UNDERPLANTED SHORTLEAF PINE SEEDLING SURVIVAL AND GROWTH IN THE NORTH CAROLINA PIEDMONT

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Abstract—A study was established in North Carolina to evaluate the viability of underplanting shortleaf pine (*Pinus echinata* Mill.) seedlings beneath a residual hardwood overstory as a method of reestablishing the shortleaf pine component to Central Appalachian Piedmont sites. Twenty-eight treatment plots were harvested to retain one of four residual overstory basal areas (RBA): 0, 15, 30, or 45 square feet per acre. Three shortleaf pine stock types were established within the RBA treatment plots; bareroot stock (BR), and containerized stock with small plugs (SP), and large plugs (LP). Overstory basal area affected survival only in the RBA0 plots which had the poorest survival for all three stock types over the first growing season. Seedling growth declined with increasing overstory basal area for all three stock types over the second growing season. Significant differences in percent survival were also noticed between the three stock types. The LP seedlings had the highest survival and the BR the lowest. Containerized seedlings achieved superior height and groundline diameter growth across all treatments but the differences were greatest between the LP and BR seedlings. Comparatively low survival in the RBA0 plots and the inverse relationship between overstory basal area and growth are attributed to gradients in overstory and understory competition levels and site harshness across the four RBA levels. The superior growth and survival of containerized seedlings is attributed to more intact root systems with higher root mass although we cannot rule out seed source differences. The results of this study suggest that underplanting may be a suitable regeneration option for the initial establishment of shortleaf pine on marginal Central Appalachian Piedmont sites. Further improvements in seedling survival and growth may be realized by planting containerized seedlings.

INTRODUCTION

Previous research suggests that underplanting shortleaf pine (*Pinus echinata* Mill.) seedlings beneath a residual hardwood overstory may be a viable regeneration option for some forest landowners. Many landowners consider the retention of some residual overstory basal area (RBA) to be less visually offensive than clearcut harvesting. Additionally, retained overstory can partially control woody and herbaceous competition and reduce the need for release herbicides (Jensen and others 2007). This regeneration approach may therefore be suitable for the rapidly developing Central Appalachian Piedmont Region where public opinion and changing landowner values can hinder the use of many traditional southern pine regeneration methods that include clearcut harvesting and herbicide applications. Unfortunately, research pertaining to this approach for shortleaf pine is sparse, and almost exclusively limited to the western portion of shortleaf pine's native range (Guldin and Heath 2001, Jensen and Gwaze 2007, Jensen and others 2007, Kabrick and others 2011).

Guldin and Heath (2001) found that bareroot shortleaf pine seedling survival was not significantly affected by RBA after three, five and seven growing seasons, but increasing RBA resulted in decreased height and groundline diameter (GLD) growth of seedlings in the Ouachita Mountains of Arkansas. Jensen and others (2007), Jensen and Gwaze (2007), and Kabrick and others (2011) found inverse relationships between residual overstory stocking and bareroot seedling growth on sites in Missouri. Kabrick and others (2011) also found that increasing overstory stocking marginally increased seedling survival.

In 2012, the North Carolina Department of Agriculture and Consumer Services Research Stations Division (NCDA&CS-RSD) and Mississippi State University applied several components of the underplanting studies from Arkansas and Missouri to a site on the North Carolina Piedmont. The goal of this study was to evaluate the effectiveness of underplanting to establish a shortleaf pine component in pine-hardwood stands in the Central Appalachian Piedmont. The specific objectives were to (1) evaluate the impact of RBA on survival and growth of underplanted seedlings and (2) evaluate differences in survival and growth between containerized and bareroot shortleaf pine planting stock.

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METHODS

Site

The study site is located on the NCDA&CS-RSD Umstead Research Farm in Durham County, NC (36° 9'25.75"N, 78°48'54.32"W). Elevations range from 434 to 486 feet along a ridge with less than 10 percent slope and well-defined east and west aspects. The site received an annual average of 47.8 inches of precipitation and has an average growing season of 194 +/- 14 days (Perry 1996, State Climate Office of North Carolina). The study site is in the Charlotte Slate Belt subsection of the Central Appalachian Piedmont Geological Province (North Carolina Geological Survey 1985, Bailey 1995). Lignum silt loam dominates the upper portions of the ridge and Helena sandy loam may be found on the lower hillslopes (Kirby 1976). Both soil types are moderately well-drained and rocky with a low percentage of organic material.

The forest cover of the study site prior to harvest consisted of a naturally-regenerated mixed upland hardwood-pine stand that developed following agricultural abandonment in the 1940s. The overstory was dominated by oak and hickory species including white oak (*Quercus alba* L.), northern red oak (*Q. rubra* L.), southern red oak (*Q. falcata* Michx.), post oak (*Q. stallata* Wangenh), black oak (*Q. velutina* Lam.), willow oak (*Q. phellos* L.), mockernut hickory (*Carya tomentosa* (Poir.) Nutt.), pignut hickory (*C. glabra* (Mill.) sweet), and red hickory (*C. ovalis* (Wangenh.) Sarg.). A number of other species occupied dominant or co-dominant overstory positions in limited portions of the stand, including yellow poplar (*Liriodendron* tulipifera L.), winged elm (*Ulmus alata* Michx.) red maple (*Acer rubrum* L.), sweetgum (*Liquidambar styraciflua* L.), Virginia pine (*Pinus virginiana* Mill.), loblolly pine (*P. taeda* L.), shortleaf pine and Eastern redcedar (*Juniperous virginiana* L.).

The midstory was dominated by winged elm, hickory, American hornbean (*Carpinus caroliniana* Walter), hop hornbeam (*Ostrya virginiana* (Mill.) K.), American holly (*Ilex opaca* Aiton), blackjack oak (*Q. marilandica* Muenchh.), and Eastern redcedar, and contained a minor component of American beech (*Fagus grandifolia* Ehrh.). Advanced regeneration within the stand was comprised primarily of winged elm, hickory species, Eastern redcedar, American holly and a limited quantity of white and post oaks. Herbaceous groundcover was sparse prior to harvest.

Procedures

Twenty-eight 0.33-acre circular RBA treatment plots were organized into seven replicated blocks and arranged across the site to account for variability in slope position, aspect, and soil type. Each block of four RBA treatment plots contained one randomly assigned replicate of each of four RBA treatments: zero (RBA0), 15 (RBA15), 30 (RBA30) and 45 (RBA45) square feet per acre. Seedlings of three different 1-0 shortleaf pine stock types were underplanted within a 0.10-acre circular seedling measurement plot originating from RBA treatment plot center. The three stock types included bareroot (BR), containerized seedlings with small plugs (SP) and containerized seedlings with large plugs (LP). Bareroot seedlings were grown using a Virginia seed source. The SP and LP seedlings were produced using North Carolina seed sources but we are unable to verify whether they were from the same seed source. The plugs of the SP seedlings measured 1.6 inches in diameter by 3.5 inches in depth. The LP seedlings plugs measured 1.5 inches in diameter by 4.75 inches in depth.

Overstory trees required to obtain the RBA targets within the treatment plots were selected based primarily on species and visual assessment of health. Tree location was also considered to ensure that RBA was evenly distributed across the plots. Healthy dominant and co-dominant oak and hickory species were targeted for retention although other species were retained where necessary to meet RBA targets and ensure appropriate overstory distribution. Treatment plots were operationally harvested to their assigned RBA targets in the summer and early fall of 2012. A broadcast burn was completed in November, 2012 to prepare the site for planting.

Seedlings were underplanted by hand in January and February of 2013. The rocky soils of the study site prevented a uniform planting spacing. Instead, each seedling measurement plot was divided into four equal quadrants. Nine each of the SP and BR were underplanted within each quadrant resulting in 36 each of these two stock types per seedling measurement plot. Limited seedling availability permitted only 20 to 22 of the LP stock to be planted in each plot using the same distribution method. Proper seedling storage, handling, and planting practices were followed during the reforestation process (Mexal 1992).

Measurements

Initial seedling height and GLD were measured and recorded in February, 2013. Seedlings were assigned a unique identification number and were tagged and flagged for future location and measurement. First year and second year seedling survival, GLD, and height were collected in September, 2013 and January and February, 2015, respectively. Initial seedling size measurements were subtracted from second year measurements to calculate seedling growth.

Statistical analysis

The four RBA levels and three stock type categories formed the treatments in this study. The plot mean survival, height, and GLD growth for each of these stock types represented response variables. A blocking factor accounted for differences in aspect, soil, slope and slope position across the site. Initial seedling height and GLD were included in the model as covariates, but removed from the analysis through backwards selection if they lacked significant effects. Mean percent survival, height growth and GLD growth were analyzed for treatment differences using analysis of covariance (ANCOVA) through a General Linear Model. The study therefore utilized a 4 x 3 factorial randomized complete block design that allowed for statistical control of the potential confounding variables associated with this study. Analysis was conducted with a significance level of $\alpha=0.05$. Tukey's Honest Significant Difference was used to compare means when significant differences were detected among treatments.

Site Damage

The study site experienced several incidents of damage between establishment and the second growing season. A straight-line wind toppled overstory trees in several treatment plots in July, 2013. Ice damage in the winter of 2013/14 also eliminated several overstory trees. The RBA treatment plots were inventoried in the winter of 2013/14 and again in 2014/15 to account for the damage. Redheaded pine sawfly (*Neodiprion lecontei*) impacted approximately 29 percent of the underplanted seedlings during the late fall of the first growing season. Deer herbivory damaged approximately 30 percent of the seedlings during the winter following the first growing season. Seedlings were inspected in February 2014 to record whether or not they had been browsed or impacted by sawfly.

The biotic and abiotic damage to both the overstory trees and the seedlings within the study area necessitated substantial data filtering to remove confounded treatment levels and experimental units from the analysis. Treatment plots with RBA measurements more than 7.5 square feet outside of their target have been removed from the analysis. Plot mean height and GLD growth values calculated from fewer than five live and unaffected seedlings have also been excluded from the study. The biotic damaging agents were presumed to have had some effect on survival. Survival analysis was limited to data which was collected after the first growing season before the sawfly damage and deer browse occurred. Analysis on height and GLD growth has been applied to data collected after the second growing season that has been filtered of damaged seedlings. All statistical analyses were performed using SAS Enterprise Guide 7.1 (SAS Inc., Cary, NC).

RESULTS AND DISCUSSION

Results

We found significant differences in mean initial seedling height (fig. 1) and GLD (fig. 2) by stock type. BR seedlings had the tallest mean heights and the largest GLD at time of planting. LP seedlings were smallest in both measures and SP seedlings were intermediate between the two. There were no significant differences in seedling size within stock type by RBA treatments.

RBA and stock type had significant effects on percent seedling survival after one growing season (fig. 3). Survival was poorest for all three stock types in the RBA0 plots which lead to the significance of the RBA effect. There were no significant differences in survival between the RBA15, RBA30, and RBA45 treatment levels. LP seedlings had the highest survival (99 percent) followed by the SP seedlings (91 percent) and the BR seedlings (64 percent), respectively. Differences in survival among all three stock types were significant.

RBA and stock type had significant effects on seedling height (fig. 4) and GLD (fig. 5) growth after two growing seasons. Height and GLD growth were best under the lower RBA treatments of RBA0 and RBA15. There were no significant differences between those two treatments for either measurement. Likewise, there were no significant differences between the pair of higher RBA treatments of RBA30 and RBA45 where seedling height and GLD growth were poorest. The groups of low and high RBA treatments were significantly different from each other for GLD. A similar grouping of significant differences between high and low RBA treatments existed for height but the two intermediate mean height values by treatment, RBA0 and RBA30, were not significantly different from each other.

The LP seedlings had significantly greater mean height growth (1.7 feet) after two growing seasons than the SP (1.1 feet) or BR (0.9 feet) seedlings. The SP seedlings had marginally better mean height growth than the BR seedlings but the differences were not significant. The LP seedlings also had significantly better GLD growth (0.4 inches) than the SP (0.3 inches) and BR (0.2 inches) seedlings. The SP seedlings had significantly better GLD growth than the BR seedlings.

Discussion

Residual overstory basal area—The significant effect of RBA on survival was due primarily to the differences in survival between the RBA0 and RBA15 plots for both the SP and BR stock types. Retaining as little as 15 square feet of residual overstory basal area significantly improved survival, although the improvements were most operationally meaningful for the BR stock where mean survival increased by over 25 percent. Survival was not significantly improved by increasing overstory

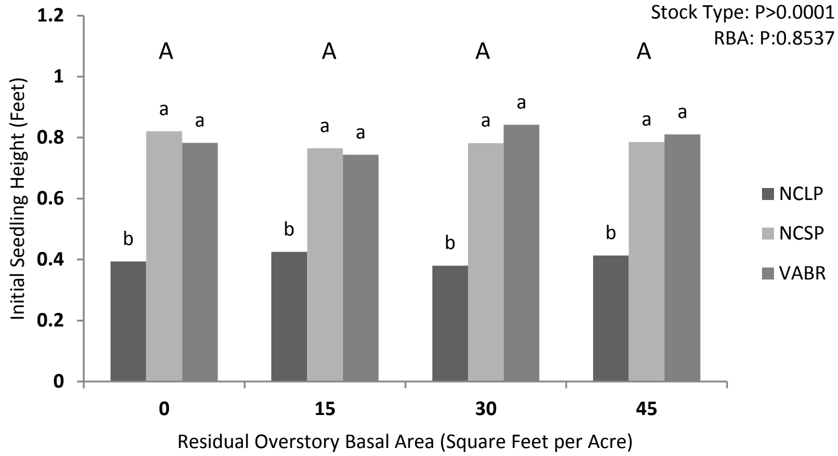

Figure 1—Initial seedling height by stock type and RBA. Same or shared letters indicate no significant differences at α=0.05.Different capital letters indicate significant differences among RBA treatments. Different lower case letters indicate significant differences between stock types within each RBA treatment.

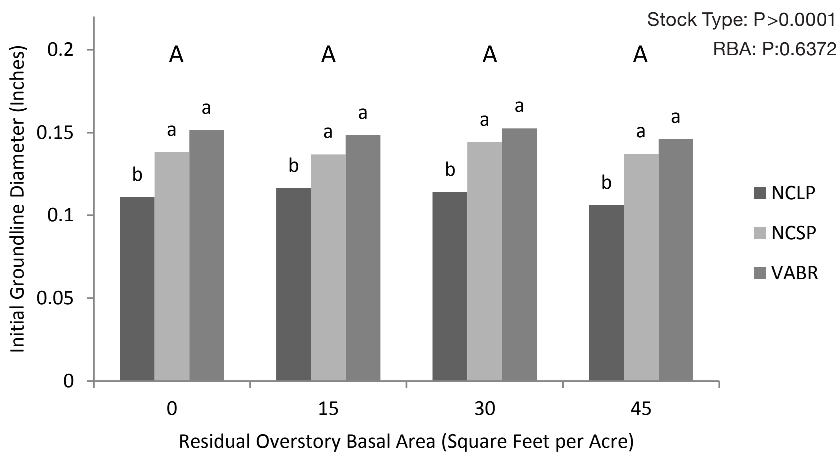

Figure 2—Initial seedling groundline diameter by stock type and RBA. Same or shared letters indicate no significant differences at α=0.05.Different capital letters indicate significant differences among RBA treatments. Different lower case letters indicate significant differences between stock types within each RBA treatment.

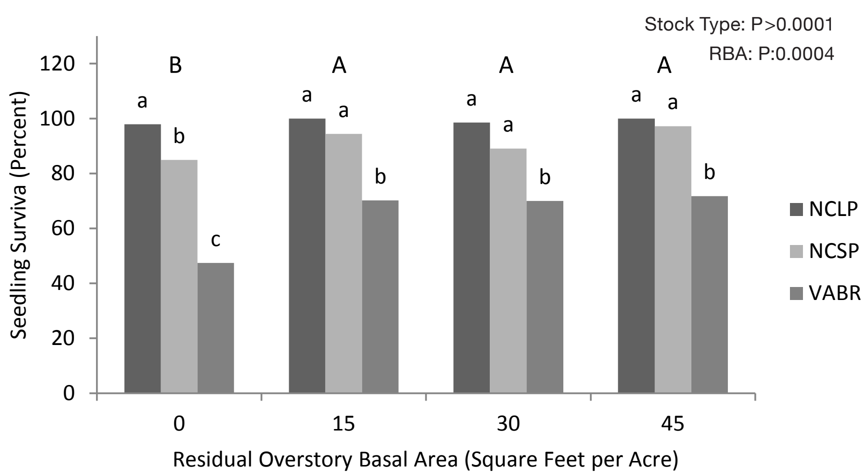

Figure 3—Percent seedling survival by stock type and RBA. Same or shared letters indicate no significant differences at α=0.05.Different capital letters indicate significant differences among RBA treatments. Different lower case letters indicate significant differences between stock types within each RBA treatment.

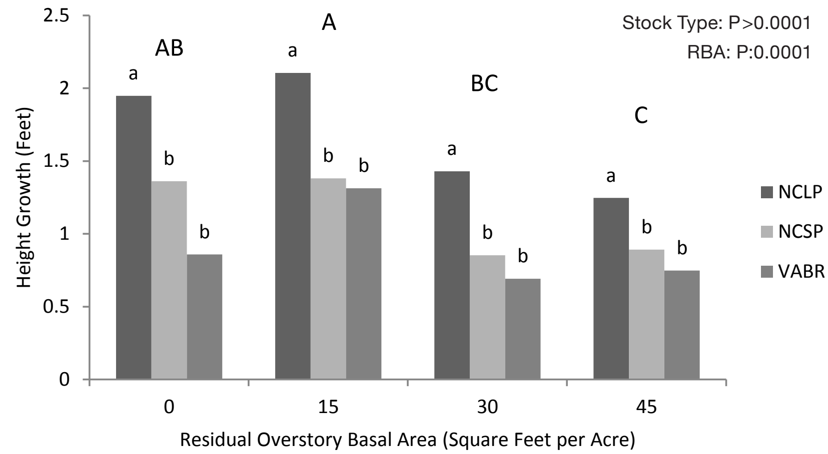

Figure 4—Seedling height growth after two growing seasons by stock type and RBA. Same or shared letters indicate no significant differences at α=0.05.Different capital letters indicate significant differences among RBA treatments. Different lower case letters indicate significant differences between stock types within each RBA treatment.

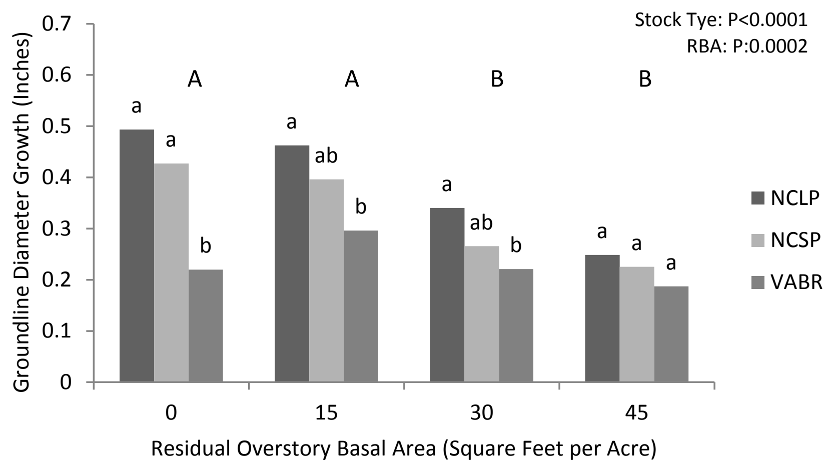

Figure 5—Seedling groundline diameter growth after two growing seasons by stock type and RBA. Same or shared letters indicate no significant differences at α=0.05.Different capital letters indicate significant differences among RBA treatments. Different lower case letters indicate significant differences between stock types within each RBA treatment.

stocking beyond 15 square feet of basal area for any of the three stock types. The positive yet mostly insignificant effect of overstory stocking on seedling survival is in line with the findings of Kabrick and others (2011). Unfortunately, Kabrick and others (2011) is the only past shortleaf pine underplanting study where seedlings were established after the stand had been thinned to different stocking levels and is therefore the only study to which we can make a comparison.

Our analysis of growth by RBA revealed a similar relationship of increasing residual overstory to decreasing seedling growth as has been found by others (Guldin and Heath 2001, Jensen and others 2007, Jensen and Gwaze 2007, Kabrick and others 2011). The lack of significant differences in height growth between the RBA0 and RBA30 treatment levels is likely do the very poor height growth of the BR stock in the RBA0 plots.

We speculated that the relationships we found between RBA and seedling survival and growth were functions of both overstory and understory competition as well as the gradient of site harshness present across the different RBA levels. Increasing levels of overstory shade resulted in decreasing levels of seedling growth. We attributed the inverse relationship between RBA and seedling growth in plots with at least 15 square feet of overstory basal area to the overstory shade. Site visits also revealed that overstory shade appeared to suppress competing vegetation. We observed high levels of competing vegetation in the RBA0 plots that decreased dramatically as RBA increased. Fully exposed clearcut sites like the RBA0 plots can also have very harsh microclimatic conditions including higher soil and air temperatures near the ground level compared to sites with some overstory cover (Guldin and Barnett 2004). We surmised that the harsh microclimatic conditions and the high amount of competing vegetation in the RBA0 plots increased seedling mortality and retarded height growth when compared to the more moderate microclimates and reduced herbaceous competition in plots with at least 15 square feet of RBA.

Stock Type—The two containerized stock types achieved better survival than bareroot stock. Containerized stock exceeded 84 percent mean survival under all of the RBA treatment levels. On the other hand, survival for the BR seedlings ranged from approximately 47 percent to 72 percent. Our results on seedling survival differ from those of Barnett and Brissette (1989) and Gwaze and others (2006) who did not find significant differences in survival between 1-0 containerized and bareroot stock. However, Gwaze and others (2006) did find a stock type x seed family interaction in survival and growth indicating that certain families of shortleaf pine perform better as containerized stock while others perform better as bareroot and also indicated that a small sample size may have influenced their results.

Containerized stock also exhibited better height and GLD growth than bareroot stock after two growing seasons. The differences between containerized and bareroot stock were most pronounced in GLD growth with both containerized stock types significantly exceeding the bareroot stock in the lower RBA treatments. The LP seedlings exceeded the height growth of the BR seedlings across all treatments, but the SP seedlings actually grew similarly to the BR in plots with at least 15 square feet of RBA. Our finding that at least one containerized stock exhibited better growth than bareroot stock is in line with those of Brissette and Barnett (1989) and Barnett and Brissette (2004). They are in contrast those of Gwaze and others (2006) who did not find significant differences in growth between 1-0 bareroot and containerized stock in Missouri.

We attributed the significantly greater survival and growth of the containerized stock to the more intact root systems and higher root mass that containerized seedlings often have compared to bareroot seedlings (Barnett 1992). We speculated that LP seedlings would have had slightly higher root mass at the time of planting than the SP seedlings given their larger container size, potentially leading to better survival and improved growth. However, the extensive range of shortleaf has resulted in a strong relationship between climate at seed source and growth at the outplanted site (Schmidtling 2001). Without knowing the specific origin of the SP stock and already knowing that the BR and LP stock are from different orchard mixes, we cannot rule out that the differences in survival and growth by stock type might be a function of seed source.

Management Implications

Future research will be necessary to determine how long the benefits provided by limited levels of residual overstory basal area persist. The residual overstory trees will presumably continue to grow and eventually reach stocking levels under which this study shows that seedling growth will decline. Future research on this site will focus on how underplanted seedling survival and growth are affected by the continually changing and likely increasing levels of residual overstory basal area and understory competition.

CONCLUSIONS

The results of this study indicated that underplanting may be a suitable method for establishing shortleaf pine on marginal sites in the Central Appalachian Piedmont. They also showed that containerized shortleaf pine performed very well on such sites compared to bareroot stock. The first year survival and second year growth analysis indicated that retaining low levels of residual overstory basal area can improve early seedling survival and growth compared to clearcut plots where competing vegetation has not been controlled.

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