COMPARISON OF SECOND GENERATION OPEN-POLLINATED, MASS CONTROL-POLLINATED, AND VARIETAL PINE PLANTING STOCK THROUGH 6 YEARS ON A NORTH MISSISSIPPI SITE

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Abstract--Landowners face a wide array of loblolly pine genetic material to choose from at the time of regeneration. In general, most opt to plant open-pollinated second-generation stock (second-Gen OP) as previously recommended by either consultants or industry personnel. The goal of this study is to evaluate a selected second-Gen OP family, a selected mass control-pollinated family (MCP), and varietal stock in terms of performance as well as form characteristics. This study was established on an old pasture site near Holly Springs, MS, in a nested randomized complete block design with six blocks, arranged by genetic stock and planted in 100-tree block plots at a spacing of 12 by 9 feet. The study was measured annually through the first 4 years. At age 6, the MCP family was significantly outperforming the second-Gen OP family and the varietal stock for both diameter and volume. The MCP family exhibited overall better performance than the second-Gen OP family and the overall means of the varietal plots. However, the comparison between the MCP family and the top-performing varietals revealed that, while the selected varietals were taller, their diameter and volume were less than the MCP. What was striking was that some of the best-growing varietals also exhibit exceptional stem form and limb characteristics making them highly suitable for higher end products.

INTRODUCTION

Currently, the majority of non-industrial private forest landowners (NIPF) in Mississippi have few options for assistance in deciding upon the best level of genetic quality for their loblolly pine (*Pinus taeda* L.) plantations. In the past, landowners relied primarily on the Mississippi Forestry Commission (MFC) not only for their pine seedlings but also for recommendations of what type of genetic stock they should be planting. Due to budget cuts, the MFC, which was a member of the Western Gulf Tree Improvement Program at Texas A&M University, made the decision to vacate this tree improvement program and to mothball the Commission's seed orchards and nurseries. With the landowners' primary source of information and seedlings gone, there is a void in terms of recommendation for the most current planting stock. Since they had become accustomed to earlier recommendations of second-generation (second-Gen) planting stock, most landowners have continued to follow this advice when ordering new seedlings for regenerating newly harvested stands. The variety of genetically improved loblolly pine seedlings available today to the landowner spans a wide range from open-pollinated 1.5-generation seedlings to clonal selections known as varietals. The high cost of membership likely restricts most small landowners or individual consultants from participating in such programs.

Genetic gains from open-pollinated seedlings can be increased by planting seedlings in single half-sib family blocks, allowing selection of parents that exhibit greater breeding values (Duzan and Williams 1988, McKeand and others 2006). 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 2006, McKeand and others 2007). Further genetic gains can be achieved by using full-sib families, produced through mass controlled-pollination (MCP) techniques, also known as supplemental mass-pollinations (SMP) (Bramlett 1997). Jansson and Li (2004) showed potential volume gains from full-sib families of up to 60 percent over unimproved stock, with realized gains dependent on the selection intensity of the specific cross.

Indications are that clonal forestry (i.e. varietals) will provide even greater genetic gains in forestry through mass propagation of highly selected genotypes. The most commonly used technique for most conifers has been rooted cuttings. 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. Advances in techniques of SE and cryopreservation have increased the potential for clonal, or varietal, southern pine planting stock (Park 2002). An important

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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). 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 varietal costs. Currently we view the end products of varietal material as being those that have the greatest potential of every seedling, combining excellent growth, stem form, and wood characteristics. Current goals are to determine the best use of varietals in relationship to advanced open-pollinated seedlings from third-cycle parents and MCP seedlings.

The objectives of this specific trial are to examine three genetic types of planting stock on a north Mississippi site and to provide on-site demonstration to landowners of the three stock types. The three types included a select open-pollinated second-generation (second-Gen OP) family, a select MCP family, and a number of varietals. In addition to this first objective, the performance of the various genotypes included in the varietal plots are a portion of an overall series of varietal trials by ArborGen examining varietal selection across the southern United States.

MATERIALS AND METHODS

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

In January 2007, prior to planting, the site was sub-soiled at a 12-foot spacing to a depth of approximately 18 inches, with glyphosate banded at a rate of 2 quarts per acre over the sub-soiled slits in March to eliminate existing herbaceous vegetation. The study was hand-planted on March 23-24, 2007 at a spacing of 12- by 9-feet, with each treatment plot consisting of 100-tree block plots arranged as 10- by 10-tree plots. As each seedling was planted, a single 20 mg. SilvaShield tablet was inserted into each dibble hole as a precautionary method for tip moth control. In May 2008, the site received a broadcast application of Oustar® at a rate of 14 ounces per acre. 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.

The study is a nested design consisting of six blocks with three treatments nested in each block. The three treatments were three distinct levels of genetic improvement of the loblolly pine planting stock. These were second-Gen OP, MCP, and varietal (SE) stock produced using SE techniques. The second-Gen OP seedlings were 1-0 bareroot stock while the MCP and SE material were both produced in containers. Each of the six blocks contained a single 100-tree plot of each genetic type.

The second-Gen OP and MCP material was selected from MeadWestvaco based on their performance in tests located in southwest Tennessee and provided by ArborGen. The SE material was not a single clone but rather a composite of 56 SE varieties, with one ramet of each variety included in each varietal treatment plot. The remaining trees in the 64-tree varietal plots included checks and filler trees. All of the SE material was provided by ArborGen and was included into the ArborGen Testing Service. Only varieties with at least four of the original six ramets surviving after the second growing season were included in this analysis.

Standard GLM techniques in SAS 9.3 were used to compare the mean height of the second-Gen OP and MCP material against that of the SE genetic type through age 6. In addition, the SE varieties were ranked by age-6 height, diameter, and volume, with the average height and volume of the three tallest varieties examined relative to the MCP stock types.

RESULTS

Overall test survival at age 6 continued to remain high, 94 percent, with a drop of only 1 percent between ages 4 and 6. Survival of the three genetic types showed the second-Gen OP was the highest at 97 percent followed by the MCP at 95 percent, and then the SE type at 90 percent. There was no significant difference between the second-Gen OP and the MCP types through age 6, but both were significantly different from the SE type.

Average height among the three genetic types showed that the MCP type was taller than the second-Gen OP and SE types from age 2 through 6. The difference in total height between the MCP and the second-Gen OP types increased to approximately 1.2 feet at age 6, whereas the difference between the MCP and SE types remained approximately the same at 1.5 feet (table 1).

Examination of height growth between age 2 and 6 showed that growth rates increased for all three genetic types between ages 2 and 4 but decreased between ages 4 and 6 (table 2). Volume growth between ages 3 and 4 and ages 4 and 6 showed that second-Gen OP and MCP were similar while the SE type was slightly lower. However, while there was no significant difference between the second-Gen OP and MCP types across either age grouping there is a trend for the MCP to be increasing its numerical difference over the second-Gen OP type (table 2). Because of the great diversity of genotypes that make up the SE type, it is difficult to compare this type to either the second-Gen OP or MCP types. While the SE type was statistically smaller in volume growth than either of the other two genetic types, the difference reflects that the vast majority of the genotypes were poorly adapted to the site.

The majority of the MCP trees at age 6 were between 22- and 29-feet tall whereas majority of the second-Gen OP trees were between only 15 and 22 feet. The same trend is also true for age-6 d.b.h., with the MCP type having a greater number of trees in the larger diameter classes compared to the second-Gen OP type

As previously mentioned, one of the objectives of this particular study was to identify the best performing planting stock at this specific site. Significant varietal (SE) differences were shown for all traits from age-1 height to age-6 height, d.b.h., and volume. Table 3 provides a comparison between the MCP type means for height at ages 3, 4, and 5 years for the top three performing varietal means. Mean height of the top three genotypes were 11.2, 16.4, and 24.0 feet at ages 3, 4, and 6 years, respectively as compared to 10.4, 15.8, and 23.2 feet for the MCP type. The mean height of the best genotype was 11.6, 17.0, and 24.1 feet at ages 3, 4, and 6 years, respectively (table 3). The top three volume-producing genotypes showed mean values of 0.45, 0.77, and 2.13 cubic feet at ages 3, 4, and 6 years, respectively. The best volume producing genotype showed a mean value of 0.45, 0.78, and 2.14 cubic feet at ages 3, 4, and 6 years, respectively (table 3).

DISCUSSION

The overall test survival has been quite good through age 6, with the majority of the mortality concentrated in one block due to intense Bermuda grass (*Cynodon dactylon* L.) competition. The SE seedlings were the only actively growing stock when the test was established; these seedlings were shipped to us just prior to planting. The other two genetic types were either bareroot, as the case of the second-Gen OP seedlings, or dormant container grown seedlings as were the MCP seedlings. In addition, the SE seedlings were less developed than the other two seedling types (in terms of height and root systems), likely accounting for the higher mortality rates and quite possibly the slower growth rates (Rousseau and others 2012). Taking into account the problem incurred with the SE seedlings and the intense grass competition, the lower survival rates of this genetic type should not be considered a genetic problem but rather one associated with planting stock quality.

Although the MCP stock showed better height, diameter, and volume performance compared to the second-Gen OP stock at both ages 4 and 6, the difference between these three traits either remained the same or increased slightly with increasing age. While it was expected that the MCP type would exhibit better performance than the second-Gen OP type, the small difference between the two types at age 6 was unexpected. Because the genetic make-up of a MCP family is based on known selected parents, the resulting progeny of a cross between two high performing parents will hopefully produce

Table 1--Least square means for d.b.h., total height, and volume for the three genetic types at ages 4 and 6 of the 2007 Loblolly Pine Genetic Comparison and Varietal Study located near Holly Springs, MS

	---------------Age 4[a]---------------			---------------Age 6[a]---------------		
Genetic type	D.b.h.	Height	Volume	D.b.h.	Height	Volume
	inches	*feet*	*feet*^{3}	*inches*	*feet*	*feet*^{3}
2[nd]-Gen OP	3.1a	14.7b	0.70b	5.5b	21.9a	1.95ab
MCP	3.5a	15.8a	0.81a	5.9a	23.2a	2.24a
Varietal (SE)	2.7b	14.2b	0.61b	5.0c	21.6a	1.69b

[a]Mean values for the same column are significantly different at the 0.05 level of the Duncan's Test if the letters are different.

Table 2--Early-age height and volume growth of the three genetic types tested in the 2007 Loblolly Pine Genetic Comparison and Varietal Study located near Holly Springs, MS

	-----------------Height (*feet*)[a]---------------			------Volume (*feet*^{3})[a]------	
Genetic type	2-3 years	3-4 years	4-6 years	3-4 years	4-6 years
2[nd]-Gen OP	4.5a	5.1a	3.6a	0.29a	0.62ab
MCP	4.8a	5.4a	3.7a	0.36a	0.71a
Varietal (SE)	4.6b	4.7b	0.6b	0.21b	0.53b

[a]Mean values for the same column are significantly different at the 0.05 level of the Duncan's Test if the letters are different.

Table 3--Least square means for height and volume at ages 3, 4, and 6 years for MCP, the top three varietals, and the best performing varietal for that specific trait in the 2007 Loblolly Pine Genetic Comparison and Varietal Study located near Holly Springs, MS

	----------Height (*feet*)[a]----------			---------Volume (*feet*^{3})[a]--------		
	Age 3	Age 4	Age 6	Age 3	Age 4	Age 6
MCP	10.4	15.8	23.2	0.45	0.81	2.24
Top 3 varietals	11.2	16.4	24.0	0.45	0.77	2.13
Best varietal	11.6	17.0	24.1	0.45	0.78	2.14
Field ID	(228)	(228)	(14)	(329)	(228)	(228)

[a]Mean values for the same column are significantly different at the 0.05 level of the Duncan's Test if the letters are different.

progeny that are less variable as well as exhibiting greater gains in growth, as long as the resulting progeny are adapted to the site conditions (Rousseau 2010). In comparison, in the second-Gen OP family, there is no control of the pollen parents. Thus we expect greater variability among the progeny and the resulting growth to be less than the designed cross of an MCP family. The variability of an open-pollinated family is not only due to the variation of the genotypes within the seed orchard but outside pollen contamination as well. Adams and Birkes (1989) showed that for an open-pollinated seed orchard, contamination from outside pollen could be as high as 50 percent in any year, thus adding to the variability among progeny and the reduction in expected gains. Further examination of the MCP and second-Gen OP types showed approximately 63 percent of the MCP test population and 41 percent of the second-Gen OP test population fell into the 22- to 24-height category at age 6. The greater age-6 height variability among the second-Gen OP test population was typical of an open-pollinated family whereas the MCP type showed much less variability among height with the preponderance of the progeny falling into a single category, thus exhibiting less variability as expected of progeny from a full-sib family. Examination of the diameter distributions between the MCP and second-Gen OP progeny showed a higher percentage of second-Gen OP progeny falling into the lower diameter classes (i.e. 3-, 4-, and 5-inch classes). This trend was reversed for the higher diameter classes (i.e. 6-, 7-, and 8-inch classes) where the MCP progeny had the highest percentage. In fact, 63 percent of the MCP progeny fell into the 6-inch diameter class, again showing less variability than the second-Gen OP progeny. Based on the better height and diameter of the MCP progeny, it was evident that the total volume (cubic feet) would be greater than the second-Gen OP type. This was shown to be true since the mean of the MCP type was 900 cubic feet compared to 790 cubic feet for the second-Gen OP type.

Unfortunately it was not possible to directly compare the performance SE material to either the MCP or the second-Gen OP types due to the fact that the SE plots consist of 54 different genotypes as well as some check lots. Because of this, only a maximum of six observations per genotype could be made, which only provides a glimpse of the type of performance that might be expected. With these limitations, the performance of the SE type was compared to the MCP type as a means of gauging the performance of selected SE individuals. As shown in table 3, the top three varietals and the best varietal were taller than the MCP mean, but there was little difference among the better performing SE genotypes. While Frampton and Huber (1995), working with loblolly clonal stock, showed that clones could yield considerably higher gains than full-sib families, this does not seem to be the case in this comparison of a limited numbers of SE genotypes. In this case, a mixture of the best three genotypes was as good as a single genotype, and this mixture would add genetic diversity to a planting. Volume production between the MCP and SE types differed very little, but the trend for higher volume production of the MCP type was due to the larger diameters exhibited by age 6. While yield in terms of volume production certainly provides a greater tonnage production, this may or may not translate into higher quality products that landowners are seeking (McKeand and others 2006, McKeand and others 2007, Sherrill and others 2008). Thus, a more appropriate factor would be to consider the variability of the SE individuals in terms of stem quality and crown characteristics that are exhibited by specific genotypes (Cumbie and others 2012, Dougherty and others 2010). Varietal 567 exhibited exceptional form as well as above average height and diameter. This is likely the type of individual that landowners would favor. However, at the current cost of approximately $400 per thousand seedlings, this material is too expensive for most small landowners (Rousseau 2010).

CONCLUSION

Age-6 results indicated that while the MCP type outperformed the second-Gen OP type, the differences in height, diameter, and volume were not as large as expected. The decreased variability among the progeny of the MCP type in comparison to the open-pollinated second-Gen OP type was seen for both diameter and height at age 6. This decrease in variability may become more important as the stand ages and moves into the various products through the rotation. The result could be higher returns per acre as well as reduced rotation lengths. In addition, the greater cost of MCP seedlings is not significantly different to the point where it would limit the use of this type of genetic material. However, landowners would benefit if there were a larger number of trials that examined a wider variety of MCP families to determine growth and quality on a diversity of Mississippi sites.

The performance of the SE material was quite variable but expected as there were 56 different genotypes. However, there were a limited number of excellent genotypes that showed not only good growth but excellent stem form and branch characteristics. Like the MCP, additional testing of a large number of SE genotypes would provide a greater base of material from which to choose. If suitable, including a number complimentary growth genotypes would add genetic diversity to a plantation establishment.

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