GENETIC EFFECTS ON EARLY STAND DEVELOPMENT OF IMPROVED LOBLOLLY PINE (*PINUS TAEDA* L.) SEEDLINGS

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Abstract: This study was conducted to assess the effect of genotype on the early performance of improved loblolly pine (*Pinus taeda L.*) seedlings planted on the University of Arkansas at Monticello School Forest located in southeast Arkansas.We used a split- plot design consisting of two spacing treatments (3.05m×3.05m and 3.05m× 4.27m) randomly assigned as main plots and three loblolly pine genotypes (Arkansas Foresty Commission 3-Star half-sibling seedling, Cellfor® clone Q3802, and Cellfor® L3791) randomly assigned to the subplots. Survival, ground line diameter, height, and flush length were collected. Genetics had a significant effect on survival, height, ground-line diameter, and flush length. Cellfor clone L3791 showed greater growth (diameter and height) and survival compared to other seedlings. Survival and growth were not affected by the spacing as expected, considering the early stage of stand development. The high growth and survival of the clonal stock suggest that productivity can be enhanced through selecting the improved genotype.

Introduction

Over the last 50 years, southern pine management in the southern US has shifted from natural stands to intensively managed plantations (Prestemon and Abt 2002, Wear and Greis 2002). These plantations have been established with an increasing amount of genetic improvement (McKeand et al., 2003, 2006). This improvement has also coincided with increasing deployment of full-sib families and clones which could result in greater stand-level uniformity and enhanced productivity (Jansson and Li 2004). Loblolly pine (*Pinus taeda* L.) is the most commonly planted tree species in the southeastern United States (McKeand 2006) primarily because it responds well to silvicultural treatments. Selection of genetic sources and planting density are among the key decisions that must be made prior to plantation establishment.These initial decisions dictate future timing of other silvicultural treatments and directly impact productivity and the quality and type of wood products generated over a rotation.

In Arkansas, there are numerous options of commericially available loblolly pine seedlings for forest managers and landowners. Half-sib seedlings produced by the Arkansas Forestry Commision (AFC) are inexpensive (less than $ 0.1per seedling) and are widely used on private lands (www.ark.org/afc2/seedlingsales.php). Mass controlled pollinated and cloned loblolly seedlings from private companies represent the next generation of improved genetics and promise even better performance, but these are considerably more expensive and less tested in the region, and hence, are not as widely planted as half-sibling seedling stocks.

Thus, the objective of this study was to assess genetic effects on survival and various growth attributes of newly planted loblolly pine. First growing season observations of flushing traits suggested that the clonal stock may gain growth advantages partially due to early flushing; therefore, flushing was quantified during the beginning of the second growing season.

Materials and Methods

Study Area

The study area is located in Drew County, Arkansas, on the University of Arkansas-Monticello Teaching and Research School Forest (Latitude 33º37'1'' North, Longitude 91º43'9'' West). Mean annual precipitation is 53.5 inches, with an average January temperature of 43.3ºF and an average July temperature of 82.0ºF (Larance et al. 1976, NOAA 2013). Soils across the study area are mapped predominantly as Calloway silt loam (Fine-silty, mixed, active, thermic Aquic Fraglossudalfs) with gentle slope (1-3%). Prior to plantation establishment, the site was a mature pine stand of about 55 years when it was harvested. The site was cleared of most debris and was hand planted in January 2012.

Experimental Design and Plant Material

To assess the relative effects of both planting density and seedling stock, a split-plot experimental design was utilized.With relatively wide (3.05m x 4.27m) and narrow (3.05ft x 3.05ft) spacing treatment were randomly assigned to the main plots, and genotypes were randomly assigned to the split-plots. The three levels of genetics and two levels of spacing made six treatment combinations which were replicated three times.

The three seedling types consisted of one half-sibling and two clonal planting stocks. The half-sibling seedlings were the Arkansas Forestry Commission 3-star loblolly pine stock which were 1-0 bare root seedlings (several bulked families) produced from seed sources selected under the Western Gulf Tree Improvement Cooperative. These seedling are reported to have a 41-51% genetic gain over woods-run stock (http://forestry.arkansas.gov/Seedlings/Pages/default.aspx). The other two genotypes were ArborGen (formerly CellFor® clones Q3802 and L3791). Both were produced as 1-0 containerized seedlings. Q3802 clone was advertised as having exceptional tree form with small branches, narrow crown, outstanding stem straightness, excellent growth rate, and high resistance to fusiform rust (CellFor clone® 2010a). Clone L3791 was advertised as having an exceptionally high growth rates and being high resistance to fusiform rust and pitch canker, and possessing outstanding stem straightness (CellFor clone® 2010b).

Data Collection

First year ground-line diameter (GLD) and height (HT) of all seedlings were measured in December (2012) through January (2013) using caliper and meter stick respectively. Survival was also determined during this sampling period. We had observed an early flush in the clones during the spring of 2012, so we tracked flushing on random sample of all genotype in the spring of 2013 to determine if this behavior was repeated

Data Analysis

Effects of spacing, family and their interactions were analyzed using as split-plot with spacing as the main effect and family as the sub-plot effect. Effect of spacing, family, and their interaction on mean height, ground line diameter (GLD), survival, first flushing and flush length were analyzed using a mixed model approach (Proc Mixed, in SAS version 9.2) with the block and genotype as a random effect with spacing as a fixed effect. Survival and presence of flushing was expressed as a percent per plot, we transformed these percentage using the arcsine function prior to running ANOVA (at α=0.05).

Result and Discussion

Effect on Survival and First Flushing

Survival was significantly affected by the genotype (*p*=0.03) (Table 1). At out site, Clone L3791 had a significantly higher survival rate (88%) than either clone Q3802 (78%) or the AFC three star seedling (73%). More time is needed to determine the reason behind this differential surviroship. Much of the region experienced drought during 2012-2013, which could have differentially impacted loblolly pine seedling survival. A Longer-term study (Adams et al. 2007) reported that the survival of loblolly pine at age of 9,13 and 17 was significantly affected by family and spacing, but given that these widely-spaced plantings have not yet reached canopy closure, spacing effects are not yet relevant in out study. Although we observed some differences in mean flushing among the families when we measured flushing rate in March (72 % for CellForclone L3791, 68% for Cellforclone Q3802, and 53 % for Halfsib), those differences were not statistically significant (Table 1).

Table 1: ANOVA table of arcsine transformed first-year survival and second year flushing in March.

Source	**Survival**					**Flushing count**			
	Num DF	**MS**	**Error DF**	**F value**	**Pr>F**	**MS**	**Error DF**	**F value**	**Pr>F**
Spacing	1	0.0014	1	0.35	0.6	0.000096	10.02	0.02	0.9
Block	1	0.0065	0.075	-4.44		0.11	0.65	1	0.5
Block*Spacing	1	0.004	10	0.41	0.5	0.004	10	0.04	0.8
Genotype	2	0.12	2	29.37	0.03*	0.16	2	0.71	0.5
Block*Genotype	2	0.0035	10	0.37	0.7	0.22	10	2.27	0.1
Residual	10	0.0097				0.99			

*** Denotes significance at α=0.05**

Effects on Diameter, Height, Flush Length

Overall, ANOVA results indicated that genotype-by-spacing interaction significantly affected diameter ($p<0.01$); however spacing did not have significant impacts on diameter (Table 2). Adams et al. (2007) reported the similar interaction effects between genotype and spacing on diameter at age of 17.The greatest diameter (1cm) occurred in the clone L3791in the narrow spacing; whereas least diameter (0.8cm) occurred in the halfsib with narrow spacing combination (Figure 1b). AFC stock (halfsib) diameter growth varied between the two spacing levels. Furthermore, AFC stock grown on narrow spacing was significantly smaller than the two clones.

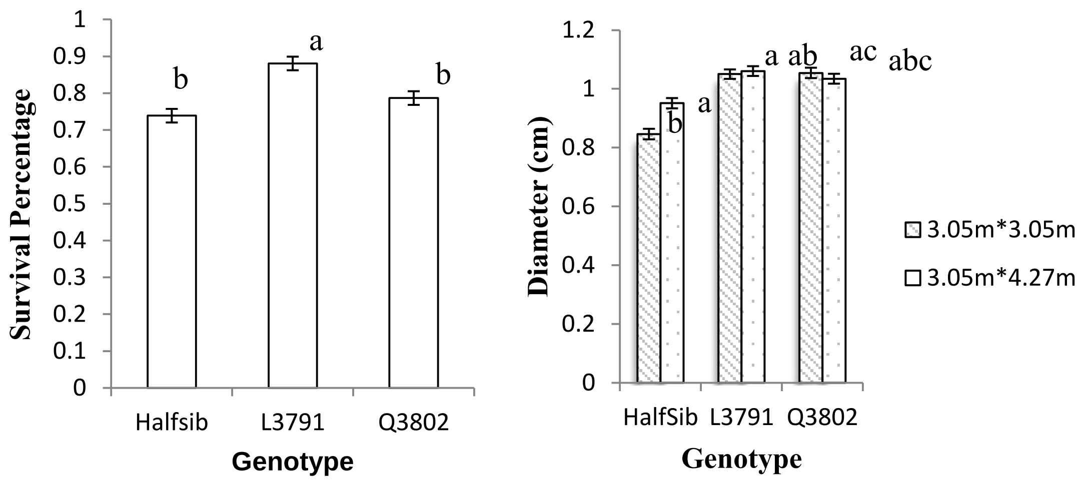

Figure 1. Mean (a) survival percentage by Genotype and (b) diameter by spacing and Genotype after one growing season. Means not followed by a common letter differ significantly (at α =0.05)

No significant effects of spacing or spacing-by-genotype interactions on height were observed, but height did vary significantly among genotype (p =0.05) (Table 2). The greatest height growth was 63.52cm for clone L3791 and the least was 41.66cm in halfsib (Figure 2a). Mulitiple comparisions with standard error and estimate indicated that clone L3791 had significantly greater height growth than the half sib seedling, but height growth was not significantly different between the two clones (L3791 and Q3802).

Also, genotype significantly affected flush length (p=0.01), while the effects of spacing and the interaction between spacing and genotype were not significant on flush length. In contrast to height growth, the flush length growth of clone Q3802 was significantly less than clone L3791 and the half-sib 3-Star stock(Figure 2b).

Table 2: ANOVA table of first year height and second year flush length.

Source	Diameter					Height					Flush length				
	Num DF	MS	Error DF	F value	Pr>F	Num DF	MS	Error DF	F value	Pr>F	Num DF	MS	Error DF	F value	Pr>F
Spacing	1	0.533	1.74	0.51	0.5	1	691.53	1	1.25	0.4	1	20.59	1	5.53	0.2
Block	1	0.0568	1.83	0.03	0.8	1	1761.91	2.34	0.44	0.5	1	29.49	77.136	-0.74	
Block* Spacing	1	0.000005	1924	0	0.9	1	553.64	1795	3.05	0.08	1	3.72	352	0.07	0.7
Genotype	2	4.63	3.59	1.48	0.3	2	69160	2	17.26	0.05*	2	127.15	2	88.97	0.01*
Block* Genotype	2	1.75	1924	23.64	<0.0001	2	4007.12	1795	22.11	<0.001	2	1.42	352	0.03	0.9
Genotype* Spacing	2	1.11	1924	15.08	<0.0001*										
Residual	1924	0.074				1795	181.27				352	52.19			

*** Denotes significance at α=0.05**

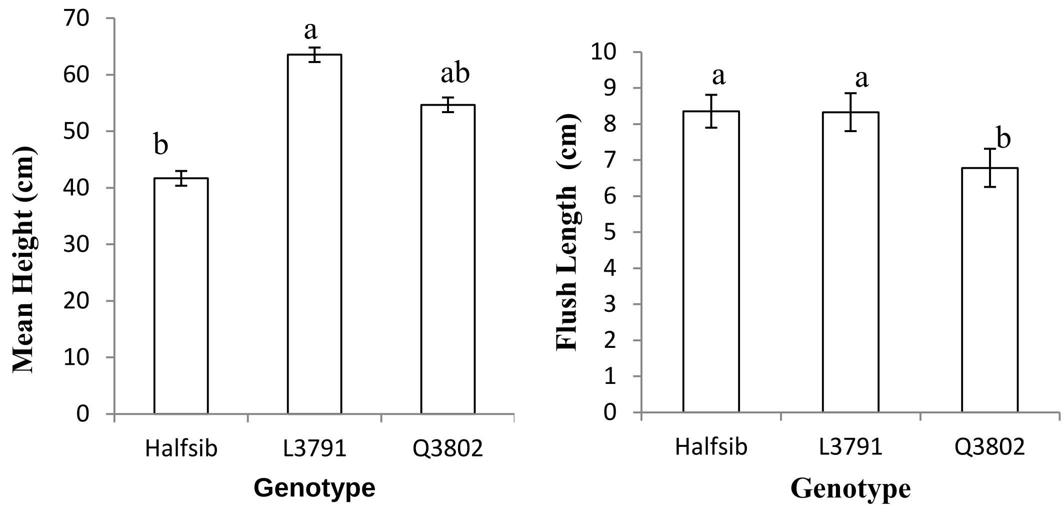

Figure 2. Mean(a) Height by genotype and(b) Flush length by genotype. Means not followed by a common letter differ significantly (at α =0.05)

Conclusion

One of the primary goals of genetic improvement is to enhance the productivity of loblolly pine plantations. Our preliminary results suggest that genotype differences appear very quickly under the conditions of our test site in southeastern Arkansas, and they provide further (albeit limited) support for the use of genetically improved planting stock. Clonal stock was found to have higher rates of survival as well as greater height and diameter growth when compared to half-sib improved stock; however, neither of the clonal varieties consistently outperformed the other in all measures. Across all parameters of interest, spacing/planting density did not vary by a statistically significant margin. These findings are not unexpected, given the early stage of stand development. More time is needed to determine if other factors, such as site conditions or intra- or interspecific competition, may change the outcomes of these measures of success. Although the clonal varieties did outperform the improved half-sibling 3-Star seedlings both in survival and growth, the lower cost and ready availability of the 3-Star stock make it a popular choice for landowners in southeastern Arkansas who want to plant improved loblolly pine. With additional data on relative improvements in stand productivity among clonal, full-sib and half-sib loblolly pine seedlings and with improvements in production and distribution of clonal stock, a greater proportion of forest landowners may seek to invest in genetically improved loblolly pine.

Literature Cited

Adams, J.P., S.B. Land, Jr., K.L. Belli, and T.G. Matney. 2007. Comparison of 17–year realized plot volume gains with selection for early traits for loblolly pine. For. Eol.Manag. 255:1781-1788.

"Arkansas Forestry Commission." Arkansas Forestry Commission.N.p., n.d. Web. 30 May 2013 (https://www.ark.org/afc2/seedlingsales.php).

Cellfor.2010a. Loblolly Pine Variety: CF Q3802 [Brochure].

Cellfor.2010b. Loblolly Pine Variety: CF L3791 [Brochure].

Jansson, G. and B. Li. 2004. Genetic gains of full-sib families from disconnected diallels in loblolly pine. SilvaeGenetica 53(2):60-64.

Larance, F.C., H.V. Gill, and C.L. Fultz.1976.Soil survey of Drew County, Arkansas.USDA Soil Conservation Service and Arkansas Agricultural Experiment Station.86 p.

McKeand, S., T. Mullin, T. Byram, and T. White. 2003. Deployment of genetically improved loblolly and slash pine in the South. J. For. 101(3): 32-37.

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

NOAA.2013.1981-2010 climate normals for Monticello, Arkansas.Online data from http://www.srh.noaa.gov/lzk/?n=wxcntl3.htm, last accessed 5 June 2013.

Prestemon, J.P. and R.C. Abt. 2002.The southern timber market to 2040. J.For.100:16-22.

Wear, D.N. and J.G. Greis (eds.). 2002.Southern Forest Resource Assessment. Gen.Tech. Rep. SRS-53. Ashville, NC: U.S. Department of Agriculture, ForestService, Southern Research Station.