MANAGEMENT INTENSITY AND GENETICS AFFECT LOBLOLLY PINE SEEDLING PERFORMANCE

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ABSTRACT

Capturing potential genetic gains from tree improvement programs requires selection of the appropriate genetic stock and application of appropriate silvicultural management techniques. Limited information is available on how specific loblolly pine varietal genotypes perform under differing growing environments and management approaches. This study was established in 2008 to examine the performance of two selected loblolly pine varieties (crop vs. competitor) at different initial planting spacings and management intensities. The two genotypes were selected based on their putative divergent crown architectures. After three growing seasons, neither initial spacing nor management intensity had any effect on tree survival. Survival of the crop tree genotype (98.0 percent) was significantly greater than that of competitor genotype (86.3 percent). Growth of surviving seedlings was affected by both genetics and management intensity. Mean year-three height of the crop genotype (8.4 feet) was significantly greater than that of the competitor genotype (7.3 feet). Mean year-three height in the high intensity management plots (9.3 feet) exceeded that on the low intensity management plots (6.5 feet). Differences in levels of competition between high and low intensity plots, while not affecting survival, appear to have had the greatest impact on seedling height growth. Somewhat surprisingly, the crop tree genotype outperformed the competitor genotype in both survival and height growth.

INTRODUCTION

Dramatic gains in the productivity of southern pine plantations have been realized over the past 30-40 years, with per acre annual increments more than doubling over the past three decades due to increased management intensity. Productivity of loblolly pine (*Pinus taeda* L.) plantations now frequently exceeds 300 ft^3/ac/yr, and in some cases 400 ft^3/ac/yr (Fox and others 2007). A major reason for the increases in productivity has been the genetic improvements that have been made in loblolly pine through the tree improvement cooperatives. However, achieving these increased yields has also required increased intensity of plantation management including improved site preparation techniques, more effective competition control, better understanding of forest nutritional requirements, and greater attention to density management.

Regional tree improvement cooperatives established in the early 1950s began the process of producing genetically improved loblolly pine seedlings, and by the mid-1980s virtually all southern pine plantations were established with seedlings produced from genetically improved seed. Gains in volume from first-generation plantations in the 1980s were generally in the range of 7-12 percent (Li and others 2000), with estimated gains in harvest value exceeding 20 percent (Fox and others 2007). By the early 2000s, over half of all southern pine planting stock was coming from second-generation seed orchards, with average volume gains from second-generation plantations estimated to range from 7-23 percent over first-generation stock (Fox and others 2007, Li and others 1997, 1999, 2000, McKeand and others 2003, 2006a). Improvements in disease resistance, stem form, and wood quality have also resulted in increased harvest levels and value.

Open-pollinated planting stock gains were further enhanced by deployment of the single half-sib family blocks, utilizing offspring of superior female parent trees of high breeding value (Duzan and Williams 1988, McKeand and others 2006b). By the early 2000s, nearly 60 percent of all southern pine plantations, and 80 percent of industrial plantations, were deploying single half-sib family blocks (McKeand and others 2006a). Even further genetic gains have been realized by planting full-sib families produced using mass-controlled pollination (MCP) techniques (Bramlett 2007). Jansson and Li (2004) show potential volume gains from full-sib families of up to 60 percent over unimproved stock.

Over the past decade, the development and refinement of techniques for mass production of clonal loblolly pine planting stock has opened the door to even further gains in plantation forestry. The operational production of elite genotypes, known as varietal planting stock, currently accounts for only a minor proportion of loblolly seedlings planted in Southeast, although this is growing annually. There remain issues, however, that need further investigation. Varietal planting stock is currently much more expensive than other planting stock options, and studies are needed on the economic efficacy of the stock. Field testing across a greater array of sites is also needed to determine appropriate varieties for specific areas, as well as comparisons between the performance of varietal stock to that of other planting stock options. Research is also needed to determine any genetics by environment interactions that

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might exist within loblolly pine varietals. Finally, studies are needed to identify the appropriate silvicultural regimes for maximizing gains when using varietal planting stock.

This paper reports on third-year results from a trial employing two distinct loblolly pine varieties that were selected based on their putative divergent crown architectures. Trees were planted at three spacings providing densities of 519, 346 and 194 trees per acre. Two silvicultural intensity treatments included intensive and sustained control of competition and insects, and standard cultural treatments through the first growing season. The long-term objective of the study is to examine if the selected loblolly pine varietal stock will exhibit their sawtimber quality traits of stem form and crown characteristics when grown at various densities. In the present analysis, age-three survival and height are reported.

MATERIALS AND METHODS

This study was established in 2008 at Mississippi State University's Coastal Plain Branch Experiment Station Experiment Station near Newton, MS (32°20'19"N 89°05 51"W). Soils on the site are a Prentiss very fine sandy loam. The site had previously been in agricultural production resulting in the soils being somewhat compacted. The site received a broadcast application of Glyphosate (64 ounces/ac) in September 2007, and was subsoiled to a depth of approximately 14 inches in October of 2007. The site received a second broadcast application of Glyphosate (32 ounces/ac) in March of 2008 prior to being hand planted with containerized seedlings in late April/early May of 2008.

The study was set up as a 2x2x3 factorial split plot design. Main effects treatments included two genetic varieties of loblolly pine and two levels of management intensity, with main effects treatment plots split by three initial planting spacings. Trees within the spacing subplots were planted in 64 tree blocks (8 x 8 trees) with the inner 36 trees constituting the measurement plots. Each treatment combination was replicated four times.

The two varietal genotypes of loblolly pine included in the study were based on their putative divergent crown architectures. The varieties, produced by ArborGen, LLC, included one considered to be a competitor ideotype (comp) characterized by a wider crown form, and another considered to be a crop tree ideotype (crop) with a more narrow, compact crown form. The two levels of management intensity included a standard intensity (low) and a high intensity (high). In addition to the chemical site preparation and subsoiling described above, both the high and low intensity plots received herbaceous competition control in year 1 through a broadcast application of Oustar® (10 ounces/ac). Additional management inputs applied to the high intensity plots included tipmoth control in the form of a single SilvaShield™ tablet (Bayer Environmental Science) in the planting hole at time of planting, PTM™ insecticide (BASF Corp.) injected 3-6 inches deep in the soil adjacent to each tree (0.05 ounces ai per tree) in years 2 and 3 for additional tipmoth control, herbaceous competition control in year 2 (1 ounces/ac of Escort®, 16 ounces/ac Arrow®, 32 ounces/ac Goal®), and mowing of competing vegetation in year 3. The three initial tree spacings were 6 x 14 feet (519 tpa), 9 x 14 feet (346 tpa), and 16 x 14 feet (194 tpa).

Initial height was measured on each seedling immediately following planting. Survival was assessed and heights measured annually following each of the first three growing seasons (2008-2010). For the analysis presented here, we tested for treatment differences in survival and mean height following the first and third growing seasons. All reported treatment differences are based on a critical value of alpha=0.05.

RESULTS AND DISCUSSION

At the end of the first growing season, overall survival was 94.1 percent (Table 1). There were no significant differences in survival between initial spacings. Surprisingly, plots receiving the lower intensity of management had slightly greater survival than the plots receiving the high intensity treatments. Since the only difference in the management intensity treatments at year 1 was the addition of the SilvaShield™ tablet in the planting hole of each tree on the high intensity plots, we attributed the difference in year-1survival between the high and low intensity treatments to random chance. Trees of the crop tree genotype had better year-1 survival (98.5 percent) than trees of the competitor genotype (89.7 percent). After one growing season, the average height of all surviving seedlings was approximately 1.7 feet, and there were no significant differences in mean height associated with genotype, management intensity, or initial seedling spacing (Table 1).

There was little additional mortality between years 1 and 3. Overall seedling survival at the end of the third growing season was high at over 92 percent (Table 1). By the third year, the initial differences in survival between the two management intensity treatments had disappeared. However, differences in survival between the two genotypes had increased to nearly 12 percent (Figure 1). As expected, initial tree spacing had no effect over the first three years on survival. The 16-feet within row tree spacing did have a slightly lower survival, but this was due primarily to high mortality on a single plot that was attributed mostly to sawfly damage. At this young age, there is no inherent reason to suspect differences in intraspecific competition related to tree spacing that would affect seedling performance.

Average height of all surviving trees after three growing season was nearly 7.9 feet (Table 1). Again, initial seedling spacing had no effect on mean tree height; but the two other treatments did. There were noticeable differences between the high and low management intensity treatments that, while not having much effect on survival, did significantly affect height growth. Mean height at age 3 on plots receiving the high intensity treatment was nearly three feet greater than on plots receiving the low intensity treatment (Figure 2).

As expected, pine tipmoth damage was lower on the high intensity plots, which had received tipmoth control at time of planting and again at the beginning of the second growing season. Observed tipmoth damage generally ranged from about 15 to 18 percent on the low intensity plots but was less than one percent on the high intensity plots. The tipmoth damage did not, however, appear to effect third year survival or heights relative to uninfested trees.

Sawfly damage was also considerably lower on the high intensity plots. As with tipmoth, sawfly damage ranged between about 15 and 18 percent on the low intensity plots and less than one percent on the high intensity plots. The fact a treatment effect on sawfly damage was observed was somewhat surprising, since neither of the chemicals used for tipmoth control have any known effects on sawfly. We were not able to show statistically that sawfly damage affected year-3 survival, largely because cause of mortality was not recorded. If a tree became infested and died in the same season, we would not have a record of the infestation. Observationally, however, we did notice considerable sawfly mortality. For surviving trees, the sawfly damage did result in about a 0.4-0.8 foot decrease in height.

By year 3, the most noticeable difference between the high and low intensity treatments was in the levels of competing vegetation present. This was expected given the extra year of herbaceous competition control in year 2 and the mowing that took place in year 3 on the high intensity plots. The differing levels of competing vegetation did not have a significant effect on survival, since most of the seedling mortality was observed in year 1 when both the high and low intensity treatments had received essentially the same inputs. The differences in competing vegetation did have a large effect on year-3 heights, with the high intensity treatment plots averaging nearly three feet taller than the low intensity plots.

Somewhat surprisingly, the crop tree genotype outperformed the competitor genotype in both survival and height growth over the first three growing seasons. Third-year survival of the crop genotype was nearly 12 percent higher than that of the competitor genotype. Trees of the crop tree genotype average about one foot taller than trees of the competitor genotype (Figure 3). Within each of the genotypes, there were no differences in survival between the high and low intensity treatments; however, genotype differences in year-3 mean heights were four times greater on the high intensity plots (1.6 feet) than on the low intensity plots (0.4 feet).

The results of this analysis support what is generally common knowledge in forestry – to achieve the best performance from a plantation it is important to select the proper genetic planting stock for a given site and set of objectives. To achieve the full potential of the planting stock requires appropriate silvicultural management. In most cases, and especially on old field sites, effective early competition control will be one of the most important, if not the most important factor affecting early seedling performance.

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LITERATURE CITED

Bramlett, D.L. 2007. Genetic gain from mass controlled pollination and topworking. J. For. 105:15-19.

Duzan, H.W., Jr. and C.G. Williams. 1988. Matching loblolly pine families to regeneration sites. South. J. Appl. For. 12:166-169.

Fox, T.R., E.J. Jokela, and H.L. Allen. 2007. The development of pine plantation silviculture in the southern United States. J. For. 105:337-347.

Jansson, G. and B. Li. 2004. Genetic gains of full-sib families from disconnected diallels in loblolly pine. Sylva Genetica 53:60-64.

Li, B., S.E. McKeand, A.V. Hatcher, and R.J. Weir. 1997. Genetic gains of second generation selections from the North Carolina State University-Industry Cooperative Tree Improvement Program. pp. 234–238 in Proceedings of the 24th Southern Tree Improvement Conference. University of Florida, Gainesville, FL.

Li, B., S. McKeand, and R. Weir. 1999. Tree improvement and sustainable forestry – impact of two cycles of loblolly pine breeding in the U.S. Forest Genetics 6:229-234.

Li, B., S. McKeand, and R. Weir. 2000. Tree improvement and sustainable forestry – results from two cycles of loblolly pine breeding in the U.S.A. Journal of Sustainable Forestry 10:79-85.

McKeand, S., T. Mullin, T. Byram, and T. White. 2003. Deployment of genetically improved loblolly and slash pine in the South. J. For. 101:32-37.

McKeand, S.E., R.C. Abt, H.L. Allen, B. Li, and G.P. Catts. 2006a. What are the best loblolly pine genotypes worth to landowners? J. For. 104:352-358.

McKeand, S.E., E.J. Jokela, D.A. Huber, T.D. Byram, H.L. Allen, B. Li, and T.J. Mullin. 2006b. Performance of improved genotypes of loblolly pine across different soils, climates, and silvicultural inputs. For. Ecol. Manage. 227:178-184.

Table 1—Survival (%) and height (feet) following years 1 and 3 for two genetic varieties of loblolly pine planted at three different spacings and managed at two different management intensities on a site previously managed for agricultural production in central Mississippi

	Survival (%)		Mean Height (feet)	
	Year 1	Year 3	Year 1	Year 3
Overall	94.1	92.2	1.69	7.89
Initial Spacing				
6 x 14 feet	94.8	93.6	1.69	8.07
9 x 14 feet	95.7	94.8	1.71	8.07
16 x 14 feet	91.8	88.2	1.66	7.52
Management Intensity				
Low	96.3*	92.7	1.66	6.53
High	91.9	91.7	1.71	9.25*
Genetic Variety				
Crop	98.5*	98.0*	1.68	8.39*
Competitor	89.7	86.3	1.69	7.38

* Values followed by an asterisk are significantly different from other values in the group at alpha=0.05

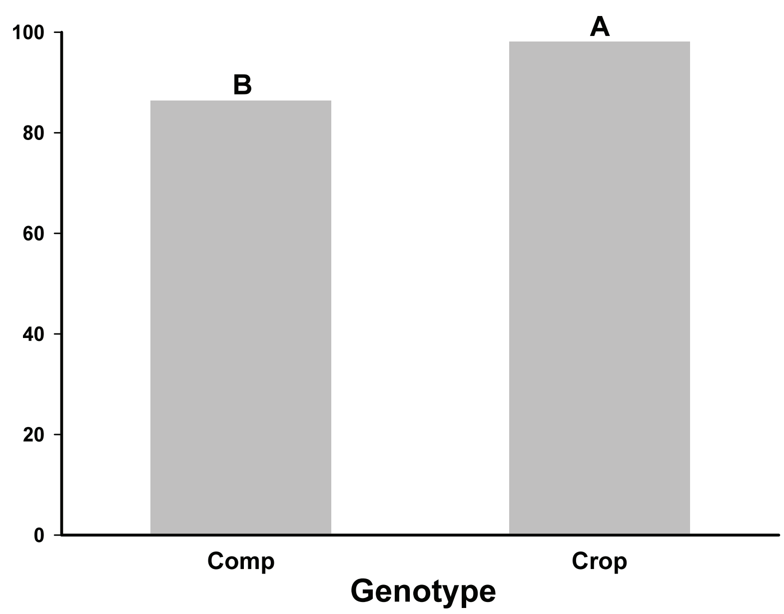

Figure 1—Mean year-3 survival for contrasting loblolly pine varieties planted in a spacing by management intensity trial in central Mississippi.

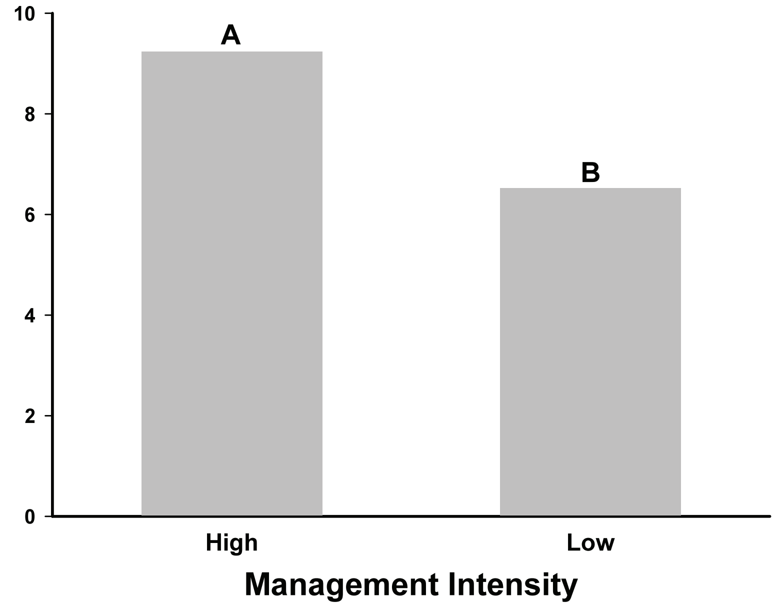

Figure 2—Mean year-3 height for loblolly pine varietal seedlings managed at different management intensities in central Mississippi.

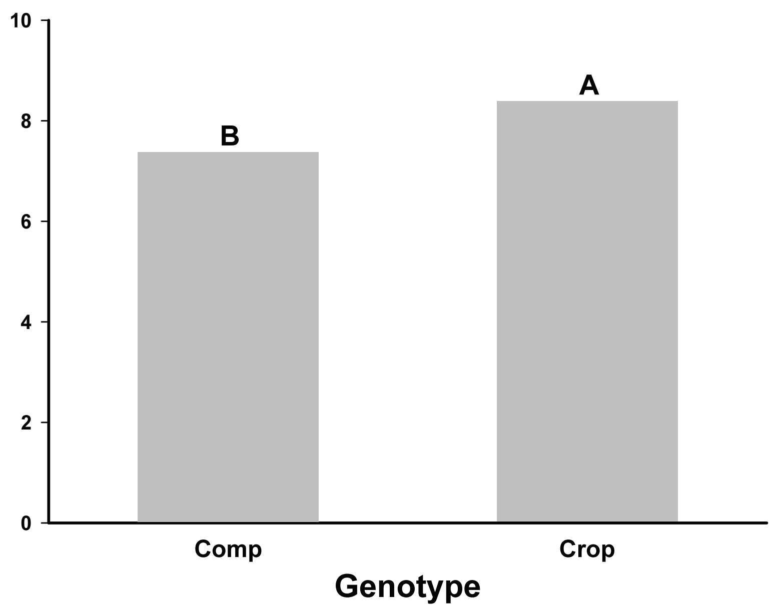

Figure 3—Mean year-3 height for contrasting loblolly pine varietal seedlings planted in a spacing by management intensity trial in central Mississippi.