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A 9-YEAR COMPARISON OF HARDWOOD CONTROL TREATMENTS FOR ENHANCING NATURAL REGENERATION AND GROWTH OF LOBLOLLY-SHORTLEAF PINES IN AN UNEVEN-AGED STAND.

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ABSTRACT

Preharvest control of hardwoods facilitated natural regeneration of loblolly and shortleaf pines (*Pinus taeda* L. and *P. echinata* Mill.) in an overstocked, uneven-aged stand in southern Arkansas. During spring 1983, hardwoods were controlled by either basal injection of Tordon® 10 1R[1], soil application of Velpar® L, or rotary mowing followed by a broadcast spray of Tordon® 10 1 applied over the hardwood stubble. After hardwood control, an improvement cut in summer reduced merchantable pine basal area from 97 to 70 sq ft/ac, just before a bumper pine seed crop that winter. Two additional improvement cuts in July 1987 and June 1991 left 55 and 48 sq ft/ac, respectively, in merchantable pine basal area. Nine years after hardwood control, untreated check plots had an adequate density of pine regeneration for uneven-aged stands, but dominant stems of pine regeneration on check plots were of low vigor, small in size, and overtopped by nonpine competing vegetation. In contrast, dominant pine regeneration on plots where hardwoods were controlled 9 years earlier averaged 10 feet taller and 1.3 inches larger in groundline diameter than the dominants on untreated plots.

INTRODUCTION

Much forest acreage in the South is stocked with pine sawlogs in the overstory but has little or no pine regeneration in the understory, even when overstory basal area is optimum (<60 sq ft/ac) for such regeneration. Hardwood trees, shrubs, vines, and brambles invade pine sites and shade out many pines of smaller size during the early years of pine development. To compound this problem, many private, nonindustrial forest landowners tend to harvest their

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[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 of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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merchantable sawlog pines periodically without controlling the hardwood component. Such harvesting practices are especially detrimental in uneven-aged pine silviculture because there must be a progression of trees from the smaller to the larger and more valuable size classes.

private, nonindustrial forest landowners are often aware of the hardwood problem on pine sites, but usually have the misconception that hardwood control involves high-cost, intensive treatments, requiring the use of heavy mechanical equipment. As a result, productive pine sites can become dominated by lowquality hardwoods that may have little commercial value as a timber resource.

The objective of this study was to assess the effects of low-cost hardwood control that can facilitate the establishment of natural pine regeneration. When the study began in 1983, there was a mature, overstocked stand of loblolly and shortleaf pines (*Pinus taeda* L. and *P. echinata* Mill.) that averaged 20 inches in dbh and contained 97 square feet of basal area per acre. The stand did not have a welldefined uneven-aged structure but did have potential for uneven-aged management. Submerchantable (<3.6 inches dbh) pine density was only 63 stems per acre compared to 2,350 stems per acre for the hardwood component. This paper reports the efficacy of three hardwood control treatments for enhancing pine establishment and growth, 9 years after treatments were applied.

METHODS AND MATERIALS

Soil on the study area is Bude (Glossaquic Fragiudalf) silt loam (6). Sixteen contiguous plots of 0.25 acre each were established in the spring of 1983 with interior subplots measuring 66 feet square (0.1 ac). The experiment was a randomized complete block design with four replications of each treatment. Blocking was based on merchantable pine basal area before the first improvement cut. preharvest treatments for controlling hardwoods were assigned at random within blocks.

Hardwood control treatments were applied only once, as follows: (1) Untreated check-There was no preharvest control of hardwoods. (2) Basal injection--All hardwoods having a groundline diameter (gld) of 1 inch or larger were injected with Tordon® 101R (picloram at 0.27 lb a.e./gal and 2,4-D at 1.0 lb a.e./gal) at the rate of 1 ml per incision and one incision per inch of gld. Injection was accomplished in late March 1983 with Jim-Gem@ tree injectors. (3) Soil-applied herbicide--Velpar® L (hexazinone) was dispersed using spotgun applicators at the rate of 4 lb a.i./acre on a 4-ft by 4-ft grid A 50/50 solution of water/hexazinone was applied as 5.5 ml spots in early April 1983. (4) Mow and herbicide spray-The major part of this treatment was accomplished with a rotary mower attached to a wheel tractor, but hardwoods >4 inches dbh were cut with chain saws and mulched with the mower, so that no hardwoods were left standing. Tordon 10 1 was applied over the hardwood stubble as a broadcast spray at the rate of 2 lb a.e./ac in 60 gal of water per acre as soon as mowing was complete. Mowing was done in late May and early June 1983.

The initial improvement cut was completed in the summer of 1983 by harvesting trees of poorest quality so that residual pine basal area averaged 70 sq ft/ac. A second improvement cut was completed in the summer of 1987, leaving 55 sq ft/ac of merchantable pine basal area. Residual pine basal area averaged 48 sq ft/ac following a third improvement cut in June 199 1. All three improvement cuts were done by contract vendors using rubber-tired tractors and skidding log lengths no longer than 36 feet. The objectives of the improvement cuts were to provide openings for natural pine regeneration, remove trees of poor form and quality, and improve spacing of residuals.

Pine seed crops were monitored during the first three winters after hardwood control. Measurements of pine regeneration, hardwood reestablishment, and percent ground cover were taken within 9 systematically spaced circular quadrats (5.27-a radius) per interior O.l-ac subplot. Nine years after hardwood control, pine seedlings (<0.6 inch dbh) and saplings (0.6 to 3.5 inches dbh) were counted within each sample quadrat. The two tallest (dominant) stems of pine regeneration (seedlings or saplings) per quadrat were measured for total height to 0.1 ft and gld to 0.1 inch and were assessed as being either overtopped by nonpine competition or free-to-grow. Percent ground cover of vegetative components was assessed on each quadrat by ocular estimation to the nearest 10%. Hardwoods of seedling and sapling size were identified by species, and rootstocks were counted within each sample quadrat. Hardwoods >3.5 inches dbh were identified as either red oaks, white oaks, gums, or others, but hardwoods with the highest density were identified by species. All merchantable-sized pines and hardwoods were counted by l-inch dbh classes within each 0.25-acre gross plot.

Data were analyzed by analysis of variance. Percent values were transformed to arcsine before analysis. Scheffe's test was used to separate mean differences among treatments (α=0.05).

RESULTS AND DISCUSSION

During the winter of 1983-84, following hardwood control and the first improvement cut, there was a bumper pine seed crop that averaged over 1,000,000 potentially viable seeds per acre (2). Nine years after hardwood control, density of pine regeneration on the mow-and-spray treatment averaged 6,737 stems/ac, which was 460% more (P=0.01) than occurred on check plots (Table 1). Quadrat stocking of these pines averaged 64% on untreated checks and better than 90% on treated plots, and the difference between mow-and-spray plots (97%) and check plots was statistically significant (P=0.02). Based strictly on density and quadrat stocking, the untreated check plots were adequately regenerated with pines to perpetuate uneven-aged management.

When size of pine regeneration is taken into account, however, the untreated check plots become a less-favorable option. After 9 growing seasons on treated plots, saplings accounted for more than 20% of pine regeneration density; whereas, no pines of sapling size occurred on untreated check plots. On the mow-and-spray treatment, more than 2,400 pines/ac had attained sapling size in 9 years as compared to a range of from 800 to 1,600 pine saplings/ac on the soil-applied herbicide and injection treatments, respectively. For the tallest 500 stems/ac of pine regeneration, total heights averaged from 7 to 12 feet taller (P<0.01) on hardwood control plots compared to untreated checks (Table 1). Similar trends were apparent in mean gld's of the tallest 500 pine seedlings and saplings per acre. Dominant pine regeneration on injection plots and mow-and-spray plots were 1.5 inches larger (P<0.01) in gld compared to dominants on check plots which averaged 0.32 inch in gld (Table 1).

After 9 growing seasons, only 22% of dominant pine regeneration was free-to-grow on untreated check plots compared to an average of 88% on injection and mow-and-spray plots, and that difference was significant (p-0.04). Dominant free-to-grow pines averaged 64% on soil-applied herbicide plots and was no different when compared to other treatment means (Table 1). Ground cover from pine regeneration ranged from less than 2% on check plots to 38% on mow-and-spray plots (Table 1). and the difference between these two treatments was significant (P=0.02).

When the study was initiated, the number of pines by diameter class did not exhibit a reversed-J distribution (5), that is characteristic of uneven-aged stands, because there was no pine regeneration. However, the release of midstory pines by three improvement cuts, as well as the ingrowth of pine regeneration during a 9-year period, resulted in a stand with an irregular uneven-aged structure (Figure 1).

Nine years tier hardwood control, density of submerchantable-sized (<3.6 inches dbh) nonpine woody competition averaged 8,502 rootstocks/ac *with* no differences *(P-0.46)* among treatments (Table 2). *Cornus florida* L., *Callicarpa umericana* L., *Vuccinium* L. spp., and *Acer rubrum* L. accounted for 70% of submerchantable-sized woody rootstock density. *Cornus florida* was the predominant species on check plots and soil-applied herbicide plots; whereas, *Vaccinium* predominated on injection and mow-and-spray plots.

Species richness (number of different species) of submerchantable-sized woody nonpine rootstocks averaged somewhat lower on mow-and-spray plots most likely because crown closure from the high density of pine saplings shaded out intolerant genera. Actual counts of species by treatments were 23 on check plots, 27 on injection plots, 24 on soil-applied herbicide plots, and 19 on mow-and-spray plots. Nine years after hardwood control, ground cover from these submerchantable-sized woody plants averaged 42% with no differences (p-0.26) among treatment means (Table 2). These data suggest that diversity of plant species was not greatly compromised by applying herbicides 9 years earlier.

For merchantable-sized hardwoods (≥3.6 inches dbh) 9 years after treatment, the mow-and-spray treatment had the fewest (P<0.0 1) stems (8/ac) compared to other treatments (Table 2). Density for tbis group of hardwoods did not differ among the other treatments even though the range was from 22 to 144 stems/ac. Obviously, some hardwoods in these merchantable size classes on inject and soil-applied herbicide plots were residuals that survived control treatments 9 years earlier.

On mow-and-spray plots where all hardwood *stems* were cut at groundline, **sweetgum** (***Liquidambar styraciflua*** L.) was the only species to attain merchantable size 9 years later. On check, inject, and soil-applied herbicide plots, the predominant hardwood species in the merchantable dbh classes *were* ***Cornus florida, Acer rubrum, Ilex opaca*** **Ait.,** and ***Sassafras albidum*** **(Nutt.) Nees,** in order of prevalence. These species as a group accounted for 65% of merchantable-sized hardwoods on check plots, 88% on inject plots, and 100% on soil-applied herbicide plots. The only treatment with merchantable-sired oaks was the untreated check, where red and white oaks comprised 11% of total stems.

Percent ground cover from merchantable-sized hardwoods ranged from only 4% on mow-and-spray plots to 42% on check plots (Table 2). Nine years **after** treatment, all three hardwood control treatments had less (P<0.0 1) ground cover from merchantable-sized hardwoods when compared to check plots.
Due to shading of the forest floor by pine cover on mow-and-spray plots and by hardwood cover on check plots, those two treatments averaged the lowest ground cover from herbaceous vegetation at 58% and **63%, respectively,** 9 years after treatment (Table 2). That coverage was less (P<0.01) than the 88% mean cover from herbaceous species on injection plots. At **78%,** herbaceous cover on soil-applied herbicide plots was no different compared to any other treatment.

Costs for hardwood control in this investigation have been previously reported (2), but are provided here for reader information: Check (no cost), injection **($64/ac),** soil-applied herbicide **($100/ac),** and mow-and-spray **($105/ac).** These costs were based on **$3.50/hr** minimum wage, retail prices of herbicides in 1983, and USDA Forest Service operating and replacement cost for fleet equipment (rubber-tire tractor used in mowing).

SUMMARY AND CONCLUSIONS

Density and **quadrat** stocking of natural pine regeneration, that becomes established after an improvement cut in an uneven-aged stand, may appear to be adequate without hardwood control. Nevertheless, under hardwood shade, dominant pine seedlings lingered in a suppressed condition with low vigor for 9 years. In contrast, all three methods of hardwood control that were compared in this study resulted in dominant pine regeneration that **averaged** larger in size and exhibited a more vigorous appearance when compared to dominant pine regeneration on plots without hardwood control. From 64% to 89% of dominant pine regeneration was judged as f&e-to-grow on treated plots compared to only 22% on check plots.

During a better-than-average seedyear, any method of hardwood control will facilitate the establishment of natural loblolly-shortleafpine regeneration when combined with a pine improvement cut on silt loam soil, as long as residual overstory pine density and basal area are within recommended guidelines (1) for uneven-aged management. Consequently, private nonindustrial forest landowners who wish to increase pine growth and yield would likely benefit **from** the low-cost hardwood control treatments tested in this study.

Nine years after establishment, density of natural pine regeneration was **exceessive (>4,000 stems/ac)** when compared to published recommendations (3, 4) for optimum postharvest density of submerchantable-size pines in uneven-aged stands (100 to 200 **stems/ac**). Nevertheless, on treated plots, where pine densities were highest and **midstory** hardwoods were **generally** absent, dominant pine regeneration exhibited a **7-** to **12-foot** height gain in 9 years as compared to dominant pines on check plots. Consequently, intraspecies competition among pines was less detrimental to growth of pine regeneration than the presence of overtopping hardwoods.

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Table 1. Status of pine regeneration, 9 years tier hardwood control in an uneven-aged stand.

Treatment	Density	Quadrat stocking[1/]	Total height[2/]	Groundline diameter[2/]	Free to grow[2/]	Ground cover from pine regeneration
	Stems/ac	%	Ft	Ins.	%	%
Check	1,195a[3/]	64a	2.33a	0.32a	22a	1.8a
Injection	4,944ab	94ab	11.73 b	1.67 b	86 b	25.6ab
Soil-applied herbicide	3,514ab	92ab	9.68ab	1.28ab	64ab	15.6ab
Mow-and-spray	6,737 b	97 b	14.68 b	1.95 b	89 b	37.8 b
Mean square error	$3,479 \times 10^3$	0.0747	10.21	0.25 19	0.1926	0.0165
P>F[4/]	0.01	0.02	<0.01	<0.01	0.04	0.02

[1/] (Number of occupied quadrats/total number of quadrats) x 100.
[2/] Based on the tallest 500 stems/ac on sample quadrats.
[3/] Columnar means followed by the same letter are not significantly different at the 0.05 level.
[4/] The probability of obtaining a larger F-ratio under the null hypothesis.

Table 2. Status of nonpine competition, 9 years after hardwood control in an uneven-aged stand.

Treatment	Density of stems <3.6 inches dbh	Ground cover from stems <3.6 inches dbh	Density of stems ≥3.6 inches dbh	Ground cover from stems ≥3.6 inches dbh	Ground cover from herbaceous species[1/]
	No./ac	%	No./ac	%	%
Check	9,167	50	144 b[2/]	42b	63a
Injection	7,431	31	22 b	8a	88 b
Soil-applied herbicide	9,042	44	26 b	11a	78ab
Mow-and-spray	9,570	45	8a	4a	58a
Mean square error	$3,763 \times 10^3$	0.02	207	0.004	0.0151
P>F[3/]	0.46	0.26	<0.01	<0.01	<0.01

[1/] Herbaceous vegetation included grasses, sedges, forbs, vines, and semi-woody plants.
[2/] Columnar means followed by the same letter are not significantly different at the 0.05 level.
[3/] The probability of obtaining a larger F-ratio under the null hypothesis.

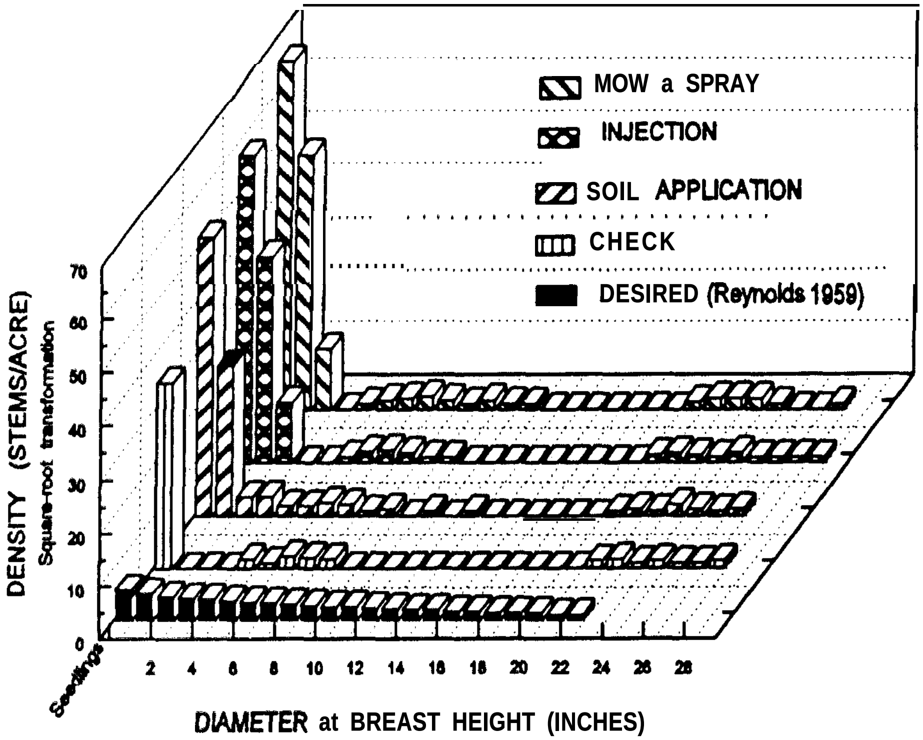

Figure 1. Diameter distribution of loblolly-shortleaf pines in an uneven-aged stand, 9 years after hardwood control.