United States
Department of
Agriculture

Forest Service

Southern
Research Station

Research Note
SRS-09

Underplanting Shortleaf Pine Seedlings Beneath a Residual Hardwood Stand in the Ouachita Mountains: Results after Seven Growing Seasons

James M. Guldin and Gerald Heath

July 2001

Abstract

An unreplicated demonstration was established in the Ouachita Mountains in which shortleaf pine (*Pinus echinata* Mill.) trees were harvested and overstory hardwoods were retained. A new stand was established by underplanting shortleaf pine seedlings. After the third growing season, five 0.5-acre plots were established, and one of five overstory hardwood retention treatments—0, 10, 20, 30, or 40 square feet per acre of residual basal area (RBA)—was randomly assigned to each. Pine seedlings were measured after the third, fifth, and seventh growing seasons. Over time, pine seedling density changed very little by treatment, but seedling basal area varied inversely with increasing overstory retention. After the fifth and seventh growing seasons, the basal area of the average tree in the RBA 0 treatment was greater than in any other treatment, and differences in height among treatments were also observed. Between the third and seventh growing seasons, average annual growth of pine in both height and basal area declined with increasing overstory hardwood basal area. The decline in height growth occurred uniformly from the RBA 0 through the RBA 40 treatments; but the decline in seedling basal area growth occurred between the RBA 0 and RBA 10 treatments. To date, seedlings have survived and growth has increased across all treatments. Future monitoring will determine if and when growth rates cease on any of the plots.

Keywords: Ouachita, plantation, shortleaf pine, survival, underplanting.

Introduction

In 1990, the USDA Forest Service initiated New Perspectives—the first step in a philosophical reorientation of land management within the agency. One element of this program was to demonstrate partial cutting methods that might be used as alternatives to clearcutting, especially in visually sensitive areas.

One such demonstration was established in a mixed pine-hardwood stand on the Fourche Ranger District of the Ouachita National Forest (NF) in Arkansas. Rather than clearcutting both pines and hardwoods in this stand, only the shortleaf pine (*Pinus echinata* Mill.) was harvested. Overstory hardwoods, primarily oaks (*Quercus* spp.) and hickories (*Carya* spp.) were retained as forest cover for the site. Shortleaf pine seedlings were then underplanted beneath the hardwoods. However, foresters questioned whether the pines could develop successfully beneath the hardwoods. Thus, an unreplicated experimental case study was established in this stand to monitor the survival and growth of planted shortleaf pines beneath the residual hardwood overstory.

Methods

Study Area

The demonstration area is located on the Fourche Ranger District of the Ouachita NF in Yell County, AR, approximately 6 miles due south of the town of Ola. This region of the Ouachita Mountains is characterized by long east-west ridges, and the study area occupies a north-facing aspect with less than 10-percent slope near the top of one of these ridges. The stand also lies within the viewshed of Lake Nimrod, a U.S. Army Corps of Engineers flood control facility on the Fourche LaFave River. The lake is a popular fishing spot among residents in the area.

All overstory shortleaf pines were harvested in November 1987. Over 40 square feet (ft^2) per acre of residual overstory and midstory hardwoods remained after the pines were cut. Management plans on the ranger district originally prescribed herbicide injection of these hardwoods, followed by ripping and planting. However, because the area was visible from the lake, managers decided to keep between one-half and two-thirds of the hardwoods. This led to a modification in the planting prescription—the site was not ripped because ripping would disrupt the roots of the hardwoods.

The site was underplanted in February 1989, using genetically improved shortleaf pine on a 7- by 8-ft spacing. The unwanted part of the hardwood component (smaller trees of poor form and trees of inferior species) was injected in March 1989 with 0.46-pound (lb) active ingredient (ai) per acre of Garlon 3A.

James M. Guldin, Project Leader, USDA Forest Service, Southern Research Station, Hot Springs, AR 71902 and Gerald Heath, District Silviculturist, USDA Forest Service, Ouachita National Forest, Danville, AR 72833.

Plot Layout and Measurement

In July 1991, five 0.5-ac plots measuring 2 by 2.5 chains were established within a relatively uniform area of the stand. Five residual basal area (RBA) treatment levels—0, 10, 20, 30, and 40 ft^2 per acre—were randomly assigned, one to each plot.

All overstory trees were measured in each treatment plot. Trees were marked for removal from below, and an updated tally was kept in the field. All trees marked as surplus above the specified treatment target were injected in August 1991 using Garlon 3A at a rate of 1-lb ai per ac.

In March 1992, after the third growing season (GS3), a central measurement area of 1 by 1.5 chains was established in each treatment plot. In this measurement area, six 0.01-acre fixed-radius subplots (radius = 11.78 ft) were systematically established on a 0.5-chain grid. All planted trees with heights $\geq$ 1.5 ft were numbered and tagged in each subplot. On each sample tree, the root collar diameter (RCD) was measured to the nearest 0.1 inch (in.) using a caliper, and the total height of the seedling was measured using a logger's tape to the nearest 0.1 ft.

In December 1993, after the fifth growing season (GS5), and again in February 1996, after the seventh growing season (GS7), all tagged pines were remeasured. Root collar diameter (RCD) was measured to the nearest 0.1 in. using a caliper or diameter tape. Tree heights were measured to the nearest 0.1 ft using either a range pole (graduated in feet and tenths) or a clinometer.

Data Analysis

Data were analyzed in three ways. Preliminary analyses quantified changes in stand density (trees per acre) and basal area (ft^2 per acre) of planted pines from the third to the seventh growing season. Because the treatments were unreplicated and only six 0.01-acre subplots were used per treatment, results should be interpreted as general trends.

The second analysis quantified changes in average tree diameter and height across the five treatments in each measurement period. Tree height (HT) was analyzed directly using the height data recorded in the field. All statistical tests for RCD were conducted using root collar basal area (RCBA), because RCBA is more robust for statistical analyses than RCD. To help interpret RCBA analyses, quadratic root collar diameter (QRCD, the RCD of the tree having mean RCBA) was calculated for mean RCBA results. The statistical analysis of RCBA and HT was conducted using a parametric general linear models procedure (SAS Institute Inc. 1989). The hypothesis of no difference in mean tree size among treatments was tested using analysis of variance. The sampling error of the subplots per treatment was used as a surrogate for experimental error. The statistical analysis was complicated by differences in initial tree RCBA and HT by treatment after the third growing season, for which the common mathematical transformations were unable to compensate. Thus, treatment differences in RCBA and HT at GS5 and GS7 were tested using analysis of covariance (Snedecor and Cochran 1967), where the initial RCBA (or HT) at GS3 was used as the covariate for RCBA (or HT) at GS5 and GS7.

The third analysis tested for differences in individual tree growth by treatment. Data were calculated as average annual growth in RCBA and HT for GS3 to GS5, and GS5 to GS7; RCBA growth was converted back to QRCD to facilitate interpretation. The hypothesis of no difference in mean annual growth among treatments was tested using analysis of variance (SAS Institute Inc. 1989). In all analyses, Sidak's test (SAS Institute Inc. 1989) was used for comparisons among means.

Results

Plantation Density and Basal Area

Pine seedling density showed very minor changes over time within any of the treatments (fig. 1). Three treatments showed no change from GS3 to GS7, and two of the treatments showed a slight decline. Seedling density among treatments differed at GS3. These differences could be attributed to variations in planting density, mortality of planted seedlings between the time of planting and the third growing season, or both. The former is more likely. Because the planting was done as an educational project by volunteers from the community, variation in planting density was not unexpected.

Pine basal area increased over time (fig. 2), and the basal area at GS7 in the RBA 0 treatment was clearly higher than that in the remaining treatments. In both the GS5 and GS7 measurements, the difference in basal area between the RBA 0 and RBA 10 treatments was larger than the difference between the RBA 10 and RBA 40 treatments. At both GS5 and GS7, the basal area of planted pines in the RBA 10 treatment was approximately one-half that in the RBA 0 treatment.

Mean Sapling Diameter and Height

At GS3, differences in the diameter and height of the average tree were observed among treatments (table 1). Generally, the RBA 0, RBA 10, and RBA 40 treatments had the largest seedlings in GS3; and the RBA 30 treatment had the smallest. These differences probably resulted from variation in the residual overstory before the third growing season. However, these differences are small for all practical purposes. Variation in diameter (QRCD) was only about 1/4 in. across all treatments (fig. 3), and variation in height was only 2/3 ft (fig. 4).

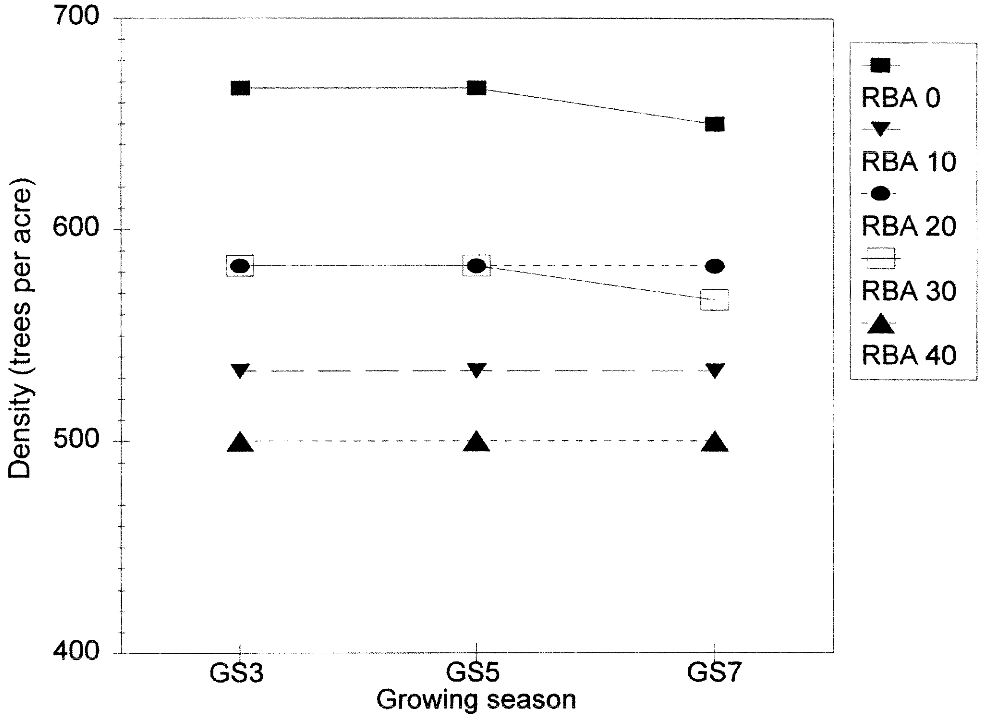

Figure 1—Pine plantation density after the third, fifth, and seventh growing season (GS3, GS5, and GS7) by treatment. RBA 0–40 are treatment levels.

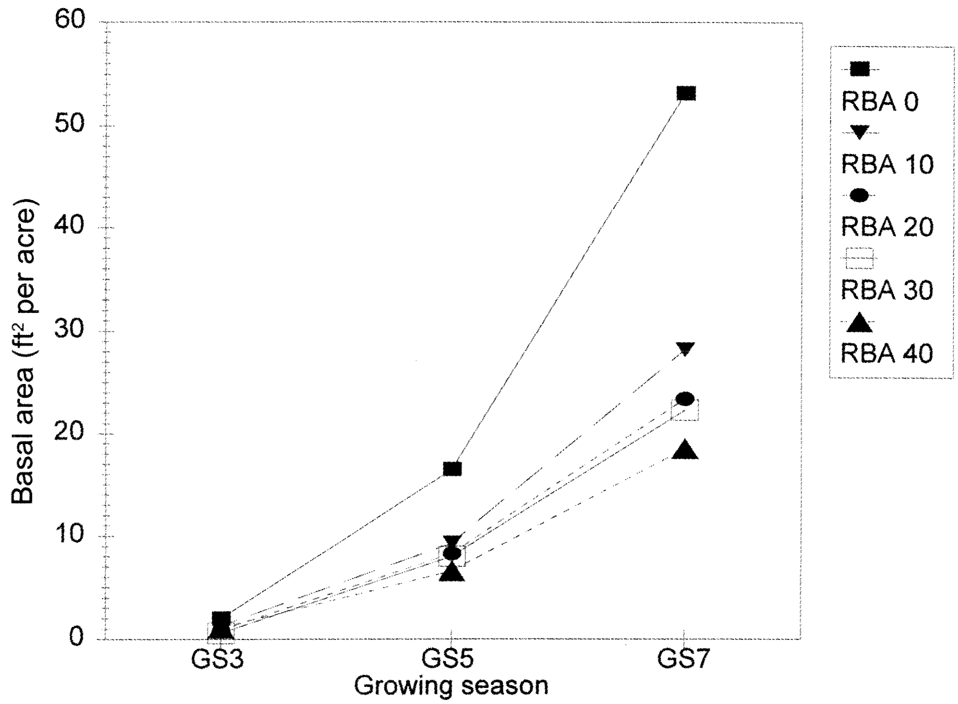

Figure 2—Plantation basal area after the third, fifth, and seventh growing seasons (GS3, GS5, and GS7) by overstory residual basal area (RBA) treatment. RBA 0–40 are treatment levels.

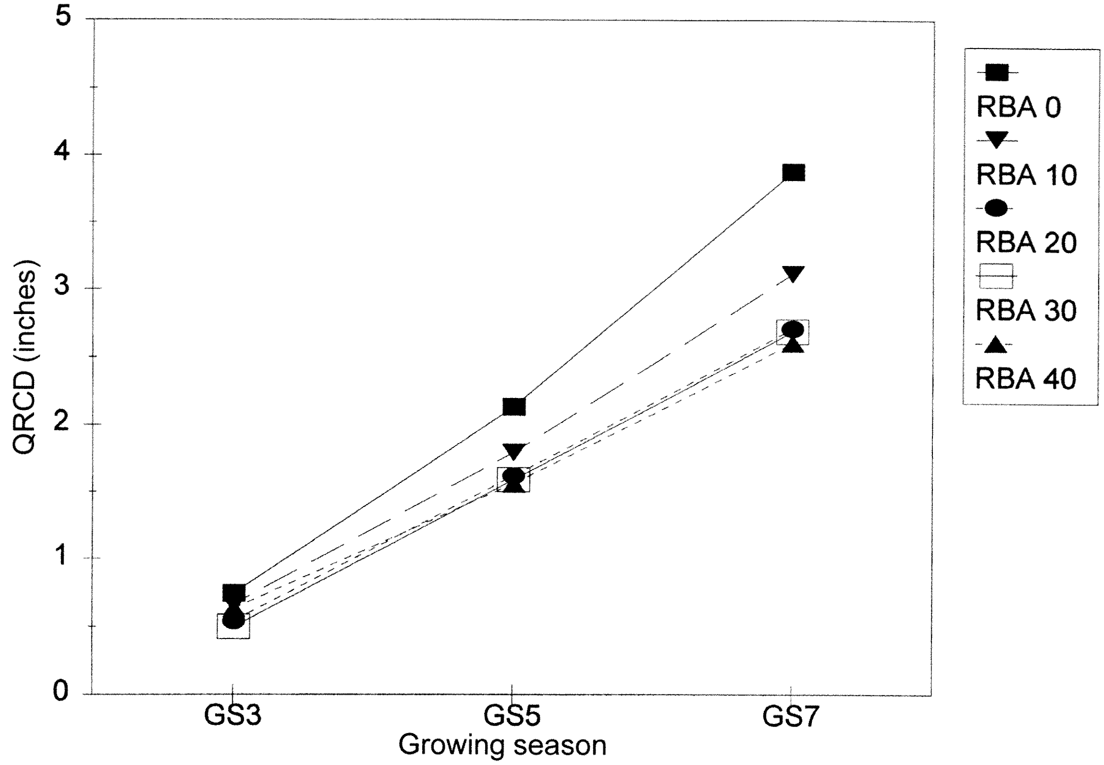

Figure 3—Mean sapling quadratic root collar diameter (QRCD) after the third, fifth, and seventh growing seasons (GS3, GS5, and GS7) by overstory residual basal area (RBA) treatment. RBA 0–40 are treatment levels.

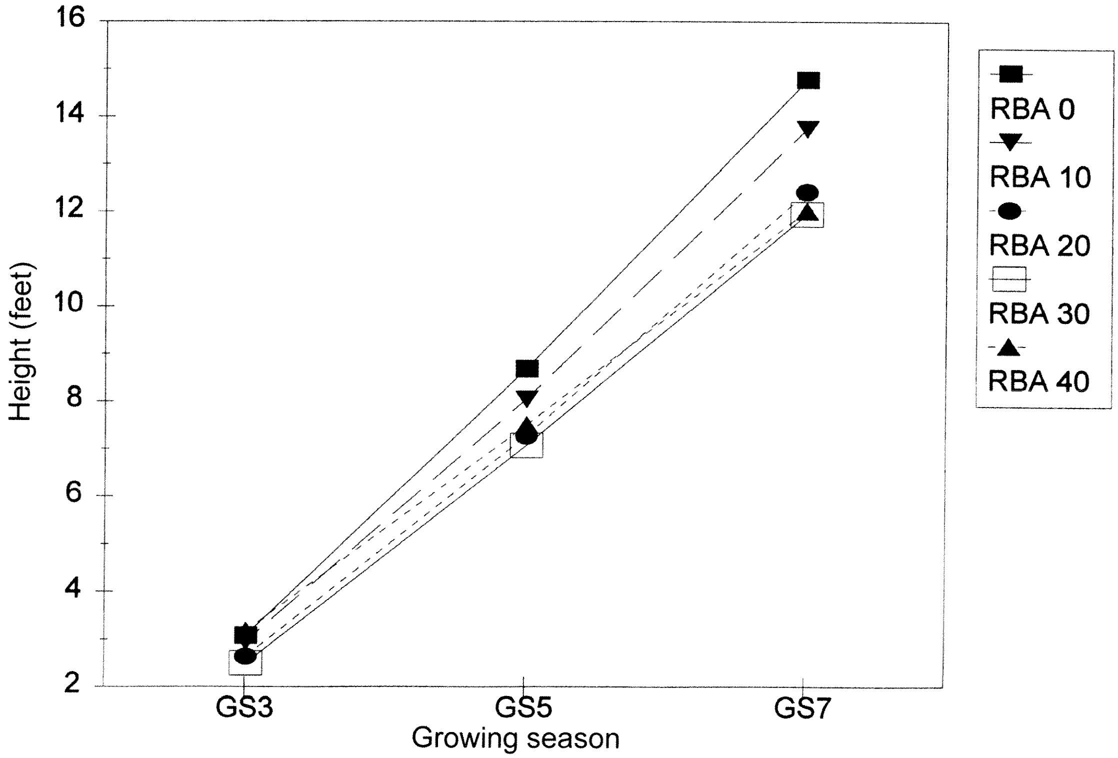

Figure 4—Mean sapling height (HT) after the third, fifth, and seventh growing seasons (GS3, GS5, and GS7) by overstory residual basal area (RBA) treatment. RBA 0–40 are treatment levels.

Table 1—Mean quadratic root collar diameter (QRCD), root collar basal area (RCBA), and height (HT) after the third, fifth, and seventh growing seasons (GS3, GS5, and GS7)

Growing season	QRCD	RCBA	Diff[a]	HT	Diff[a]
	In.	*Ft²*		*Ft*	
GS3					
RBA 0[b]	0.74	0.0030	a	3.09	ab
RBA 10	0.66	0.0024	ab	2.96	abc
RBA 20	0.54	0.0016	bc	2.65	bc
RBA 30	0.50	0.0014	c	2.50	c
RBA 40	0.64	0.0022	ab	3.18	a
MSE[c]	—	0.0013		0.75	
GS5					
RBA 0	2.13	0.0248	a	8.68	a
RBA 10	1.79	0.0175	b	8.04	ab
RBA 20	1.62	0.0143	b	7.27	bc
RBA 30	1.59	0.0138	b	7.07	bc
RBA 40	1.56	0.0132	c	7.50	c
MSE	—	0.0071		1.57	
GS7					
RBA 0	3.87	0.8189	a	14.78	a
RBA 10	3.11	0.0529	b	13.75	ab
RBA 20	2.71	0.0401	b	12.42	bc
RBA 30	2.69	0.0394	bc	11.95	cd
RBA 40	2.60	0.0370	c	12.02	d
MSE	—	0.0197		2.40	

[a] Within a column, means followed by different letters indicate differences in size after accounting for size differences at the start of the study.
[b] RBA 0–40 are treatment levels in all growing seasons.
[c] MSE is the root mean square error of the sample (not included for QRCD, because QRCD was calculated directly from RCBA).

At GS5, differences in basal area and height among treatments were observed based on analysis of covariance (table 1). Average diameter (QRCD) was largest in the RBA 0 treatment and smallest in the RBA 40 treatment, and the remaining treatments ranked in order between them (fig. 3). The mean RCBA in the RBA 0 treatment was greater than that in any other treatment. Average height was largest in the RBA 0 treatment and smallest in the RBA 30 treatment (fig. 4). However, the RBA 40 treatment had the smallest mean height after compensating for initial differences in height using the covariance analysis.

At GS7, size differences in mean RCBA and height were similar to those observed in GS5 (table 1). Average diameter (QRCD) was largest in the RBA 0 treatment and smallest in the RBA 40 treatment, and the remaining treatments were ranked in order between them (fig. 3). The GS7 RCBA in the RBA 0 treatment was greater than that in any other treatment. Average height was largest in the RBA 0 treatment and smallest in the RBA 30 treatment (fig.4). Again, the mean height for the RBA 40 treatment was greater than the mean height in the RBA 30 treatment but looked poorer in the analysis after compensating for unequal mean height at GS3.

Annual Growth Rates Over Both Measurement Periods

Between GS3 and GS5, the average annual growth rate of pine differed among treatments (table 2). The RBA 0 treatment exceeded all others in diameter growth and exceeded all but the RBA 10 treatment in height growth. For the RBA 10 through the RBA 40 treatments, individual tree growth in both basal area and height decreased slightly with increasing RBA, but the differences were not great.

Between GS5 and GS7, the average annual growth rate of pine also differed among treatments (table 2). Mean RCBA growth in the RBA 0 treatment was greater than all other treatments; mean RCBA growth also differed between the RBA 10 and RBA 40 treatments. Differences in height growth rates among treatments were also observed. Saplings in the RBA 0 treatment grew faster than those in either the RBA 30 or RBA 40 treatments, and saplings in the RBA 10 treatment grew faster than those in the RBA 40 treatment.

Table 2—Mean annual growth in quadratic root collar diameter (QRCD), root collar basal area (RCBA), and height (HT) for two growth intervals—the third to fifth growing seasons (GS3-GS5), and the fifth to seventh growing seasons (GS5-GS7)

Growing season	QRCD	RCBA	Diff[a]	HT	Diff[a]
	In.	*Ft*^{2}		*Ft*	
GS3-GS5					
RBA 0[b]	0.69	0.0109	a	2.79	a
RBA 10	0.56	0.0075	b	2.54	ab
RBA 20	0.54	0.0063	b	2.31	b
RBA 30	0.55	0.0062	b	2.29	b
RBA 40	0.46	0.0055	b	2.16	b
MSE[c]	—	0.0031		0.59	
GS5-GS7					
RBA 0	0.87	0.0283	a	3.00	a
RBA 10	0.66	0.0177	b	2.85	ab
RBA 20	0.55	0.0129	bc	2.58	abc
RBA 30	0.55	0.0128	bc	2.44	bc
RBA 40	0.52	0.0119	c	2.26	c
MSE	—	0.0072		0.76	

[a] Within a column, means followed by different letters indicate differences in size after accounting for size differences at the start of the study.

[b] RBA 0–40 are treatment levels in all growing seasons.

[c] MSE is the root mean square error of the sample (not included for QRCD, because QRCD was calculated directly from RCBA).

Four-Year Growth Trends

Over the 4-year period, growth in both diameter and height decreased with increasing RBA (fig. 5). The decrease in height growth was roughly proportional to RBA; treatments that differ by 10 ft^2 of residual basal area show less than a 10 percent difference in relative height growth.

However, basal area growth was 36 percent less in the RBA 10 treatment than in the RBA 0 treatment, and 24 percent less in the RBA 20 treatment than in the RBA 10 treatment—whereas the difference between the RBA 20 and RBA 40 treatment was less than 10 percent. This basal area response also appears when mean RCBA growth is compared between the GS3-GS5 growing season and the GS5-GS7 growing season (fig. 6). In the RBA 20 through the RBA 40 treatments, RCBA growth in the GS5-GS7 period is double that in the GS3-GS5 period. However, RCBA growth in the RBA 10 treatment is 2.3 times greater in the GS5-GS7 interval than in the GS3-GS5 interval and RCBA growth in the RBA 0 treatment is about 2.6 times as great.

Discussion

These data indicate that pines planted in the RBA 0 treatment have developed more rapidly than pines planted in the other treatments on the site during the 4-year period of this study. This is not surprising; the absence of overstory hardwoods maximized the availability of site resources to the underplanted pines. However, with increasing residual overstory, basal area growth declined disproportionally even under the RBA 10 treatment. Despite this effect, pines underplanted beneath the RBA 40 treatment survived and continued to grow through seven growing seasons.

The trends observed in plantation basal area by treatment (fig. 2) are attributable to two factors: tree density and overstory shade. First, the RBA 0 treatment had 18 percent more trees than the RBA 10 treatment at GS7, which means it will have higher basal area. But the RBA 0 treatment also had 44 and 89 percent more basal area at GS5 and GS7, respectively, than the RBA 10 treatment. This suggests the second factor—that even the initial 10 ft^2 of overstory shade results in a disproportionate decline in basal area.

With respect to individual trees, the data suggest that retaining overstory trees results in reductions in height more or less proportional to the overstory basal area. If the annual height growth for RBA 0 is set at 100 percent, annual height growth for RBA 10, RBA 20, RBA 30, and RBA 40 is 92, 84, 81, and 76 percent, respectively. This trend is roughly a linear decline in height with increasing overstory basal area.

Conversely, data suggest that for diameter or basal area, even a slight retention of overstory hardwoods disproportionally reduces seedling diameter. If the annual basal area growth for RBA 0 is set at 100 percent, annual

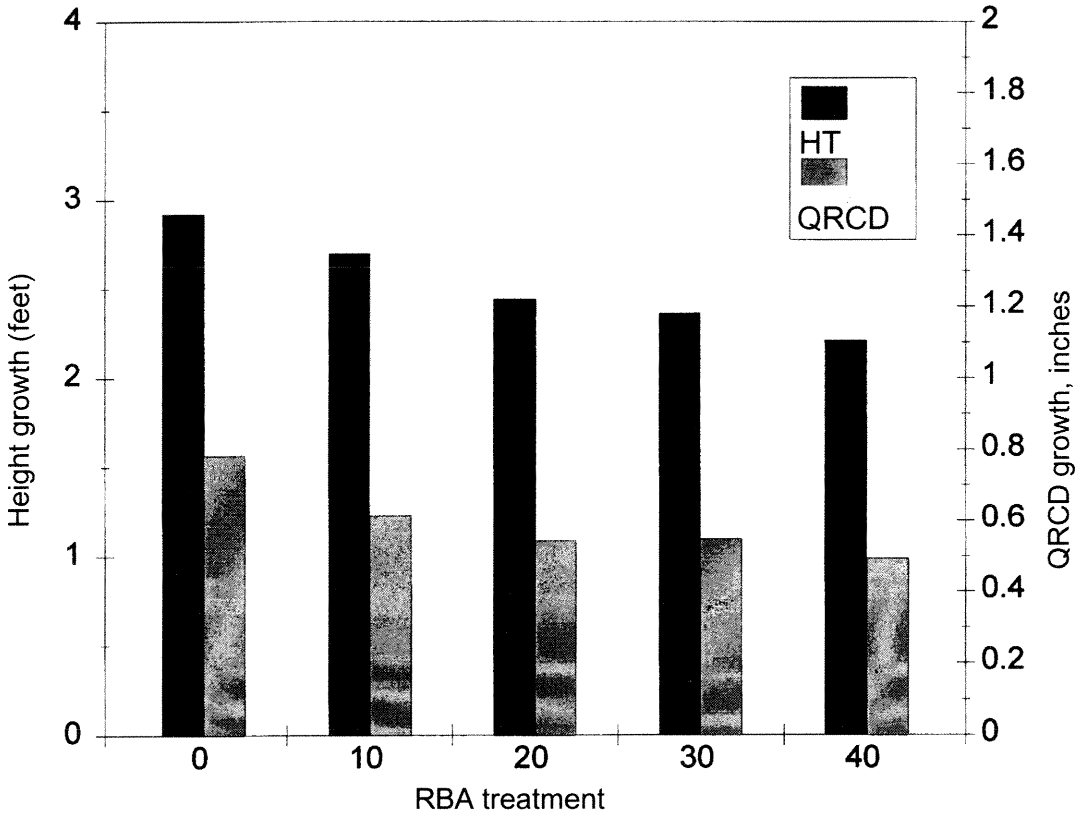

Figure 5—Mean annual sapling quadratic root collar diameter (QRCD) growth and mean annual sapling height (HT) growth by overstory residual basal area (RBA) treatment over the 4-year study.

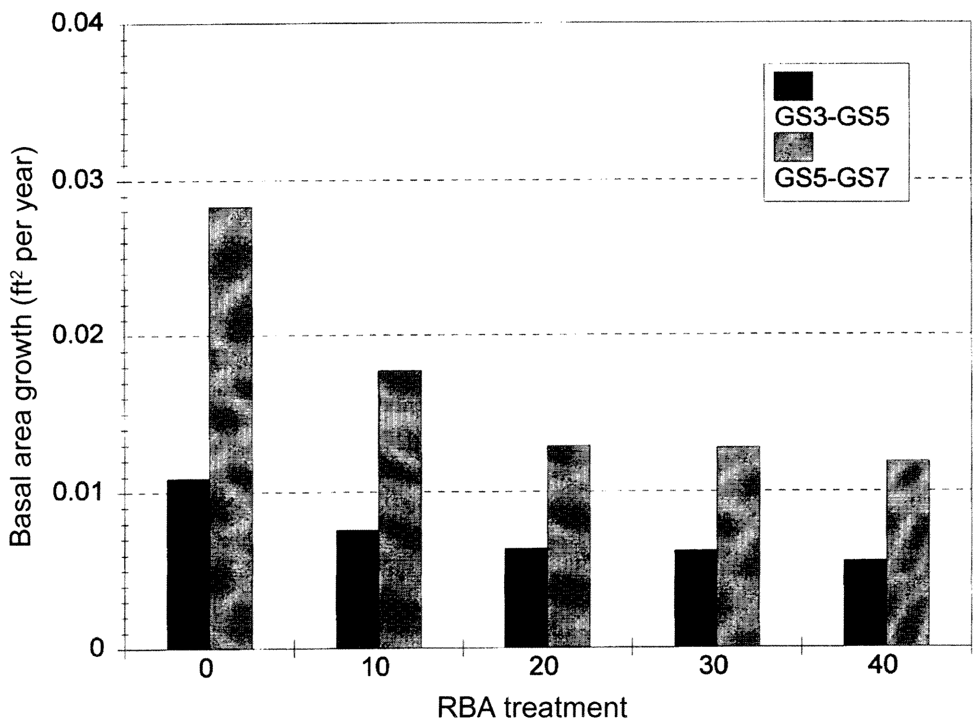

Figure 6—Mean annual root collar basal area growth by overstory residual basal area (RBA) treatment for the first 2-year period (GS3–GS5) and the second 2-year period (GS5-GS7) of the study.

basal area growth for RBA 10, RBA 20, RBA 30, and RBA 40 is 64, 49, 48, and 44 percent, respectively. The first 10 ft^2 of basal area account for a greater reduction in seedling diameter than the additional 30 ft^2 of overstory basal area.

If no catastrophic event intercedes, these trends in height and diameter growth should continue until the planted seedlings reach crown closure, if not longer. If fast early growth is the most important goal for plantation establishment on this type of site, no overstory hardwoods should be retained. However, at this point in the development of the stand, experimental evidence does not suggest that seedlings underplanted beneath 40 ft^2 per acre of residual overstory will become suppressed to the point of mortality. Because volume is a function of basal area and height, this study suggests that early volume development would be much greater in the RBA 0 treatment than in any of the partial overstory retention treatments.

None of the underplanted plots can be considered a failure 4 years after treatment and seven growing seasons after underplanting beneath the residual overstory. In all plots, individual tree height growth exceeds 2 ft per year, and both height and basal area growth were greater in the GS5-GS7 period than in the GS3-GS5 period. The basal area trends suggest that pines in the RBA 0 and RBA 10 treatments are in a better position to remain competitive with hardwoods in the developing stand than those in the RBA 40 treatment. Future monitoring of this study would provide more information about whether the underplanted pines in the higher RBA plots can maintain adequate growth through the first decade of development.

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Southern Research Station, U.S. Department of Agriculture, Forest Service, P.O. Box 2680, Asheville, NC 28802

☆U.S. GOVERNMENT PRINTING OFFICE: 2001- 665-023 00041