ASSESSING POTENTIAL GENETIC GAINS FROM VARIETAL PLANTING STOCK IN LOBLOLLY PINE PLANTATIONS

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Abstract—Forest landowners have increasingly more options when it comes to loblolly pine (*Pinus taeda* L.) planting stock. The majority of plantations in recent decades have been established with seedlings produced from second-generation open-pollinated (second-Gen OP) seed. However, foresters have begun recognizing the increased gains obtainable from full-sib families produced using mass-controlled pollination (MCP) techniques. The next step in genetic improvement is varietal forestry. Forest biotechnology firms are producing loblolly pine varietal planting stock for deployment in the Southeastern United States. Continued testing of this material will determine individual genotypes best suited for specific sites or desired products. In 2007, a Loblolly Pine Genetic Level Study was installed in northern Mississippi to examine differences in growth among second-Gen OP seedlings, MCP seedlings, and loblolly pine varieties derived from somatic embryogenesis. Following two growing seasons, the average height of the MCP material was slightly but significantly taller than that of the varietal planting stock. The average height of the top five performing varieties was 18 percent taller than the varietal average, 14 percent taller than the average height of the second-Gen OP, and 6 percent taller than the MCP material.

INTRODUCTION

The southeastern region of the United States is the largest wood-producing region in the country, accounting for over 56 percent of the total U.S. harvest (Adams and others 2006). There are a variety of reasons why the region has become such an important wood producer. One is the prevalence of plantations. There are currently over 30 million acres of pine plantations in the Southeast, with some projections showing this to increase to as high as 40 to 50 million acres by 2040 (Wear and Greis 2002). Given the typically higher yields of plantations over naturally regenerated forests, this increase in plantation acreage alone accounts for much of the regional increase in production.

In addition to the large increases in southern pine plantation acreage, the region has realized dramatic increases in per-acre yields of southern forests resulting from increased management intensity over the past 30 to 40 years. Over the past three decades, the average mean annual increment of southern pine plantations has more than doubled, while rotation lengths have been cut nearly in half. Productivity of newly established plantations can operationally achieve over 300 cubic feet per acre per year, and in some cases to over 400 cubic feet per acre per year (Fox and others 2007). These increases in plantation yields have resulted from several factors, such as improved site preparation techniques, effective competition control, and fertilization. Another major factor in the increased productivity seen over the past 40 years has been the genetic improvement of loblolly pine (*Pinus taeda* L.).

Genetically improved seedlings from first-generation seed orchards started becoming available for plantation establishment by the end of the 1950s. By the mid-1980s virtually all southern pine plantations were established with seedlings produced from genetically improved seed; and by the early 1980s, harvests from plantations established using genetically improved planting stock were beginning to show the benefits of the tree improvement programs. Gains in volume from first-generation plantations in the 1980s were generally in the range of 7 to 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. Estimates of average volume gain from second-generation plantations range from 7 to 23 percent over first-generation stock, to 10 to 35 percent over unimproved stock (Fox and others 2007; Li and others 1997, 1999, 2000; McKeand and others 2003, 2006a). Improvements in fusiform rust resistance, stem straightness, and wood quality further increase harvest values over unimproved stock.

Realized genetic gains from open-pollinated seedlings can be further increased by planting seedlings in single half-sib family blocks through the selection of female parent trees exhibiting greater breeding values (Duzan and Williams 1988, McKeand and others 2006b). As of 2002, nearly 60 percent of all southern pine plantations, and 80 percent of industrial plantations, were deploying seedlings in single half-sib family blocks (McKeand and others 2006a). Further genetic gains can be made by planting full-sib families produced using mass-controlled pollination (MCP) techniques (also known as supplemental-mass pollinations) (Bramlett 2007). Crossing elite parents can produce volume gains of up to 30 percent, although actual gains are typically reduced somewhat due to pollen contamination (Sutton 2002). Jansson and Li (2004) showed potential volume gains from full-sib families of up to 60 percent over unimproved stock, with realized gains dependant on the selection intensity of the specific cross.

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Clonal forestry offers the hope of providing even greater genetic gains in forestry through mass propagation of highly selected genotypes. The most commonly used technique for many conifers has been rooted cuttings. However, this technique allows mass production of a given genotype for a limited number of years due to problems associated with tissue maturation (Park 2002, Sutton 2002). Mass production of planting stock via tissue culture or somatic embryogenesis (SE) techniques, while common with some hardwood species, has until recently been impractical in southern pines due to lack of an efficient propagation system. However, recent advances in techniques of SE and cryopreservation have increased the potential for clonal, or varietal, southern pine planting stock. An important advantage of clonal propagation via SE is that the embryonic tissue can be cryopreserved while the varietal lines are tested for genetic superiority, thus, overcoming the problem of tissue maturation (Park 2002, Sutton 2002).

Varietal planting stock currently accounts for only a minor proportion of loblolly pine seedlings planted in the Southeast, and there remain issues that need further investigation. Field testing of varietal lines is needed in order to realize the potential genetic gains of varietal forestry. In addition, varietal planting stock is currently much more expensive than other options. Despite the tremendous promise of this technology, studies have yet to confirm that the enhanced growth and quality produced by these trees is economically justifiable at current costs. How much greater yield can be expected from varietal stock? Can varietal stock be tailored to suit specific desired end products? Are there genotypes by site interactions that can be exploited with varietal stock? The answers to these and other questions are needed before large-scale adoption of varietal planting stock can be expected.

Here we describe second-year results from a study designed to examine differences in growth and form among loblolly pine planting stock of three different levels of genetic improvement. Height growth of SE varietal “seedlings” is compared to that of a second-generation, open-pollinated (second-Gen) half-sib family and a full-sib family produced via MCP techniques. The long-term objectives of the study are to determine if the best performing SE varietal stock will outperform the second-Gen and the MCP stock; and if so, how much more could a landowner afford to spend on varietal planting stock. The specific objective of this analysis was to examine early height growth trends among the three stock types.

METHODS

This study was established in 2007 at the Mississippi State University, North Mississippi Branch Experiment Station near Holly Springs, MS. Soils on the site are a Loring silt loam. The site had previously been a pasture, thus, the soils were somewhat compacted.

The study was set up in a complete block design containing three distinct levels of genetic improvement in loblolly pine planting stock: open-pollinated second-generation (second-Gen), MCP, and varietal stock produced using SE techniques. The second-Gen material, planted as bare-root stock, was a selected MeadWestvaco half-sib family that has been found to perform well in southwest Tennessee. The MCP material, also a MeadWestvaco selection, and SE material, provided by ArborGen LLC, were both produced in containers. Each of the 6 replicated blocks contained a single 100-tree plot of each stock type, with a 64-tree internal measurement plot.

In January 2007, prior to planting, the site was subsoiled to a depth of approximately 18 inches. A banded application of 64 ounces per acre glyphosate occurred in early March to eliminate existing herbaceous vegetation. Plots were handplanted on March 23–24, 2007, at a density of 403 trees per acre (12 by 9 foot spacing). In May 2008, the site received a broadcast application (14 ounces per acre) of Oustar®. At the end of both the first and second growing seasons, stem heights were measured on the 64-tree internal measurement plots within each treatment plot.

Fifty-six SE varieties were included in the study, with 1 ramet of each variety included in each varietal treatment plot. The remaining trees in the 64-tree plots included checks and filler trees. Only varieties with at least four of the original six ramets surviving after the second growing season were included in this analysis. Standard analysis of variance techniques were used to determine whether there were significant differences in average height among the second-Gen, MCP, and the SE stock. In addition, the SE varieties were ranked by age 2 height, and the average height of the five tallest varieties was examined relative to the other stock types.

RESULTS

At the end of first growing season, there were no significant differences in height among the three genetic stock types (table 1). The MCP trees were slightly taller on average with a mean height of nearly 2.0 feet, while the second-Gen and varietal stock both had average heights of about 1.9 feet.

The MCP stock showed the greatest amount of height growth in year 2, and by the end of second growing season had increased its height advantage (table 1). Average second-year height of MCP material was over 5.4 feet, which was significantly taller than the SE varietal stock by over 0.5 feet. The maximum height attained by any MCP tree at age 2 was 8.1 feet. The maximum height for any of the varietal and second-Gen trees was 7.7 feet and 7.6 feet, respectively.

At the end of first year, differences in mean height among the individual varieties were minimal. By second year, these differences had increased, although few of the height differences were statistically significant (fig. 1). Only one of the five tallest varieties after the first year remained among the tallest five varieties following year 2. Four of the varieties had a mean height greater than the 7-56 OP check after year 2, and five varieties had a mean height greater than the average of the MCP material, although these differences were not significant (fig. 1).

By the end of the second growing season, the top five performing varieties were 18 percent taller than the overall average height of all varieties. The top five varieties were 14

Table 1—Mean height following the first- and second-growing seasons for loblolly pine derived from three genetic stock types

Genetic type	Height – age 1	Height – age 2	Growth
	feet		
Mass-controlled pollination	1.98 a	5.41 a	3.43 a
Second-generation open-pollinated	1.90 a	5.02 ab	3.13 ab
Somatic embryogenesis varietals	1.88 a	4.85 b	2.96 b

Numbers within the same column followed by different letters are significantly different at alpha = 0.05.

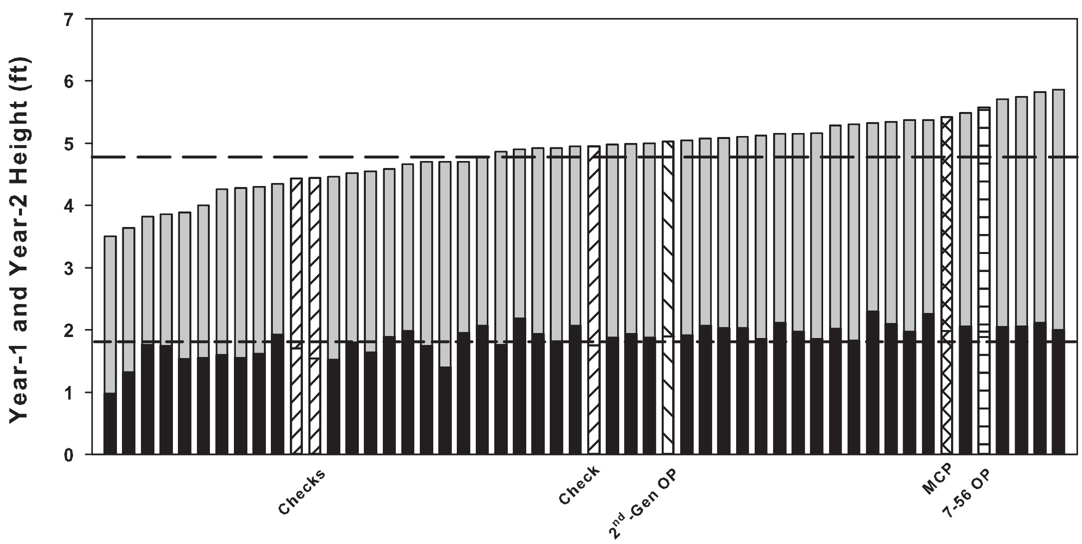

Figure 1—Forty-six somatic embryogenesis (SE) varieties of loblolly pine ranked by average height following year 2. Black portion of the each bar represents the average height of the variety following year 1. Horizontal dashed lines show the mean height of all 46 varieties following years 1 and 2. Crosshatched bars show the mean height following year 2 for the second-generation seedings, the mass-controlled pollination seedlings, nursery checks, and a 7-56 OP family.

percent taller than the average height of the second-Gen material, and 6 percent taller than the average height of the MCP material (fig. 2). Differences between the varietals and the MCP were not significant.

DISCUSSION

The knowledge and technologies needed to mass produce loblolly pine somatic seedlings are currently available, although current cost of production remains relatively high (Dougherty and Wright 2009, Wright and Dougherty 2006). There is an ongoing need for additional studies addressing the economic effectiveness of varietal stock. There is also a continued need to field test clonal varieties to determine which individual genotypes are best suited for mass production of planting stock for specific characteristics.

Currently, companies producing varietal stock produce thousands of varietal genotypes from several dozen elite parental crosses. Based on results from extensive field testing, fewer than 5 percent of these varietals will likely be selected for mass production of varietal planting stock (Sutton 2002).

Some estimates predict that clonal selections may produce volume gains 40 to 50 percent greater than the average of open-pollinated second-generation seed orchards (Sutton 2002). After two growing seasons, the varietal material in our study is not, on average, outperforming the other two genetic stock types. In fact, the average height of the MCP material is statistically greater than that of the varietal material. However, the best performing varieties are growing better than the

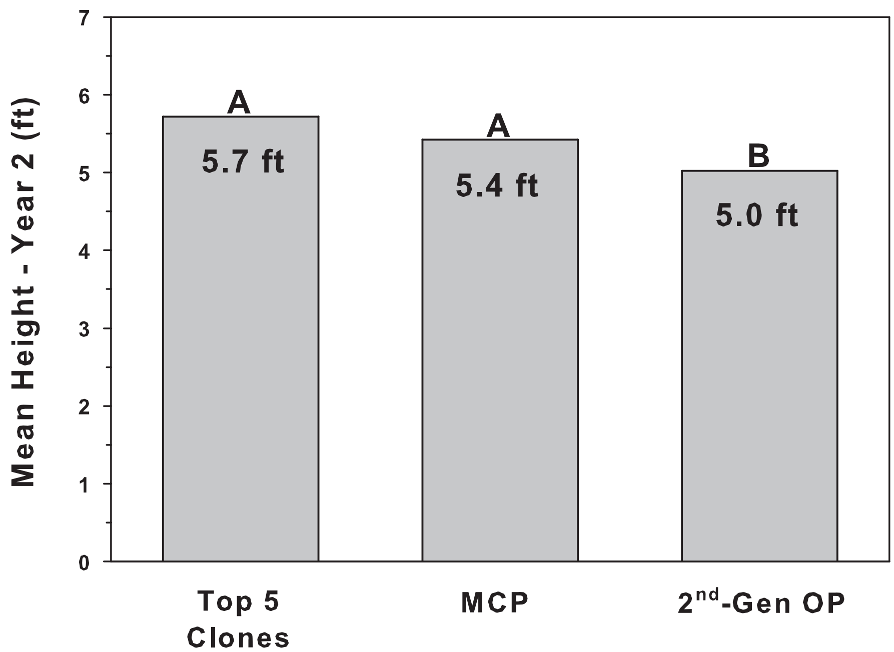

Figure 2—Average height following the second growing season for the top five performing somatic embryogenesis varieties compared to the average height of the mass-controlled pollination and second-generation genetic stock. Bars with different letters above indicate mean heights are significantly different at alpha = 0.05.

more common stock types. Our results showed that the top 10 percent of the varieties tested were outperforming both the second-Gen and the MCP material.

As expected, we observed considerable variability in growth among the 56 varieties tested in this study. This variability is due to the specific crosses that made up these varieties, as well as physiological differences associated with production of the somatic tissue. However, we feel that this test, when combined with data from many others across the Southeastern United States, will provide information on specific varieties suited to the local area.

Two years is certainly very early to draw firm conclusions about the performance of individual varieties. The relative performance of these varieties may change in future years, much like they did between the first and second year when only one of the best growing varieties after year 1 remained among the tallest varieties after the second year. However, our early results are beginning to suggest that the best varietal material may be able to outperform MCP stock, and especially the standard second-Gen stock, on these sites.

ACKNOWLEDGMENTS

The authors would like to acknowledge the cooperation and assistance of ArborGen LLC for providing planting stock and other resources for this study. We would also like to thank Mr. Randy Saunders of the North Mississippi Branch Experiment Station for his invaluable assistance with this project. Dr. Cetin Yuceer and Mr. Jeff Wright provided reviews on an earlier draft of this manuscript. This manuscript was approved for publication as Journal Article FO-383 of the Forest and Wildlife Research Center, Mississippi State University.

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