning schedules were judged to be less important than timing the burns to coincide with better-than-average pine seed crops and site disturbance from harvest activity.

Recurring dormant-season burns tended to be effective in reducing the size of hardwood competition when compared to unburned plots, but root-collar sprouts developed profusely as soon as burning ceased. Past research has shown that a reduction in number of hardwood rootstocks will require repeat burns during the growing season (Harrington and Stephenson 1955, Lotti 1956, Ferguson 1957, Brender and Cooper 1968, Grano 1970). Well-planned growing-season burns may be compatible in natural stand management when converting even-aged, sawtimber-sized, loblolly-shortleaf pine stands to uneven-aged structure because large pines would likely tolerate the fire before the initiation of cycle cuts for basal area reduction and establishment of pine regeneration.

During this 19 yr investigation, none of the burning regimes achieved adequate stocking and movement of pine seedlings into the sapling size classes in uneven-aged stands. Herbicides applied at 10 yr intervals in the absence of fire resulted in the development of substantially more pine saplings compared to recurring dormant-season burn treatments. For that reason, the use of dormant-season burns in combination with herbicides might be more effective in uneven-aged pine management than the use of fire alone. Although there are problems associated with the use of fire, there are also opportunities for incorporating dormant-season prescribed burns in uneven-aged management of loblolly and shortleaf pines. Results from the present investigation suggest that a series of annual or biennial burns are likely to keep the submerchantable-size hardwoods in check temporarily. Then, by monitoring cone production, managers can time the last burn in a series so that it coincides with a better-than-average pine seed crop and site disturbance from cycle harvest activity. That particular prescribed burn should be complete by early autumn before the majority of pine seeds have dispersed (Cain and Shelton 2001). Additional dormant-season burns should be delayed until at least 200 stems/ac of well-distributed pine saplings are established, and they should be taller than 8 ft or greater than 1.5 in. gld to withstand subsequent prescribed winter burns (Cain 1993a).

## Endnote

[1] This publication reports research involving herbicides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses must be registered by appropriate state and/or federal agencies before they can be recommended. The use of trade or firm names in this publication is forreader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

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