EFFECTS OF CANOPY TREATMENTS ON EARLY GROWTH OF PLANTED LONGLEAF PINE SEEDLINGS AND GROUND VEGETATION IN NORTH CAROLINA: A PRELIMINARY STUDY

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Abstract—We installed a field experiment to support the development of protocols to restore longleaf pine (*Pinus palustris* Mill.) to existing mature loblolly pine (*P. taeda* L.) stands at Camp Lejeune, NC. Seven canopy treatments included four uniform and three gap treatments. The four uniform treatments were defined by target residual basal area (BA) [control (uncut), BA9, BA4.5, and BA0 (clearcut) m^2/ha] and three gap treatments: designated large-gap (5027 m^2), medium-gap (2827 m^2), and small-gap (1257 m^2). We quantified treatment effects on planted longleaf pine seedlings and ground vegetation after the first-growing season. Canopy treatments significantly affected the growth of planted longleaf pine seedlings, with the largest root-collar diameter on BA0 (12.4 mm) and the smallest on control (10.6 mm). Total vegetation cover and total herbaceous cover, measured in both May and September 2008, were also significantly influenced by canopy treatments.

INTRODUCTION

Throughout the Southeastern United States, fire suppression and exclusion has resulted in the replacement of historically dominant longleaf pine (*Pinus palustris* Mill.) (LLP) with faster growing, less fire-tolerant species, especially loblolly pine (*P. taeda* L.) (LBP). Compared to LBP, LLP is longer lived, less susceptible to a variety of pests and diseases, and an ideal habitat for the red-cockaded woodpecker (*Picoides borealis*) (RCW) and other rare animals and plants (Walker 1993). Once established, LLP stands are conducive to management with prescribed fire. LLP restoration could be accomplished by clearcutting the existing canopy trees and planting LLP seedlings, because LLP is widely recognized as intolerant of competition for light, moisture, and nutrients (Boyer 1990). However, because the widespread loss of LLP forests has resulted in existing RCW populations using LBP stands for nesting and foraging habitat in recent decades, clearcutting is not desirable (U.S. Fish and Wildlife Service 2003).

The structure of naturally regenerated LLP stands and the results of recent studies that examined the response of naturally and artificially established LLP seedlings in canopy gaps within LLP overstories (Brockway and Outcalt 1998; Gagnon and others 2003; McGuire and others 2001; Palik and others 1997, 2003; Rodriguez-Trejo and others 2003) suggest that LLP could be restored with partial canopy retention, a strategy that would retain RCW habitat values. However, protocols for restoring LLP in LBP stands while retaining a LBP canopy sufficient for RCW use are not currently available. Our study was designed to answer the question: What are optimal silvicultural practices for restoring LLP to LBP stands while retaining mature trees and enhancing the herbaceous ground layer? In this preliminary report, we quantified the effects of canopy treatments on early growth of planted LLP seedlings and ground-layer vegetation based on data collected in 2007 and 2008.

METHODS AND MATERIALS

Study Site

This study was conducted on Marine Corps Base Camp Lejeune, in Onslow County, NC. The area is located within the Atlantic Coastal Flatlands Section of the Outer Coastal Plain Mixed Forest Province (Bailey 1995). The climate is classified as warm-humid temperate with hot, humid summers and mild winters. Mean annual temperature is 16 °C, and annual precipitation averages 1420 mm, which is evenly distributed throughout the year (National Climatic Data Center, Asheville, NC). The sites are on well-drained soils with low-to-moderate available water-holding capacity, including the Norfolk loamy fine sand, Wando fine sand, and Baymeade fine sand soil series (Barnhill 1992).

We used information from land managers at Camp Lejeune to identify two types of LBP stands in greatest need of conversion to LLP. The first condition included extensive, 35-year-old LBP plantations established on sites that are better suited for LLP, and the second stand type was dominated by 60-year-old LBP canopies, composed of large trees at irregular spacing.

Experimental Design

The study used a randomized complete block design, with location as the blocking factor, and consisted of seven treatments replicated on eight blocks. The study area was harvested from February to May 2007, by a local logging crew frequently used at Camp Lejeune. We were unable to apply the large-gap (LG) treatment to one of the blocks due to spatial constraints within the forest.

Seven canopy treatments (described in table 1) were applied in each block, with each main plot receiving a randomly assigned canopy treatment. Prior to planting LLP seedlings,

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Table 1—Summary of overstory treatments implemented in the study

Treatment	Silvicultural practice	Plot size	Number
Control	No cutting	100 by 100 m	8
BA9	Single tree selection to create uniform canopy with target basal area of 9 m^2/ha	100 by 100 m	8
BA4.5	Single tree selection to create uniform canopy with target basal area of 4.5 m^2/ha	100 by 100 m	8
BA0	Clearcut with basal area of zero m^2/ha	141 by 141 m	8
LG	Group selection to create circular “large” canopy gap with radius = 40 m	120 by 120 m	7
MG	Group selection to create circular “medium” canopy gap with radius = 30 m	100 by 100 m	8
SG	Group selection to create circular “small” canopy gap with radius = 20 m	100 by 100 m	8

our study sites were prepared with mechanical mowing in the late summer of 2007 and prescribed burning in fall 2007. Container-grown LLP seedlings were handplanted in December 2007 at a spacing of 1.8 by 3 m by contracted crews. Root-collar diameter (RCD) of planted LLP seedlings was measured in March 2008 and averaged 8.62 mm with a standard deviation of 1.49 mm.

Data Collection

Postharvest Stand Structure—In the summer of 2007, we measured characteristics of stand structure to describe postharvest conditions and to assess treatment uniformity among the blocks. Within each uniform treatment (control, BA9, BA4.5, and BA0), we permanently marked all overstory trees [diameter at breast height (d.b.h.) ≥ 10 cm] with aluminum tags and recorded species and d.b.h. Tree height was measured on a subsample of canopy LBP ($n \geq 30$) with a Laser Technology Impulse 200 Laser rangefinder. D.b.h. measurements were converted to basal area (BA) (m^2/ha) at the plot level.

Within each gap treatment—large-gap (LG), medium-gap (MG), and small-gap (SG)—we marked all overstory trees extending 20 m from the gap edge into the forest and recorded species and d.b.h. BA within the matrix surrounding each gap was then calculated from d.b.h. measures. Distance and azimuth from gap center to each tree within 10 m of the gap edge were recorded to determine the spatial distribution of trees surrounding each gap. Height of each LBP tree extending 10 m from gap edge into the forest was measured with a Laser Technology Impulse 200 Laser rangefinder.

LLP Seedlings Survival and Growth—In the summer of 2008, within each uniform treatment plot (control, BA9, BA4.5, and BA0), a sample of 120 seedlings was randomly selected and permanently marked for repeated measurements. Within each gap plot (LG, MG, and SG), we selected four rows of seedlings spaced at equal intervals and permanently marked each seedling for repeated measurements. Distance from the center of the measurement row to each tagged seedling was also recorded in the gap plots. RCD was measured for each marked seedling using digital calipers in October 2008.

Vegetation—We surveyed the amount (cover) of ground-layer vegetation in the beginning (May/June) and end (September/October) of the 2008 growing season. Within each uniform treatment (control, BA9, BA4.5, and BA0), we established eight parallel, 20-m transects across each plot, with the position of each transect located randomly. Along each transect, we randomly located ten 1- by 1-m sampling quadrats, for a total of 80 quadrats per plot. Within each gap treatment (LG, MG, and SG), we established eight transects along the four rows selected for seedling measurements, with one transect running north and one transect running south from each row center. Along each transect, we established ten 1- by 1-m sampling quadrats at equal intervals, covering the gradient of conditions from gap center to forest edge. All transects were permanently marked with nails and flags, and quadrat locations were recorded for future measurement.

Within each 1-m^2 sampling quadrat, we recorded ocular estimates of the percentage of the quadrat covered by vegetation <1 m tall. The vegetation cover was recorded by functional group (bunchgrasses, other graminoids, ferns, forbs, woody shrubs/trees, and woody vines), species groups of interest (legumes, invasive species), and other (species of interest, pine straw, coarse woody debris, bare mineral soil, and disturbance). Cover was recorded using the following cover classes: 1 = trace, 2 = 0 to 1 percent, 3 = 1 to 2 percent, 4 = 2 to 5 percent, 5 = 5 to 10 percent, 6 = 10 to 25 percent, 7 = 25 to 50 percent, 8 = 50 to 75 percent, 9 = 75 to 95 percent, and 10 = 95 to 100 percent.

Data Analysis

LLP Seedlings Growth—We tested effects of canopy treatments on RCD of LLP seedlings with analysis of variance using PROC GLM in SAS (SAS Institute Inc 2004). Log transformations were used to normalize data.

Vegetation—We analyzed the cover data to detect canopy treatment effects on total vegetation cover, total herbaceous cover, and total woody cover. Plot means were calculated for the analysis using midpoints of the cover classes recorded in the field. Data were analyzed using PROC GLM in SAS (SAS Institute Inc 2004).

RESULTS AND DISCUSSION

Postharvest Stand Structure

BA of control averaged 16.4 m^2/ha with a standard error (SE) of 1.14 m^2/ha (fig. 1). BA of BA9 was slightly smaller than our target BA, with an average of 8.48 m^2/ha (0.53 SE). However, BA of BA4.5 was almost 40 percent larger than our target BA with a mean of 6.17 m^2/ha (0.18 SE). The residual matrix of overstory trees surrounding gaps had a wider range of BAs, with standard errors of 1.78 m^2/ha in LG, 1.45 m^2/ha in MG, and 1.76 m^2/ha in SG. In the majority of gap plots, the residual canopy had BAs that were similar to control, with the averages of 14.4 m^2/ha in LG, 16.5 m^2/ha in MG, and 17.9 m^2/ha in SG.

Mean d.b.h. and tree height of residual LBP trees at the block level are shown in figure 2. Mean d.b.h. ranged from 26.5 cm in block 3 to 45.4 cm in block 8. Mean tree height varied from 18.3 m in block 4 to 27.9 m in block 8. The size of residual LBP trees reflected the two stand conditions at Camp Lejeune. Blocks 1 through 4, established in 35-year-old LBP plantations, had smaller mean d.b.h. (28.8 cm) and tree height (20.5 m) than blocks 5 through 8, which were established in 60-year-old natural LBP stands (mean d.b.h. of 42.6 cm and tree height of 26.5 m).

Root-Collar Diameter Growth

After the first-growing season, RCD was significantly affected by canopy treatment ($F = 4.52$, $P = 0.0013$) (fig. 3) with RCD largest on BA0 (12.4 mm) and smallest on control (10.6 mm).

Across the four uniform treatments (control, BA9, BA4.5, and BA0), there was a consistent increasing trend in RCD as residual overstory LBP BA decreased (mean RCD of 10.6 mm on control, 11.6 mm on BA9, 12.0 mm on BA4.5. 12.4 mm on BA0). Similarly, Palik and others (1997) found that the growth of container-grown LLP seedlings (measured as above- and belowground biomass) 1 year after planting increased with decreasing BA of overstory LLP at the Joseph W. Jones Ecological Research Center in southwestern Georgia, U.S.A.

We found that gap size positively affected RCD of planted LLP seedlings, although differences in RCD among gap treatments were not significant (11.0 mm, 11.5 mm, and 11.6 mm for SG, MG, and LG, respectively). Our results agreed with the study of McGuire and others (2001), conducted in 60- to 90-year-old, second-growth LLP stands in southwestern Georgia, who found that average RCD of planted LLP seedlings was similar among three gap sizes (0.11 ha, 0.41 ha, and 1.63 ha) after the second growing season, although average RCD of planted LLP seedlings was larger within gap openings than under intact LLP canopies (12 mm vs. 9 mm, respectively). Our results and those of McGuire and others (2001) suggest that early growth of planted LLP seedlings within gaps may not be strongly affected by gap size.

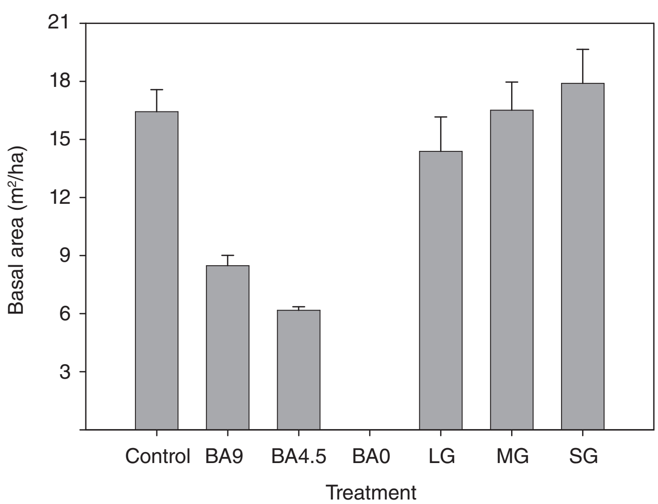

Figure 1—Stand basal area (mean ± 1 standard error) by canopy treatments.

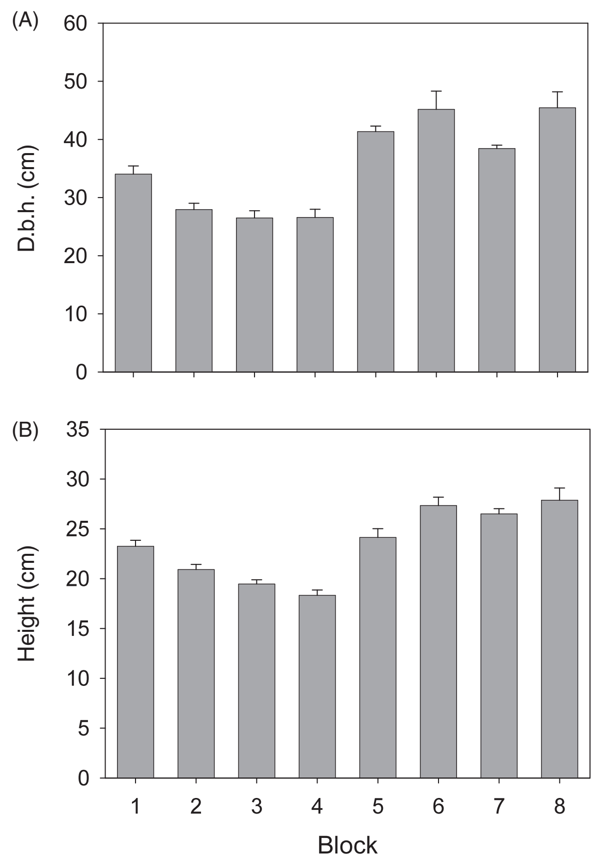

Figure 2— (A) D.b.h. (mean ± 1 standard error) and (B) height (mean ± 1 standard error) of loblolly pine by block.

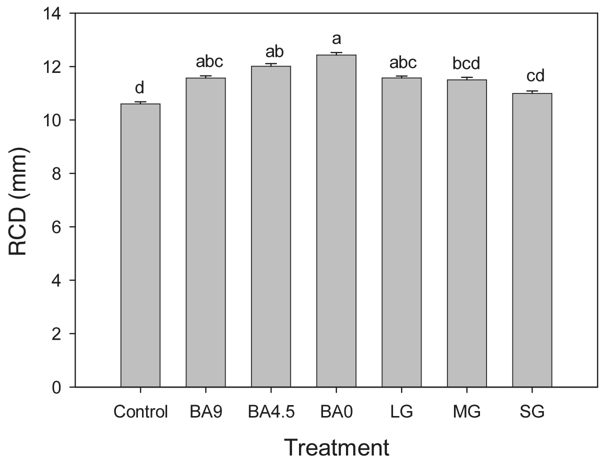

Figure 3—Root-collar diameter (RCD) (mean ± 1 standard error) of first year longleaf pine seedlings by canopy treatments in October 2008. The same letters indicate no significant difference at α <0.05.

Vegetation

Total vegetation cover was significantly influenced by canopy treatments in May (F = 4.22, P = 0.0021) and September (F = 5.54, P = 0.0003) (fig. 4A). In May, LG and MG had the largest total vegetation cover; BA9, BA0, SG, and BA4.5 were intermediate; and control had the least. Similarly, in September, all of thinning treatments (MG, LG, BA0, BA4.5, BA9, and SG) had significantly greater total vegetation cover than control. Total herbaceous cover (the sum of bunchgrass, other graminoid, fern, and forb cover) was also significantly influenced by canopy treatment in May (F = 3.28, P = 0.0099) and September (F = 3.40, P = 0.0081) (fig. 4B). In May, LG had significantly greater total herbaceous cover than control (34.5 percent vs. 14.4 percent, respectively). In September, only MG had significantly greater total herbaceous cover than control (45.1 percent vs. 19.9 percent, respectively). Although not statistically significant, we found that total herbaceous cover on control was less than any other treatment. Our results were similar to a study conducted in young and old Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] stands in western Oregon (Bailey and others 1998), where they found that total herbaceous cover was greater in thinned stands relative to unthinned or old-growth stands, although commercial thinning had occurred 10 to 24 years previously.

Total woody cover (the sum of woody shrub/tree and woody vine cover) did not show significant differences among canopy treatments in either May or September (F = 0.93, P = 0.485 in May; F = 1.50, P = 0.202 in September; fig. 4C). Jack and others (2006) reported an increase in biomass of woody stems following harvest treatments that was likely associated with resource availability. In our study, the mechanical mowing used for site preparation removed standing vegetation and resulted in vigorous resprouting of woody stems during the first growing season. It is likely that the resprouting response was similar among treatments, regardless of the overstory condition.

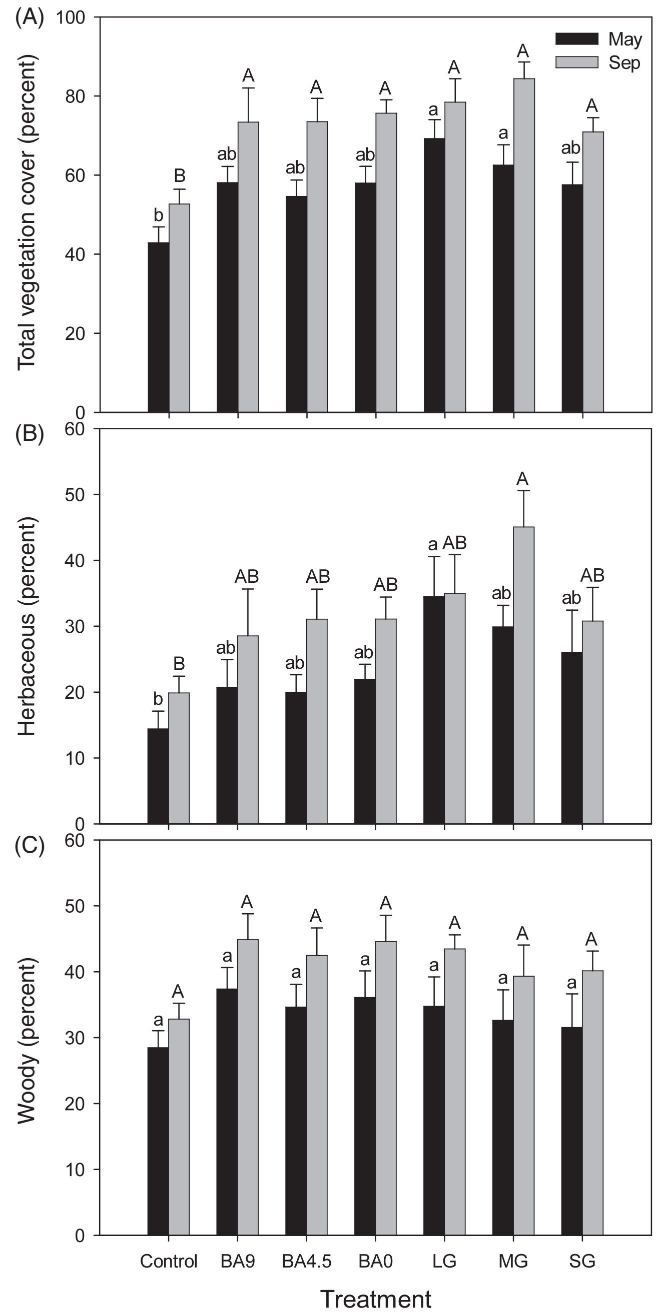

Figure 4—(A) Total vegetation cover (mean ± 1 standard error), (B) total herbaceous cover (mean ± 1 standard error), and (C) woody cover (mean ± 1 standard error) by canopy treatments in May and September 2008. The same letters within each time period indicate no significant difference at α <0.05.

CONCLUSIONS

It is well understood that LLP can be established following removal of canopy trees, but less is known about restoring LLP while retaining canopy trees for RCW habitat. After one growing season, we found RCD of planted LLP seedlings was larger on uniform thinning and gap treatments compared to control. Canopy gap size did not affect RCD and may be a useful restoration option for regenerating pockets of LLP within a matrix of RCW habitats, as suggested by Palik and others (1997). As expected, all uniform thinning and gap treatments had greater total vegetation cover by the end of the growing season than control. Total herbaceous cover, important for good quality RCW habitat, was also greater in uniform thinning or gap treatments than control, although some of those differences were not statistically significant. However, total woody cover was not different among the treatments, a likely result of vigorous resprouting on all treatments following site preparation.

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