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One-Year Health, Mortality, and Growth in Southeast Virginia of Shortleaf Pine From Three Sources

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Abstract

Restoration of shortleaf pine (*Pinus echinata* Mill.) in Virginia has become a priority of various state and federal agencies. For shortleaf pine restoration to be successful in Virginia, private lands must be considered because 89 percent of forestland in Virginia is privately owned, and most private landowners are likely to use commercially available seedling sources.

Shortleaf seedlings from commercially available sources in Virginia, Arkansas, and Missouri were planted in two sites in Southeast Virginia to test growth and yield. After one year, height and ground-line diameter were measured and observations were made on health and mortality of the plants. The Virginia seed source was significantly taller than the Arkansas source. At the first site, mortality and disease were low, but at the second site, mortality and poor health were very high, possibly due to soils combined with weather conditions. No significant seed source effects on disease and mortality were found at either site.

Introduction

Southern yellow pines are a significant timber resource throughout the Southeastern U.S. Loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* Mill.) are the most commercially important and widespread of the Southern pines (Cain and Shelton 2001) and are commonly found together within their native ranges. Shortleaf pine is second to loblolly pine in standing timber volume. The wide distribution of both species suggests a large amount of genetic variation due to adaptation to a variety of environments (Xu, Turner, and Nelson 2008; Raja et al. 1997; Gwaze et al. 2005).

Despite the wide distribution and desirability of shortleaf pine, it has become less prevalent in Virginia due to extensive harvesting, conversion of stands to loblolly pine, conversion of forestland to other uses, and succession due to fire suppression. The extent of shortleaf pine in Virginia in 2006 was estimated at just 74,000 acres, down from 1.4 million acres in 1940 (VDF 2006).

Shortleaf pine can be an alternative to loblolly pine in managed stands. Growth in the first years is slower than loblolly because shortleaf pine develops a strong root system (Lawson and Kitchens 1983; Burner 2003), but shortleaf tends to be longer-lived than loblolly and maintains good growth rates for more than 60 years (Pelkki 1997; Murphy, Lawson, and Lynch 1992). Shortleaf responds well to silvicultural treatments such as chemical or mechanical competition control (Amishev and Fox 2006; Gwaze, Johanson, and Hauser 2007), and thinning (Pelkki 1997). Because of its longer lifespan, less-dense foliage, and good wood properties, shortleaf is considered to have potential benefit for private Virginia landowners with objectives such as production of nontimber forest products and management of quality wildlife habitat (Gagnon and Johnson 2009).

Superior quality trees, with regard to growth rate and other desirable qualities (Dorman 1976), can be grafted into seed orchards to produce seeds for planting programs. During the 1960s, the Virginia Department of Forestry and its cooperators located high-quality shortleaf pine trees in native forest stands in Virginia and grafted stem cuttings onto rootstock to establish seed orchards. These orchards were managed and cones harvested to produce seedlings for a number of years. Orchard maintenance was stopped as priorities shifted

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and the demand for shortleaf pine declined. As the Virginia seed orchard fell out of production, most shortleaf seed for production of seedlings in Virginia was obtained from out-of-state sources, such as Arkansas and Missouri.

The Virginia Department of Forestry's 2007 Strategic Plan identified restoration of diminished species, including shortleaf pine, as a goal. This plan included re-establishing a supply of seed from native Virginia populations of shortleaf. A new seed orchard has been established at VDF's New Kent Forestry Center in Providence Forge, Va., but it will be approximately 10 years before the trees produce significant quantities of seed. In the interim, the existing seed orchards at NKFC have been refurbished to generate a supply of native seedlings.

For shortleaf pine restoration to be successful in Virginia, private lands must be considered because 89 percent of forestland in Virginia is privately owned (Rose 2009). Most private landowners are likely to use commercially available sources such as those produced at the VDF nurseries, which include seedlings from seed orchards in Virginia, Arkansas, and Missouri. In 2011, Virginia State University and VDF established a research trial in Southeast Virginia to compare the growth and yield of shortleaf seedlings from the Virginia-originated genetic material to the more commercially established sources from Arkansas and Missouri.

Background

Many foresters and others from related professions have long believed that seeds from local plant populations are likely to be better adapted to local conditions, and thus should outperform provenances from farther away. However, various studies have shown that while local populations may be better adapted to withstand possible climatic extremes in the area, other populations may be more productive (in terms of growth and yield) if risks from those extremes can be mitigated (Schmidtling 1994; Namkoong 1969; Lambeth et al. 2005). For example, trials of loblolly pine provenances in states in the western part of its range, such as Oklahoma and Arkansas, commonly show that seedlings from Eastern seed sources such as North Carolina outperform the local provenances in terms of growth and yield but with some additional risks in terms of susceptibility to infrequent weather events (Wells and Lambeth 1983; Lambeth et al. 1984; Will et al. 2010).

Provenance testing with shortleaf pine is less common. The only rangewide testing of numerous provenances of shortleaf pine on sites throughout the U.S. South was carried out in the Southwide Southern Pine Seed Source Study[1], a cooperative effort initiated in 1951 by the Southern Forest Tree Improvement Committee (Schmidtling 2001; Wells 1979). The results of that study suggest it is common for some nonlocal seed sources to outperform local sources, with the general trend that shortleaf pine seedlings from provenances that have slightly warmer minimum winter temperatures (within 5 F) outperform local sources (Schmidtling 2001; Schmidtling 1994). There also is some evidence that shortleaf pine populations west of the Mississippi River may have faster growth rates than the Eastern populations (Wells 1979; Schmidtling 1994), although in at least one instance the opposite was true (more northerly and easterly sources outperformed the local and other nonlocal sources) (Gwaze, Myszewski, and Kabrick 2007). The overall trend that shortleaf provenances from warmer areas are more productive than local sources is consistent with evidence from other Southern pines (Schmidtling 2001; Lambeth et al. 2005).

Materials and Methods

Bare-root shortleaf pine seedlings from Virginia, Missouri, and Arkansas provenances[2] were obtained from the NKFC and planted at a site in Greensville County, Va., near the locality of Skippers, Va., and the North Carolina border. The soils at the site are a combination of Peawick clay loam, Roanoke loam, and state loamy sand. Rainfall averages approximately 44.8 inches per year, with a mean January temperature of 39 F and July temperature of 79 F.

Orchard-mix seeds for the Virginia provenance were collected during 2009-2010 from the 1960s-era orchard at NKFC. The trees in that orchard include selections from around the state of Virginia. The Arkansas and Missouri provenance seeds were similarly produced by seed orchards in those states, developed from genetic material from selected trees around each state.

[1] The Southern Forest Tree Improvement Committee includes representation from the U.S. Department of Agriculture Forest Service, state forestry agencies, universities, the forest industry, tree improvement cooperatives, and others.

[2] While genetic material from trees that originated from an area as large as a state might not be considered a "provenance" in a strict sense, it does represent the genetically closest seed populations that would be commercially available to most landowners; therefore, we use provenance here in a broad sense.

As previously discussed, relative minimum winter temperatures at the source of the genetic material are important in recommendations for seed transfer (Schmidtling 2001). Because the genetic sources are from entire states rather than a precise location, it is impossible to state with precision exactly how different the winter temperatures for each "provenance" are. In general, Arkansas and Missouri both have similar winter temperatures to Virginia, with Arkansas on the whole being slightly warmer than Virginia, and Missouri slightly colder (NADF 2006; Schmidtling 2001).

In February 2011, after one year of growth in the VDF nursery under the same conditions, seedlings of all three seed sources were removed from the nursery, transported to Greensville County, and planted on a scalped field using standard dibble bars with no fertilization, irrigation, or further competition control. On this site, scalping proved to be an effective method for controlling weeds; despite the lack of chemical or mechanical competition control after planting, weeds did not seem to pose a problem for the pine growth.

The experiment was replicated at a second site in Chesterfield County, Va., near the Appomattox River between the villages of Ettrick and Matoaca. The only difference in the treatment between the Chesterfield and Greensville County site was that the Chesterfield site was treated with Imazapyr (Polaris AC) herbicide during the summer of 2011 to control for weeds. The soils at that site consist of Aquults, which are poorly drained and frequently flooded soils. Rainfall averages approximately 46.4 inches per year, with a mean January temperature of 41 F and July temperature of 81 F. Plants at this site suffered very high levels of mortality, and those that did survive were very obviously in only fair or poor health, based on needle coloration and quantity, in addition to the poor height and diameter growth. We report here mortality and health from that site, as well as speculation about the cause of mortality.

Trial plots at each site were arranged in a randomized complete block design (Hoshmand 2006), with three replicates. Each replicate contained a plot of shortleaf pines from each of the three provenances. Each plot contained 25 individual trees for measurement, and a buffer of one row (24 total trees) around the plot. An additional buffer of one row was planted around the entire trial at each site to reduce edge effects.

In February 2012 (one year after transplanting), trees were measured for height to the nearest half inch and diameter at the ground line to the nearest hundredth of an inch (figure 1). Mortality was noted, as well as evidence of pests or disease. During data collection, it was discovered that in the third replicate, five of the Virginia and two of the Arkansas trees at the Greensville site had been browsed by an herbivore, reducing their height. The height that these trees would have reached was estimated with an ordinary least squares regression

Figure 1. One year of growth of shortleaf pines at Greensville County, Va. site.
Photo credit: Jerre Creighton

with diameter as the independent variable (for Virginia, $R^2 = 0.42$, slope coefficient p-value <0.001; for Arkansas, $R^2 = 0.54$, slope coefficient p-value <0.001).

Two mixed linear models (SAS procedure mixed) were used to test for differences in mean diameters and heights (the dependent variables) of the three seed sources. Individual tree data was used with the fixed-effect independent variable of seed source and random-effect independent variables of block, site, and the interactions between block and site; block and seed source; and site and seed source. An F-statistic was calculated to test the null hypothesis that all three seed sources had the same mean diameters and heights, and, if significant, t-tests were used to test for differences between individual sources.

Results and Discussion

Results for the mean diameter and height are shown in figures 2 and 3, including the estimated height of the seven browsed trees. The mean diameters and heights were greatest for the Virginia seedlings, intermediate for Missouri, and lowest for Arkansas. An F-statistic was calculated to test the null hypothesis that there was no significant difference between the mean diameters and heights of all three provenances. At a 0.05 alpha level, there was no statistical significance among the three groups for diameter (F-statistic p-value 0.13), but differences in height were significant (F-statistic p-value 0.04). When comparing the heights of the three provenances pairwise with a t-test at a 0.05 alpha level, the Virginia provenance was statistically taller than Arkansas (p-value 0.02), and insignificantly taller than Missouri (p-value 0.053). Heights of trees from the Arkansas and Missouri provenances were not significantly different from each other (p-value 0.14).

Mortality and disease were not major problems for the trees at the Greensville County site. We did not find any significant difference in mortality, pests, or disease between the three seed sources. As previously mentioned, two (2.7 percent) of the Arkansas trees and five (6.7 percent) of the Virginia trees were browsed. One (1.3 percent) of the Arkansas trees, two (2.7 percent) of the Missouri trees, and two (2.7 percent) of the Virginia trees died. Two (2.7 percent) of the Arkansas trees, two (2.7 percent) of the Missouri trees, and one (1.3 percent) of the Virginia trees suffered from defoliation likely caused by pine sawfly (*Neodiprion* spp.).

The pest/disease with the greatest prevalence at the Greensville County site was the pine tip moth (*Rhyacionia* spp.), whose larvae feed on the young shoots and conelets of various pine species (Yates, Overgaard, and Koerber 1981). This is a common pest in shortleaf pine seedlings, especially in open areas such as plantations (Lawson and Kitchens 1983; Yates, Overgaard, and Koerber 1981). These insects generally do not kill the seedling but can negatively impact its growth and yield (Yates, Overgaard, and Koerber 1981). Sixteen (21.3 percent) of the Arkansas trees, 26 (34.7 percent) of the Missouri trees, and 15 (20 percent) of the Virginia trees showed tip moth damage.

Precipitation in Chesterfield County averages approximately 8.7 inches for the months of August and September. The actual total in 2011 exceeded 16 inches, most of which came in a 10-day period from late August through early September due to Hurricane Irene, which set single-day precipitation records in the area, and Tropical Storm Lee. This high precipitation combined with the poorly drained soils was the most likely cause of the high mortality. Aside from the soils, the only difference in treatment between the sites was the application of herbicide to the Chesterfield County site, but this was not the likely cause of mortality and poor health because it is a common practice for site preparation and competition control for Southern pines.

There was no significant difference in mortality between the three provenances at the Chesterfield site, with 26 (34.7 percent) of the Arkansas trees, 23 (30.7 percent) of the Missouri trees, and 12 (16 percent) of the Virginia trees dying in the first year. At the time of measurement, a subjective assessment of health based on live needle quantity and coloration suggested that 66.7 percent of Arkansas trees, 56 percent of Missouri trees, and 56 percent of Virginia trees were either dead or in extremely poor health, such that they would be nonresilient to any other type of stress (e.g., drought or flooding, pests, or disease).

Furthermore, height and diameter growth of the surviving trees at the Chesterfield site was significantly lower than the Greensville site for all provenances, even though seedlings from both counties were from the same batch from the nursery, with Arkansas trees averaging 0.66 foot in height and 0.25 inch in diameter (33 percent and 13 percent decreases relative to Greensville County site, respectively), Missouri trees averaging 0.74 foot and 0.31 inch (31 percent and 10 percent decreases), and Virginia trees averaging 0.93 foot and 0.29 inch (22 percent and 21 percent decreases).

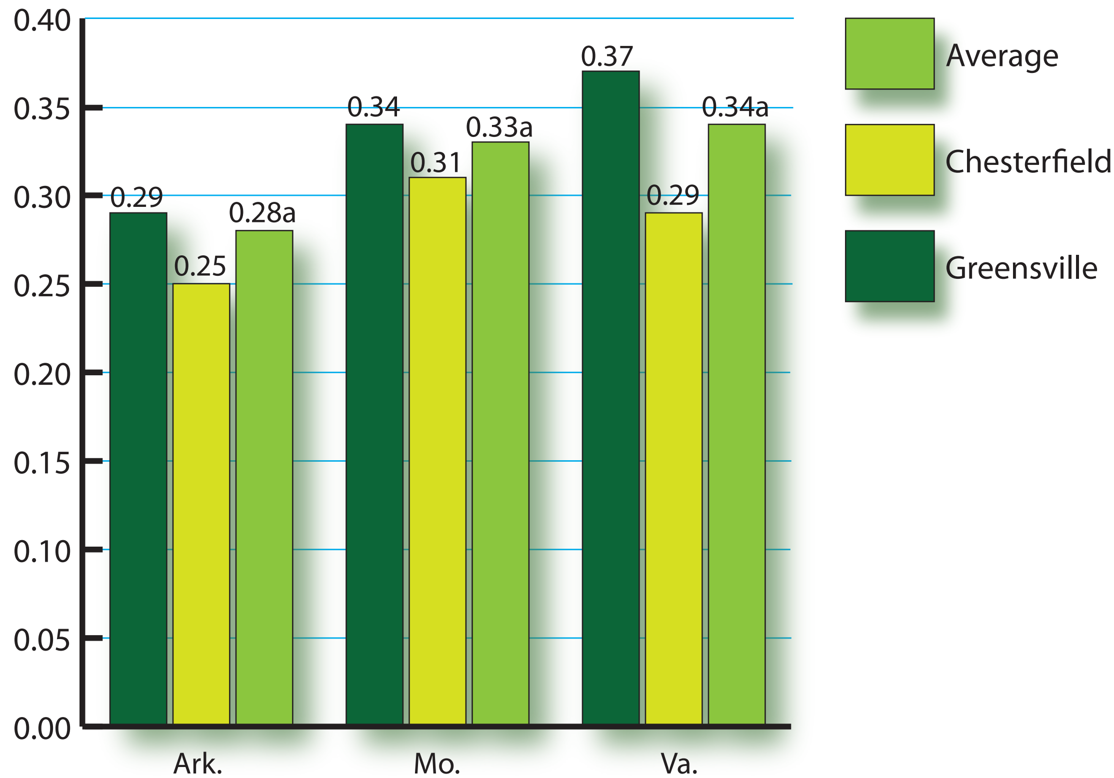

Figure 2. Ground-line diameter (inches) of shortleaf pine from Arkansas (Ark.), Missouri (Mo.), and Virginia (Va.) sources of shortleaf pine seedlings at both sites, one year after transplanting. There was no significant difference in the diameters of the trees.

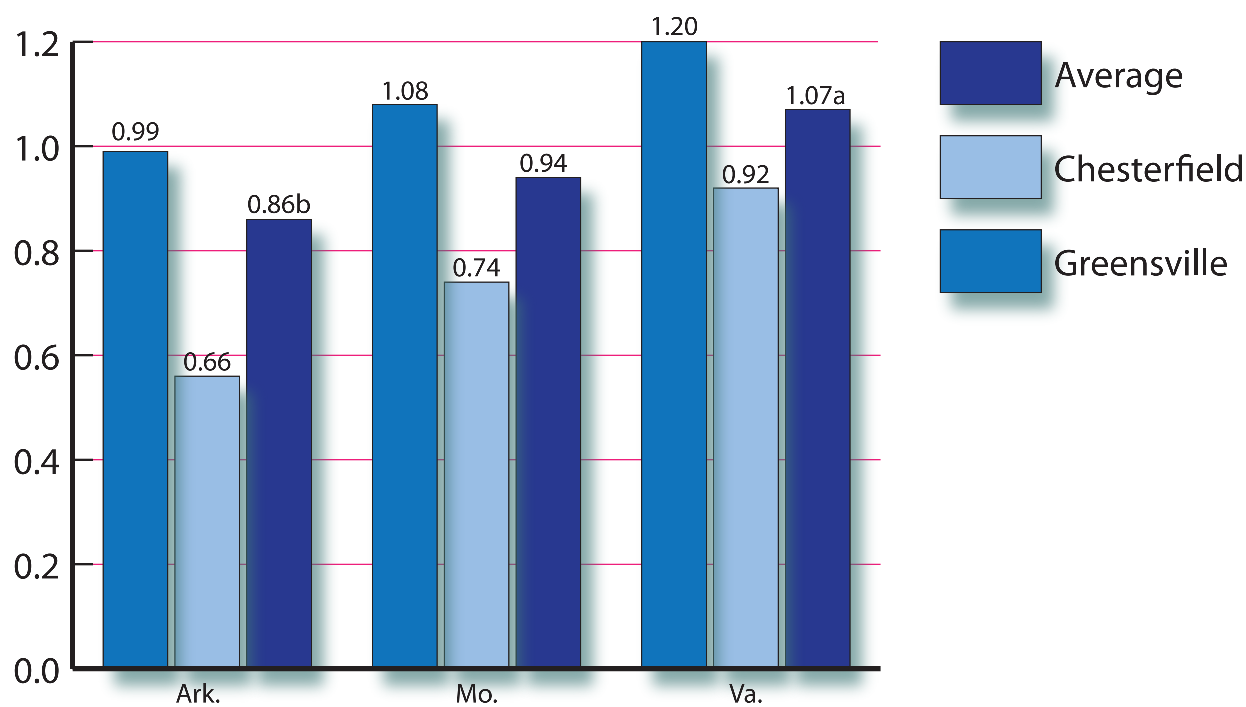

Figure 3. Height (feet) of shortleaf pine from Arkansas (Ark.), Missouri (Mo.), and Virginia (Va) sources of shortleaf pine seedlings at both sites, one year after transplanting. The Virginia provenance was significantly taller than the Arkansas source.

Conclusions

One-year height growth for shortleaf pine at the two sites was shown to be greater for pines from the Virginia seed source than for those from the Arkansas source. Height growth between Virginia and Missouri and diameter growth between all three sources were not statistically different but tended toward the same result. This tendency is somewhat contrary to the general trend among past shortleaf pine provenance studies, which indicated that trees from slightly warmer areas tend to outperform local seeds and those from cooler areas. That trend would have suggested that Arkansas might outperform Virginia and Missouri. However, since each seed "source" represents a mixture of genetic material from around each respective state, it is impossible to say with confidence that our results contradict this trend.

No major difference between pest or disease problems was noted, but, with the exception of animal browsing, the small differences in prevalence tended to favor the Virginia trees. While these combined results suggest that the Virginia provenance trees may be better adapted for the conditions in Virginia, these results are very early and limited in scope. Further, the magnitude of the response is relatively small at this point. It is possible that Missouri and/or Arkansas could overtake Virginia in subsequent years or that they might perform better on different sites within Virginia.

Finally, site conditions seem important in terms of the health and mortality of shortleaf pine. Although shortleaf pine can grow well on a wide variety of sites (Lawson and Kitchens 1983), given weather conditions in any particular year, there can be a risk of high mortality, poor growth, or both. In particular, poorly drained sites may cause problems for shortleaf pine growth.

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