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Growing-Season Burns for Control of Hardwoods in Longleaf Pine Stands

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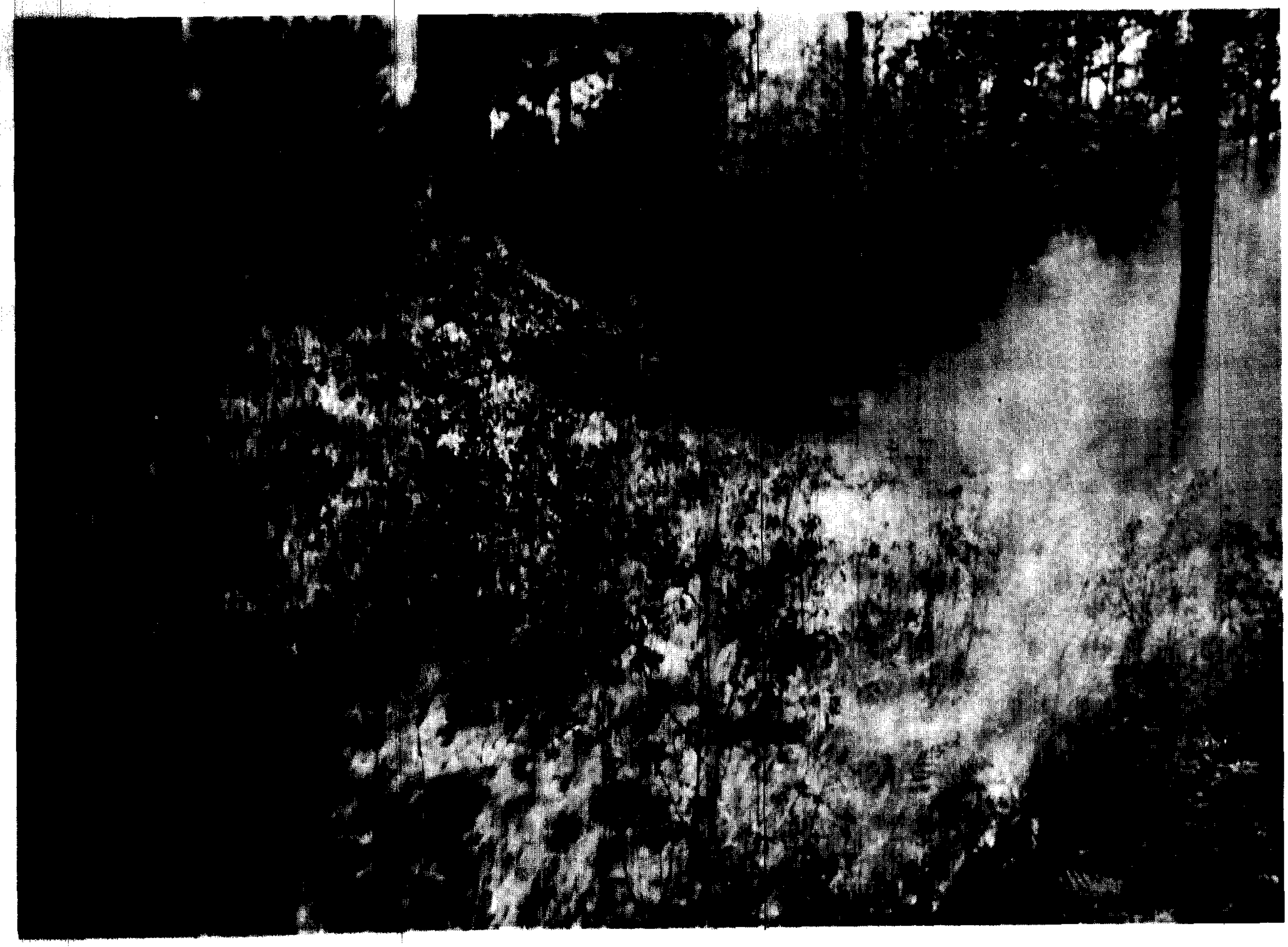

SUMMARY

Experimental spring and summer burning for control of hardwoods was conducted in longleaf pine (*Pinus palustris* Mill.) stands in southwestern Alabama. When two summer burns were conducted 2 years apart in stands of mainly mature longleaf pine, most hardwood mortality occurred after the second fire-mainly among stems that had suffered complete top-kill after the first fire. Only hardwoods in the l-inch d.b.h. class suffered over 50-percent mortality, and mortality among stems in the 4-inch and larger d.b.h. classes was negligible. Fire damage to some upland hardwood species increased with increasing density of overstory pine, probably because needle-litter fuels burn hotter than hardwood leaf-litter fuels. A single hot summer fire was more destructive to longleaf pines than to hardwoods; pine mortality in the 1- through 4-inch d.b.h. classes was as great after the first fire as hardwood mortality in the same diameter classes after both fires. Significant mortality also occurred among pines in the 16-inch and larger d.b.h. classes after the first fire. Summer burning for hardwood control in existing longleaf pine stands is inadvisable because of the danger of unacceptably high pine mortality. Hardwood damage caused by single spring fires in longleaf pine seedling stands seemed less affected by timing of the burn than by burning conditions affecting fire intensity.

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INTRODUCTION

Hardwood control is often necessary for the regeneration and optimum development of southern pines, especially longleaf pine, which is particularly sensitive to competition. Fire is the least expensive cultural treatment available to control small hardwoods in pine stands and to reduce or eliminate hardwood encroachment into the midstory. The use of fire is preferred over more costly mechanical or chemical treatments if it can reliably achieve hardwood control objectives without excessive damage to the pines.

Prescribed burns conducted during the growing season are more effective than those conducted in the dormant season in controlling small hardwoods in southeastern pine stands (Brender and Cooper 1968, Chaiken 1952, Ferguson 1961, Grano 1970, Grelen 1975, Hodgkins 1958, Langdon 1971, Lotti and others 1960, Trousdell 1970, Waldrop and others 1987). Although periodic winter fires in the upper Coastal Plain of Alabama resulted in the top-kill (death of all aboveground portions of the plant) of hardwoods up to 3 inches in d.b.h. and were as effective as periodic summer fires in complete kill of understory hardwoods, they were less effective than summer fires in reducing the size and vigor of sprouts (Chen and others 1975). Grano (1970) found that winter fires can cause top-kill in hardwoods with basal diameters as great as 3.5 inches, but he also found that these hardwoods would later sprout prolifically. Waldrop and others (1987) reported that annual winter fires did not reduce the number of sprouts per tree and actually resulted in many more stems per acre than winter fires at longer intervals.

On an Atlantic Coastal Plain site, prescribed summer fires caused top-kill in most hardwoods up to 4 inches in d.b.h. and many as large as 6 inches in d.b.h. (Riebold 1955). Complete top-kill by summer fires was found to average about 50 percent for trees in the 2-inch d.b.h. class, more for smaller trees, and progressively less for larger size classes on both upper Coastal Plain (Ferguson 1961) and Piedmont pine sites (Brender and Cooper 1968). While single fires may result in hardwood top-kill, they destroy very few rootstocks (Langdon 1971). Successive annual summer fires have been found to be highly effective in killing hardwood rootstocks, thus reducing the total number of woody stems (Chaiken 1952, Grano 1970, Trousdell 1970, Waldrop and others 1987).

Four successive annual summer fires in the lower Coastal Plain flatwoods eliminated about 50 percent of small hardwood stems and reduced the size and vigor of the rest (Chaiken 1952). Summer fires at less frequent intervals, even biennial summer fires, are less effective in causing complete-kill, as hardwoods always have at least one growing season in which to recover from burning. Summer fires, however, are more damaging to small longleaf pines (*Pinus palustris* Mill.) than fires in the winter or spring (Grelen 1975).

Fires early in the growing season, soon after leaves are fully expanded, should be the most effective for weakening and eventually killing deciduous hardwoods, as root reserves have reached their lowest point at this time (Woods 1955). However, relatively little information is available on spring burning for control of hardwoods. In one study, the number of surviving hardwood stems up to and including the 3-inch d.b.h. class were reduced with each successive spring burn (Harrington and Stephenson 1955). In another, the number and size of hardwood sprouts were less with a spring burn than with a winter or late-summer burn (Ferguson 1961). Furthermore, spring burns are beneficial in that they are more effective than winter burns (or no burns) in promoting height-growth initiation by grass-stage longleaf pine seedlings (Grelen 1983, Maple 1977).

In this paper the results of two studies aimed at increasing our knowledge of the effects of spring and summer burning on longleaf pines and on common hardwood competitors are reported. Both studies were installed in the Escambia Experimental Forest[1] in southwestern Alabama.

PROCEDURE

Summer Burns

In the first study, the effects of summer burns conducted in 1976 and 1978 were observed. The 28-acre study area consisted primarily of mature longleaf pines

[1] Maintained by the Southern Forest Experiment Station, Forest Service-USDA, in cooperation with the T. R. Miller Mill Company.

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with a hardwood midstory that had survived periodic prescribed winter fires. Basal area of pines was 49 ft^2 per acre, 45 percent of which was in trees 15.6 to 26.5 inches in d.b.h. and 32 percent of which was in trees 7.6 through 15.5 inches in d.b.h. Basal area of hardwoods averaged 15 ft^2 per acre, 70 percent of which was in trees 3.6 inches in d.b.h. and larger. The study area had last been burned in February 1974.

The first summer burn was conducted on July 23, 1976. Flank fires were used. This fire was very intense, burning through brushy streamside borders to running water. During the burn, air temperatures reached 99 °F and relative humidity was as low as 34 percent. The last rain before the fire, according to a recording rain gauge less than a mile from the study site, was 0.8 inch on July 14.

The second burn, on August 15, 1978, was of much lower intensity and was rained out an hour after ignition, when only about half of the study area had burned. At the start of the fire, air temperature was 94 °F and relative humidity was 52 percent. By the end of burning, air temperature had fallen to 80 °F, and relative humidity had risen to 98 percent. The last rain before the fire was 0.1 inch on August 13. The balance of the study area was burned on August 21, 1978. Air temperatures ranged from 93 to 97 °F and relative humidities from 53 to 57 percent. The previous rain had been 0.1 inch on August 1.9. Headfires were used, and estimated fireline intensity, derived from flame lengths (Nelson 1980), averaged about 100 BTU/ft/sec.

Fifty sampling points were established in the summer-burned study area during the December 1976 through January 1977 period. A BAF (basal area factor) 10 wedge prism was used to estimate basal area in pines and hardwoods at each sample point. All pines and hardwoods intercepted by the prism were selected, marked, and examined. To increase the sample size, all other pines and hardwoods in the l-inch d.b.h. class and larger (>0.5-inch d.b.h.) within 17 feet of each sample point were selected, marked, and examined in October 1977. Sample trees killed by the fire were not excluded. There were 557 pine and 277 hardwood sample trees, of which 187 hardwoods were on the upland and 90 in streambottoms. The species distribution of sample trees is given in table 1.

At the time of the first examination, the following information was recorded for each sample tree:

1. Species.
2. D.b.h.
3. Whether living or killed by fire.
4. Proportion of live crown killed by fire, estimated to nearest 10 percent.
5. Presence or absence of sprouting. When sprouting was present, then it was recorded as originating from: (a) roots or root collar, or (b) aboveground stems or branches.

Table 1.—*Species distribution of sample trees in the study area*

Species	Number
Pine	
Longleaf (*Pinus palustris* Mill)	511
Slash (*Z? elliottii* Engelm. var. *elliottii*)	45
Loblolly.(*P. taeda* L.)	
Upland hardwoods	
Dogwood (*Cornus florida* L.)	89
Bluejack oak (*Quercus incana* Bart.)	23
Post oak (*Q. stellata* Wangenh.)	21
Water/willow oaks (*Q. nigra* L., *Q. phellos* L.)	13
Turkey oak (*Q. laevis* Walt.)	10
Blackjack oak (*Q. marilandica* Muenchh.)	4
Southern red oak (*Q. falcata* Michx.)	4
Blackgum (*Nyssa sylvatica* Marsh.)	19
Persimmon (*Diospyros virginiana* L.)	4
Streambottom hardwoods	
Titi (*Cyrilla racemiflora* L., *Cliftonia monophylla* (Lam.) Britton ex Sarg.)	52
Red maple (*Acer rubrum* L.)	17
Gallberry (*Ilex coriacea* (Pursh) Chapm.)	11
Sweetleaf (*Symplocos tinctoria* (L.) L'Her.)	4
Sweetbay (*Magnolia virginiana* L.)	3
Black cherry (*Prunus serotina* Ehrh.)	3

The sample trees selected by the prism-intercept method were examined in April and again in October 1977. All sample trees were examined in October 1978, following the second fire, and again in May 1979. Recorded at each examination were:

1. Proportion of preburn live crown still alive, estimated to nearest 10 percent.

2. Presence or absence of sprouting, as described previously.

Spring Burns

The second study tested the effects of spring burns on oaks and dogwoods at three distinct stages of phenological development. Burning took place in 1980 and 1981. Four experimental blocks were established in clearcut regeneration areas where longleaf pine seedling stands were overtopped by hardwood brush. All four blocks had been burned periodically. Blocks 1 and 2 had last been burned in the winter of 1978, and blocks 3 and 4 had last been burned in the spring of 1979. Blocks 1 and 2 were to be burned in 1980, and blocks 3 and 4 were to be burned in 1981.

Each block contained nine plots. Each gross plot was 1.5 by 2 chains in size and consisted of a l-chain by 1.5-chain net plot surrounded by a 0.25-chain isolation border. Each of three burning treatments was randomly assigned to three of the nine plots in each block. Three shoots on each of five dogwoods in each block were marked for observation. Treatments were spring burns that were conducted as soon as possible after sample dogwoods reached one of the following phenological stages:

1. Bud break beginning; vegetative buds cracked but leaves not yet visible.
2. Bud break complete; leaflets visible on all sample shoots.
3. Full leaf; all sample shoots in full leaf (leaves no longer expanding).

Wherever possible, 10 dogwoods and 20 oaks within each of the 36 plots were selected and marked for observation. Not all plots contained the necessary number of trees, and the sample consisted of 296 dogwoods and 767 oaks. Species, diameter at 6 inches above groundline, and total height were recorded for each sample tree.

Forty-three percent of the oaks were bluejack, 19 percent water or willow oak, 14 percent southern red oak, 14 percent post oak, 9 percent turkey oak, and 1 percent blackjack oak. Tree diameters 6 inches above groundline ranged from 0.6 to 3.1 inches. Forty-six percent of the sample trees were in the l-inch diameter class (0.6 to 1.5 inches), 49 percent were in the 2-inch class, and the remaining 5 percent were in the 3-inch class.

At the end of the first and second growing seasons after burning, the fate of each sample tree was recorded by a number:

1 =Dead, with no sprouts.

2=Suffering from complete top-kill. All aboveground parts dead. Sprouts only from roots or root collar.

3=Suffering from top-kill, but with sprouts along mainstem or branches.

4=Partial crown survival, with or without sprouts.

5 =No apparent effect.

A numerical value for overall impact of fire in each plot was obtained by averaging the above values for all sample trees in a plot.

The following information was also obtained for each sample tree:

1. Percent age of live crown reduction (excluding sprouts), based on preburn crown, estimated to the nearest 10 percent.
2. Number and average length of sprouts originating from roots or root collar.

Before each burn, surface organic litter was sampled to determine fuel load. Five 0.96 ft^2 sample plots were randomly located in each 0.15-acre net plot. The organic layers in these sample plots were collected, ovendried at 80 "F, and weighed. All living green plant material in each sample plot was also collected, dried, and weighed. After each burn, the residual organic litter in five randomly distributed 0.96 ft^2 sample plots in each net plot was collected, ovendried, and weighed. Fuel consumption was estimated as the difference between preburn and postburn weight. In 1980, preburn fuel sampling was conducted in blocks 1 and 2 on March 11, 14, and 25 (for treatment 1 plots, treatment 2 plots, and treatment 3 plots respectively), and postburn sampling was conducted on March 18, March 25, and April 21. Preburn sampling dates in 1981 for blocks 3 and 4 were March 10, March 19, and April 9; postburn sampling dates for blocks 3 and 4 were March 24, April 8, and May 4 for treatments 1, 2, and 3 respectively.

In 1980, the prescribed phenological stages were observed on March 9, March 18, and April 10, and the block-l and block-2 plots were burned on March 11, March 19, and April 16. In 1981, the three phenological stages were observed on March 16, March 30, and April 20. Burn dates were March 23, April 2, and April 29 for block 3 and May 1 for block 4. Burning conditions for each plot were documented. Fireline intensity was estimated from average observed flame lengths using relationships reported by Nelson (1980).

An analysis of variance was used to determine the significance of the effects of burning treatment on recorded study variables. Each year's results were analyzed separately. The analysis of variance was of the form:

Source	Df
Block	1
Treatment	2
Error	14
Total	17

Duncan's multiple range test was used to separate treatment means when treatment effects were significant.

RESULTS

Summer Burns

Hardwood Damage.-The first summer fire was very effective in destroying the live crowns of upland hardwoods. Dogwoods suffered an average defoliation of 99 percent, while oaks and blackgums had defoliation averages of 89 and 91 percent, respectively.

Following the second summer fire (1978), 25 percent of the upland hardwoods had been completely killed, and an additional 15 percent had suffered complete top-kill but had sprouted (table 2). Complete kill ranged from 20 percent for dogwoods to 32 percent for blackgums. Seventy-nine percent of upland-hardwood mortality occurred after the second fire, mostly among trees with complete top-kill from the first fire. It appears that a second fire is needed to "finish off" trees with complete top-kill from an earlier fire and that a low-intensity burn is adequate for this purpose. Surviving hardwoods had damaged crowns. By May of 1979, average crown

Table 2.-*Fire damage to hardwoods following two summer fires*

Site and species	Trees	Mean d.b.h.	First fire Complete kill	First fire Top-kill	Second fire Complete kill	Second fire Top-kill	Crown recovery*
	Number	*Inches*			*Percent*		
Upland							
Dogwood	89	2.4	0	21	20	18	46
Oaks	75	3.2	9	20	20	11	53
Blackgum	19	2.5	16	21	16	16	47
Persimmon	4	3.2	0	25	25	25	50
Streambottom							
Titi	52	1.9	29	58	21	44	3
Red maple	17	1.6	0	100	53	47	0
Gallberry	11	1.2	0	100	36	64	0
Sweetbay	3	6.8	100	.....	.....	.....	....
Sweetleaf	4	2.2	0	100	0	100	0
Cherry	3	0.7	0	100	100	.....	....

*Percentage of preburn live crown,

recovery (sprouts excluded), ranged from 46 percent for dogwoods to 53 percent for the oaks as a group. Unless burning continues, however, damaged hardwoods will recover and outgrow susceptibility to fire-kill.

Streambottom hardwoods were much more susceptible to fire-kill than the upland hardwoods. Fifty percent of all streambottom hardwoods were killed outright, and an additional 47 percent suffered from complete top-kill. Again, most of the trees killed by the second fire had suffered from complete top-kill after the first fire.

Percentage of upland hardwoods killed, suffering from complete top-kill, or showing at least partial crown recovery following two successive summer burns, by diameter class, are given in table 3. Mortality and damage declined as tree diameter increased; crown recovery increased with increasing tree diameter.

The degree of crown reduction persisting to the year following the second summer burn was associated, through regression analyses, with variables such as species or species group, tree d.b.h., and densities (basal areas) for pines, hardwoods, and the stand as a whole at each sample point. Crown reduction was strongly associated with d.b.h., as expected. This effect was greatest for blackgums and least for streambottom species as a group. Increases in pine density were associated with significantly increased crown-kill in the oaks and streambottom species, but not in dogwoods or blackgums. Increases in hardwood density were associated with significantly reduced crown-kill in dogwoods, while increases in total stand density were associated with significantly reduced crown-kill in blackgums. Hardwood leaf litter fuels burn with difficulty, if at all, under conditions in which other fuels burn very well (Lotti and others 1960). Dogwood leaf litter burns very poorly, and it seems clear that heavy leaf litter in dogwood thickets helps protect dogwood stems from surface fires. Longleaf pine needle litter, on the other hand, creates more intense fires than oak leaf litter (Williamson and Black 1981) and other surface fuels, and this may explain the increasing damage to oaks and streambottom hardwoods with increasing density of pine overstory.

Pine Damage.-Summer burns killed both small and large longleaf pines. Fifty-three percent of all pines in the l-inch d.b.h. class and 28 percent of those in the ‘L-inch d.b.h. class were killed by the first burn (table 4). Neither

Table 3.-*Fate of upland hardwoods, by diameter class*

Diameter class	Killed	Top-killed	Crown recovery
Inches		percent	
1	58	22	20
2	15	20	65
3	13	6	81
4	7	7	86
≥ =5	4	0	96

Table 4.—*Crown scorch and mortality of pines after summer bums*

D.b.h. class	Trees	Average crown scorch 1st fire	Average crown scorch 2nd. fire	Pine mortality
Inches	*Number*		*Percent*	
1	162	81	10	53
2	106	43	5	28
3	43	18	2	5
4	22	13	0	5
5-6	14	14	0	0
7-9	18	11	1	0
10-12	22	10	1	0
13-15	55	4	0	0
16-18	77	7	0	12
19-21	30	8	0	13
22+	8	3	0	25

burn killed any pines in the 5- to B-inch d.b.h. classes. However, 13 percent of the pines larger than 15.5 inches in d.b.h. were killed, and 80 percent of this mortality resulted from the first burn. Pine mortality amounted to 8 percent of all sawlog-size trees (those with d.b.h. >9.5 inches). This is much higher than long-term mortality rates observed for a number of mature longleaf pine stands distributed throughout the Southeastern United States, which ranged from 0 to 2.6 percent and averaged 0.9 percent annually (Boyer 1979). Lightning, a major cause of mortality for large longleaf pines, was not a factor during this study. The first summer fire was much more intense than the second and resulted in greater crown scorch (table 4). Even so, for all the larger pines (d.b.h. >12.5 inches), crown scorch averaged less than 10 percent in the first fire and did not occur in the second. L. E. Chaiken (Langdon 1971) observed that summer burns in stands of mature loblolly pines sometimes resulted in cambial kill at the groundline, where the bark becomes extremely thin as it joins the roots. Accumulations of dead bark and needle litter at this vulnerable point might possibly fuel fires hot enough to kill large trees.

Spring Burns

The Fires.-Fuel loads (dry weight) averaged about 5,200 pounds per acre for the two blocks burned in 1980 and 6,600 pounds per acre for the two blocks burned in 1981. The 1980 burn was preceded by a prescribed burn in the winter of 1978, and the 1981 burn was preceded by a prescribed burn in the spring of 1979. Fuel composition was predominantly cured and green herbaceous vegetation. The proportion of green to cured fuel increased with later burning dates. Estimated preburn fuel weights, proportion of green fuel, amount of fuel consumed by the fire, and average fireline intensity are given in table 5 for each treatment each year. All plots were burned with headfires.

Table 5.—*Fuel weights and fire intensity for each treatment and year*

Burn date	Total fuel	Green fuel	Fuel consumed	Fireline intensity
	Pounds/acre	*--------Percent*	*--------*	*BTU/ft/sec*
1980 Burns				
3/11	4784	17	30	171
3/19	6933	19	67	170
4/16	3893	23	64	110’
1981 Burns				
3/23	7010	6	14	112
4/02	8777	14	18	132
4/29	4152	29	11	29

Hardwood Damage.-Timing of the 1980 spring burns did not significantly affect fate of hardwoods (relative damage), average crown reduction, or number or size of sprouts at the end of the first or second growing season after burning (table 6). Crown reduction for all three treatments averaged 47 percent at the end of the first year after burning and fell to 39 percent at the end of the second. Fires completely killed only 5 of the 537 sample trees burned in 1980. Three of the five dead trees were in treatment 3. Fires resulted in the top-kill of 131 more trees, all of which sprouted from the roots or the root-collar. Fifty-three of these trees were in treatment 3 plots and 51 in treatment 2 plots.

Timing of the 1981 spring burns significantly affected fate, or average degree of injury, crown reduction, and sprouting (table 6). Treatment 2 resulted in a higher average crown reduction, 82 percent, than either of the other two treatments, or any of the 1980 treatments, and also resulted in more and larger sprouts. Crown recovery between 1 and 2 years after burning was slower in treatment 2 plots than in others. Treatment 3 produced the lowest recorded fire intensity but still resulted in significantly greater hardwood damage than treatment 1. Only 12 of the 526 sample hardwoods burned in 1981 were killed outright, 9 by treatment 2, and 3 by treatment 3. An additional 144 trees suffered complete top-kill but

Table 6.-*Effect fire treatments on hardwood fate, crown reduction, and sprouting*

Treatment	Fate *	Crown reduction†	Sprouts/stem	Mean sprout length
		Percent	*Number*	*Inches*
1980 Burns				
First year after treatment				
1	3.7a‡	40a	5a	10a
2	3.4a	47a	6a	10a
3	3.3a	53a	5a	9a
Second year after treatment				
1	4.0a	32a	6a	18a
2	3.7a	40a	6a	20a
3	3.6a	44a	5a	18a
1981 Burns				
First year after treatment				
1	4.5a	9c	1b	3b
2	2.5c	82a	5a	21a
3	3.9b	34b	2b	4b
Second year after treatment				
1	4.9a	4c	1b	4b
2	2.6c	77a	5a	29a
3	4.3b	24b	2b	6b

*Average degree of damage scale, from 1=dead to 5=no effect.

†As percent age of preburn live crown.

‘Treatment means in the same column (by year of burn and postburn remeasurement) followed by same letter are not significantly different at the 0.05 level.

sprouted. Of these, 117 were in treatment 2 plots and 23 were in treatment 3 plots.

This study suggests that the burn at full leaf might have' been more effective than either of the earlier two burns-and would certainly have been more effective than the first burn-if fire intensities had been equal. The third 1980 burn resulted in somewhat greater crown reduction than the first two 1980 burns, even though its estimated fire intensity was lower. The third burn in 1981 was significantly more effective than the first 1981 burn, even though the third burn had the lowest estimated fire intensity.

Species Susceptibility to Fire.-Upland hardwood species differed in their susceptibility to fire damage. Fate, percent age of crown reduction, and mean diameter (at 6 inches above groundline) for these species are given in table 7.

The species most resistant to fire injurywere bluejack and turkey oak, common associates of longleaf pine on dry, sandy upland sites historically subject to frequent fires.

CONCLUSIONS

A single hot summer fire did not cause much upland hardwood mortality. A second summer fire 2 years later resulted in most of the mortality in both upland and bottomland hardwoods, even though it was not a very intense fire. Mortality occurred mainly among trees that had suffered complete top-kill after the first fire. Among upland hardwoods, only these in the l-inch d.b.h. class suffered over 50-percent mortality, and damage to hardwoods in the 4-inch and larger d.b.h. classes was negligible. The presence of pine needle-litter fuels was apparently conducive to increased fire damage to some upland hardwood species, as degree of damage increased with increasing pine density. Results of other studies suggest that a second summer fire 1 year rather than 2 years after the first might have caused greater damage, as the trees would not have had a full growing season to recover from the first burn.

Prescribed summer fires have the potential of causing unacceptable levels of damage to longleaf pines. In the present case, a single hot summer fire was more destructive to pines than to hardwoods. Mortality among pines in the 1- through 4-inch d.b.h. classes following the single summer burn was as great as mortality among hardwoods of the same size following two summer fires. In these size classes, all pine mortality resulted from the first fire. While there was no mortality among pines in d.b.h. classes from 5 to 15 inches, significant mortality occurred among pines in the 16-inch and larger d.b.h. classes. Eighty percent of this mortality also followed the first burn.

No conclusive evidence was obtained from this study that the timing of spring burns, based on phenological stage of development of target species, had a significant impact on the degree of hardwood crown reduction. Mortality was minimal, as it usually is, with just one burn. Fire intensities differed among the three burning treatments but could not be accurately estimated. It may be much more important to burn when conditions will support hot fires, with phenological stage of hardwood development being only a secondary consideration.

The results reported here suggest that if all other factors are equal, hardwood damage in terms of complete top-kill or crown reduction may increase with later burning dates in the spring. Spring burns, especially when conducted later in the spring, may be effective chiefly because they result in depletion of hardwood root reserves and thus increase the effectiveness of subsequent growing season fires. This possibility should be investigated further.

Table ***I.--Species susceptibility to** fire damage*

Species	Fate*	Crown reduction	Mean diameter'
		Percent	***Inches***
Water oak	3.0	68	1.6
Dogwood	3.5	52	1.5
Red oak	3.5	51	1.8
Post oak	3.6	45	1.5
Bluejack oak	3.9	29	1.7
Turkey oak	4.1	23	1.8

*Average degree of damage scale, from 1 =dead to 5=no effect.
'Measured 6 inches above groundline.

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Summer fires in existing longleaf pine stands carry undue risk of pine mortality. One summer fire caused as much mortality among pines in the 1- through 4-inch d.b.h. classes as two successive summer fires among hardwoods of the same size. Mortality among mature pines was also excessive. Hardwood top-kill following a spring fire seemed affected more by fire intensity than by timing of the fire.

Keywords: Hardwood control, ***Pinus palustris*** Mill., prescribed fire.