GENETIC EFFECTS ON STAND-LEVEL UNIFORMITY, AND ABOVE- AND BELOWGROUND DRY MASS PRODUCTION IN JUVENILE LOBLOLLY PINE

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Several decades of tree improvement operations have drastically increased loblolly pine plantation productivity in the southern U.S. (McKeand et al., 2003). This work has lead to the availability of a number of highly productive open-pollinated and full-sib families (McKeand et al., 2006). In addition, vegetative propagation (somatic embryogenesis) has also made it possible to clonally multiply elite genotypes (Bettinger et al., 2009). Open-pollinated, full-sib, and clonal trees contain varying amounts of inherent genetic variation which allows land managers to balance the gains and risks of deploying less genetically diverse, yet potentially more productive genotypes (Bridgwater et al., 2005). In many forest plantation species, deployment of clones has been suggested to result in more uniform plantation growth and development (DeBell and Harrington, 1997, Bettinger et al., 2009), and greater stand uniformity may lead to greater resource-use efficiency and enhanced productivity (Binkley et al., 2010, Ryan et al., 2010a). Clones have been suggested to show more uniform growth and development because they possess no tree-to-tree genetic variation (Zobel and Talbert, 1984). However, there are no known studies in loblolly pine and few other forest plantation species that have directly investigated the impact of genetic homogeneity on stand growth, development, and uniformity. Furthermore, genetic variation in stand uniformity and above- and belowground dry mass partitioning may ultimately impact stand resource capture and carbon (C) sequestration. Additionally, increases in C sequestration with genetically improved loblolly pine genotypes will be proportional to increases in volume or dry mass production (Ryan et al., 2010b). Therefore, with rising atmospheric CO_2 concentrations expected to continue, increases in above- and belowground dry mass production with improved loblolly pine genotypes could provide a potential means of increasing C sequestration and offsetting further fossil fuel emissions (Johnsen et al., 2001, Ryan et al., 2010b).

The goal of this study was to compare stand-level uniformity, dry mass production, and partitioning among several loblolly pine genotypes which possess varying amounts of inherent genetic variation. Our hypothesis was that less genetically diverse genotypes (clones) would show more uniform stand-level growth relative to more genetically diverse genotypes (full-sib and half-sib families). To examine genetic effects on stand uniformity and productivity, we grew ten different genotypes (3 open-pollinated families, 3 full-sib families, 3 clones, and 1 seed orchard mix variety) in a plantation setting for four years, at two different planting densities (~539 and 1077 trees ha^{-1}), and used allometric relationships to estimate standing dry mass and annual dry mass production. The study site was located at North Carolina State University's Hofmann Forest in Onslow County, North Carolina (34°49.4'N, 77°18.2'W).

In the low planting density treatment, age 3 total standing dry mass of the most productive genotype (5.8 Mg ha^{-1}) was 82% higher than that of the least productive genotype (3.2 Mg ha^{-1}) (Figure 1). In the high planting density treatment, age 3 total standing dry mass of the most productive genotype (11.4 Mg ha^{-1}) was 110% higher than that of the least productive genotype (5.4 Mg ha^{-1}) (Figure 1). Genetic differences in annual dry mass production were of a similar magnitude with peak rates during the third year as high as 4.2 and 8.2 Mg ha^{-1} yr^{-1} in the low and high planting density treatments, respectively. More genetically homogeneous genotypes did not show greater stand-level uniformity under operational management conditions. Over time, genotypes showed no consistent differences in the coefficient of variation (CV) for ground-level diameter; however, two full-sib and two half-sib families showed significantly lower CV's for total tree height than all three clones. Moreover, genotypes with lower CV's for height growth displayed greater stand-level dry mass production which supported the premise that greater stand uniformity will lead to enhanced productivity. Since uniformity and stand-level productivity of loblolly pine clones will be principally governed by environmental heterogeneity, our results highlight the need for silvicultural prescriptions that maximize site uniformity. In addition, our results demonstrate how the deployment of highly productive loblolly pine genotypes may provide a means of enhancing southern pine ecosystem sustainability by sequestering C in both harvestable aboveground biomass and woody belowground biomass.

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LITERATURE CITED

Bettinger, P.; Clutter, M.; Siry, J.; Kane, M.; Pait, J. 2009. Broad implications of southern United States pine clonal forestry on planning and management of forests. 2009. International Forestry Review. 11(3): 331-345.

Binkley, D.; Stape, J.L.; Baurle, W.L.; Ryan, M.G. 2010. Explaining growth of individual trees: light interception and efficiency of light use by Eucalyptus at four sites in Brazil. Forest Ecology and Management. 259: 1704-1713.

Bridgwater, F.; Kubisiak, T.; Byram, T.; McKeand, S. 2005. Risk management with current deployment strategies for genetically improved loblolly and slash pines Southern Journal of Applied Forestry. 29: 80-87.

DeBell, D.S.: Harrington, C.A. 1997. Productivity of Populus in monoclonal and polyclonal blocks at three spacings. Canadian Journal of Forest Research. 27: 978-985.

Johnsen, K.H.; Wear, D.; Oren, R.; Teskey, R.O.; Sanchez, F.; Will, R.; Butnor, J.; Markewitz, D.; Richter, D.; Rials, T.; Allen, H.L.; Seiler, J.; Ellsworth, D.; Maier, C.; Katul, G.; Dougherty, P.M. 2001. Meeting global policy commitments: carbon sequestration and southern pine forests. Journal of Forestry. 99(4): 14-21.

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

Mckeand, S.E.; Jokela, E.J.; Huber, D.A.; Byram, T.D.; Allen, H.L.; Li, B.; Mullin, T.J. 2006. Performance of improved genotypes of loblolly pine across different soils, climates, and silvicultural inputs. Forest Ecology and Management. 227: 178-184.

Ryan, M.G.; Stape, J.L.; Binkley, D.; Fonseca, S.; Loos, R.A.; Takahashi, E.N.; Silva, C.R.; Silva, S.R.; Hakamada, R.E.; Ferreira, J.M.; Lima, A.M.N.; Gava, J.L.; Leite, F.P.; Andrade, H.B.; Alves, J.M.; Silva, G.G.C. 2010a. Factors controlling Eucalyptus productivity: How water availability and stand structure alter production and carbon allocation. Forest Ecology and Management. 259: 1695-1703.

Ryan, M.G.; Harmon, M.E.; Birdsey, R.A.; Giardina, C.P.; Heath, L.S.; Houghton, R.A.; Jackson, R.B.; McKinley, D.C.; Morrison, J.F.; Murray, B.C.; Pataki, D.E.; Skog, K.E. 2010b. A synthesis of the science on forests and carbon for U.S. Forests. Issues in Ecology. 13: 1-16.

Zobel B.J.; Talbert, J. 1984. Applied forest tree improvement. New York: John Wiley & Sons. 413 p.

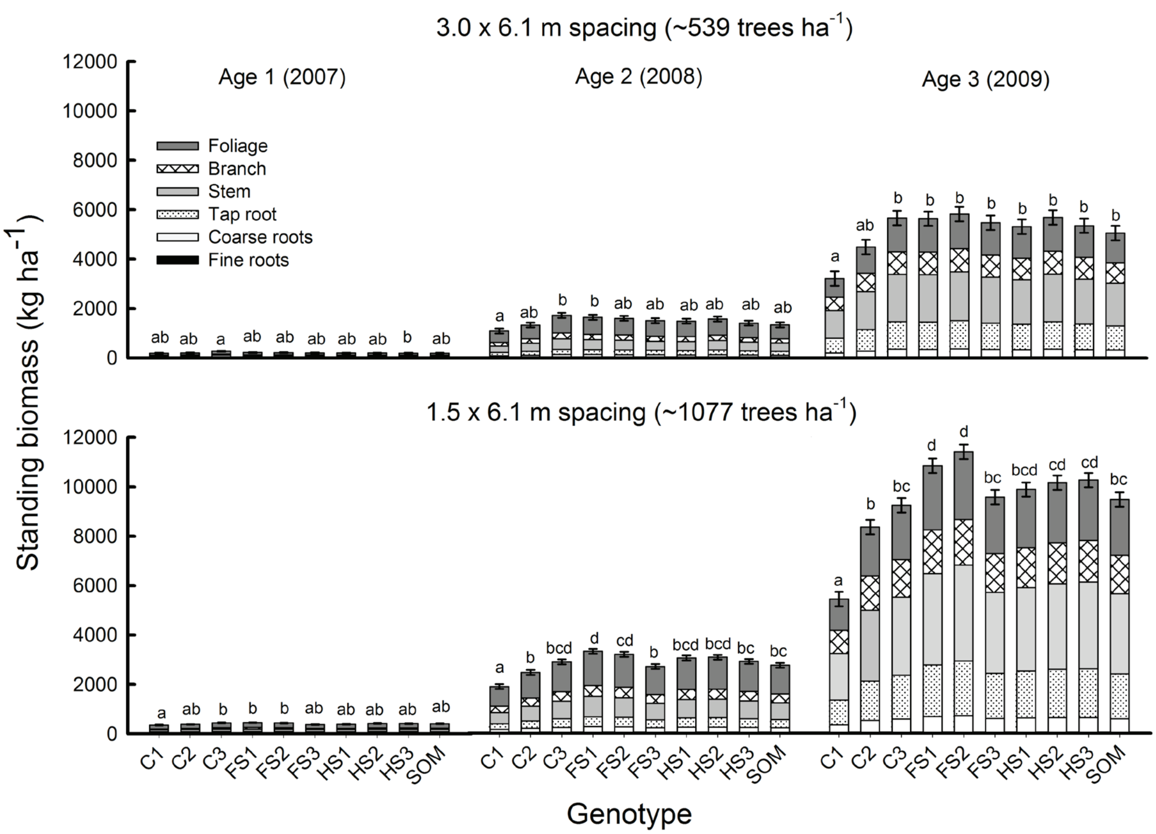

Figure 1—Estimates of component and total standing dry mass among different loblolly pine clones (C1, C2, C3), full-sib families (FS1, FS2, FS3), half-sib families (HS1, HS2, HS3), and one seed orchard mix (SOM) variety after three years of growth in the Hofmann Forest Genetics × Spacing × Thinning (GST) study on the lower Coastal Plain of North Carolina. Within each age group and spacing treatment, genotypes with the same letters are not significantly different at the P≤0.05 significance level.