SILVICULTURE OF VARIETAL LOBLOLLY PINE PLANTATIONS: SECOND YEAR IMPACTS OF SPACING AND SILVICULTURAL TREATMENTS ON VARIETIES WITH DIFFERING CROWN IDEOTYPES

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ABSTRACT

A long-term study has been established to address the following objectives: 1) Evaluate the crown ideotype approach to clonal testing in loblolly pine; 2) Determine impacts of increasing genetic uniformity on growth and uniformity of loblolly pine plantations; 3) Compare growth response, carbon allocation patterns (above and below ground), and ecophysiological processes of loblolly pine clones under different management intensities and planting densities; and 4) Compare the effects of different climatic and edaphic conditions and silvicultural regimes on growth and ecophysiology of loblolly pine varieties. This study has two North American installations in the southeastern United States (Virginia Piedmont, North Carolina Coastal Plain) and one South American installation in Brazil (Santa Catarina State). A split-split plot design was used in this study with two levels of silviculture (operational, intense), as the main plot treatment, six genotype entries (1 open pollinated, 1 control pollinated, 4 clonal) as the split-plot treatment, and three planting densities (250, 500, and 750 trees per acre) as the split-split plot treatment. The clones were a range of crown ideotypes, with two moderately wide crown ideoptypes and two broad crown ideotypes. Second year growth responses are presented.

INTRODUCTION

Despite the large gains in productivity resulting from previous forestry research, growth rates in many loblolly pine (*Pinus taeda* L.) plantations in the United States remain well below what is possible (Amateis et al. 2000, Borders and Bailey 2001, Jokela et al. 2000). As silvicultural inputs become more intensive and tree improvement efforts continue to produce more intensively selected and less genetically heterogeneous full-sib families or clones, there is a greater need to understand how elite genotypes respond to silvicultural manipulations (Li et al. 1991). For this reason a long-term study has been established to address the following objectives: 1) Evaluate the crown ideotype approach to clonal testing in loblolly pine; 2) Determine impacts of increasing genetic uniformity on growth and uniformity of loblolly pine plantations; 3) Compare growth response, carbon allocation patterns (above and below ground), and ecophysiological processes of loblolly pine clones under different management intensities and planting densities; and 4) Compare the effects of different climatic and edaphic conditions and silvicultural regimes on growth and ecophysiology of loblolly pine varieties.

METHODS

STUDY ESTABLISHMENT AND LOCATION

This study has two North American installations that were established within the United States (Virginia Piedmont, North Carolina Coastal Plain) in 2009 and one South American installation was established within Brazil (Santa Catarina State) in 2011. These three locations were selected to form a gradient of productivity within the planted range of loblolly pine. The Virginia Piedmont site was chosen to represent the lower end of loblolly pine productivity due to the increased intensity and duration of winter. The soil at this installation is mapped as a well drained Fairview series (Fine, kaolinitic, mesic Typic Kanhapludults). The North Carolina Coastal Plain site was selected to be representative of more typical conditions for loblolly pine planted in the southern United States. The soil series at this installation is mapped as a somewhat poorly to poorly drained Rains series (Fine-loamy, siliceous, semiactive, thermic Typic Paleaquults). The Brazil site was selected to represent the upper end of productivity for loblolly pine in the world (Cubbage et al. 2007). Since the Brazil site has not yet completed a growing season, the remainder of this report is restricted to the two North American installations.

STUDY DESIGN

A split-split plot designed was used in this study (Fig. 1). The main plot treatment was two levels of silviculture (operational, intense), the split-plot treatment was six different genotype entries (1 open pollinated, 1 control pollinated, 4 clonal), and the split-split plot treatments was three different planting densities (250, 500, 750 trees

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per acre). Operational silviculture consisted of practices commonly used by many landowners over a typical rotation for loblolly pine including strategic weed control and nutrient amendments. Intensive silviculture consisted of practices intended to approach the maximum growth rate of loblolly pine for existing soil and climate conditions at each installation. These intense practices included attempts at complete and sustained weed control as well as the avoidance of nutrient limitations.

Six genetic entries (varieties) provided by Arborgen were used as the split-plot treatments. These included one open-pollinated family (op), one control-pollinated family (mcp), and 4 different clones (c1, c2, c3, c4). Each entry is from Atlantic coastal plain sources. The clones included a range of crown ideotypes: c1 and c2 were moderately wide crown ideotypes; c3 and c4 were broad crowns ideotypes. The open-pollinated and control-pollinated seedlings were bare-root stock. All clonal material was containerized.

Three different initial planting densities served as the split-split plot treatments (250, 500, and 750 trees per acre). The 250 trees per acre planting density was designed as a sawtimber regime where diameter growth is maximized. The 500 trees per acre planting density was designed as a mixed product regime including both pulp and sawtimber production. The 750 trees per acre planting density was designed as a pulpwood or biomass regime. The spacing between planting rows in all three densities was 12 feet. To achieve the desired densities, the tree spacing on each planting row was 14.5 feet for the 250 trees per acre planting density, 7.26 feet for the 500 trees per acre planting density, and 4.84 feet for the 750 trees per acre planting density. Planting spaces were measured and marked with pin prior to planting. Seedlings were hand-planted at both North American installations during February-March 2009. Following planting, the location of all trees at each installation was georeferenced to sub-meter accuracy.

The study was replicated four times at the Virginia Piedmont installation, and three times at the North Carolina Coastal Plain installation. Each split-split plot (planting density) was intended to include 81 trees in a 9 row by 9 planting space configuration, permitting a 5 by 5 (25 tree) internal measurement plot with two rows available for destructive sampling and an additional two rows serving as a buffer from adjacent treatments. Due to area constraints this was not possible for all replications at each installation. When plot size was restricted by area, each split-split plot included 63 trees in a 7 row by 9 planting space configuration. At the Virginia Piedmont installation three replications were established using the 81 tree design, and one replication established using the 63 tree design. All replications at the North Carolina Coastal Plain installation were established using the 63 tree design. Large buffers of several planting rows were established between the main plots (silviculture intensity).

FIRST YEAR TREATMENTS

The silviculture applied within each treatment level (operational and intense) was similar, but due to varying site conditions, particularly drainage, there were some differences. The Virginia Piedmont installation was chemically site prepared using an aerial application of 4 quarts of Accord XRT II + 4 quarts of Milestone VM Plus + 20 ounces of Chopper with 20 ounces of DLZ oil per acre. A broadcast burn was completed following the chemical site preparation. Banded herbaceous weed control was applied following planting in the operational silviculture treatment; broadcast weed control was applied in the intense silviculture treatment. The North Carolina Coastal Plain installation was chemically site prepared with a ground application of 32 ounces of Chopper + 5 quarts of Krenite + 21 ounces of Garlon XRT with 32 ounces of methylated seed oil per acre. The site was V-blade bedded with 12 feet between bed centers using a Savannah bedder. Banded herbaceous weed control was applied following planting in the operational silviculture treatment; broadcast weed control was applied in the intense silviculture treatment.

SECOND YEAR TREATMENTS

There was considerable mortality on many plots at the Virginia Piedmont installation following the first growing season. Given that initial density is a treatment in this study, mortality within the future internal measurement plots was replanted. Greenhouse reserves of extra seedlings from the initial establishment planting were planted as available, but were limited in number. Virginia state nursery bareroot seedlings were used to replant remaining mortality.

Following the first growing season a second broadcast herbaceous weed control was applied on the intense silviculture plots at both locations using 4 ounces of Arsenal AC + 2 ounces of Oust XP in 10 gallons of water per acre. At the Virginia Piedmont location 0.25 ounces per acre of Escort was added to control blackberry. A fertilization treatment of 100 pounds nitrogen + 10 pounds of phosphorous per acre in the form of Arborite coated urea fertilizer (39-9-0) was applied by hand to the intense silviculture plots following the first growing season. This was applied to individual living trees at a rate of 0.5 pounds per tree due to the varying planting densities.

MEASUREMENTS

Measurements were taken in January following the first and second growing season at each location. Following the first growing season the total height of each tree was measured. Evidence of disease and damage was recorded for each tree. At both locations the area immediately surrounding each tree was given a categorical evaluation of site prep quality, soil drainage, and weed control efficacy. At the coastal plain location bed height was measured at each tree. Following the second growing season measurements of each tree included total height and height to live crown. Each tree was again inspected for disease and damage. The diameter at breast height and crown width was measured on a subset of 25 trees in each split-split plot following the second growing season. Foliage samples were collected at the time of measurement each year.

RESULTS AND DISCUSSION

CROWN WIDTH

Crown width was measured on a subset of 25 trees within each measurement plot following the second growing season. At the North Carolina Coastal Plain installation most varieties had an average crown width near 3.5 feet in the intensive plots and around 2.5 feet in the operational plots (Table 1.). At the time of measurement there was not a significant silviculture effect on crown width, but there were differences between varieties. All of the clones were significantly different from the open pollinated variety, but only clone 4 was different from the control pollinated variety. There was a significant difference in crown width between clone 3 and clone 4, both broad crown ideotypes. That difference is most notable in the operational plots. There were differences by density but no discernable trend at the time of measurement. There was no significant difference in crown width between the North Carolina Coastal Plain and Virginia Piedmont installations. However, there was a significant silviculture effect at the Virginia Piedmont installation. Crown widths in the intense plots at the Virginia Piedmont averaged at least 3.5 feet for all varieties, but only clone 2 and clone 4 approached that width in the operational plots. There were significant varietal differences: clone 4 was significantly wider than all other varieties except clone 2. All of the clones except clone 1 were significantly wider than the control and open pollinated varieties. The two moderate crown ideotypes, clone 1 and clone 2, were significantly different in crown width. There was no significant density effect overall, but there was an individual difference for clone 2.

STEM VOLUME

After 2 growing seasons about 40 percent of the trees at the North Carolina Coastal Plain installation had a measurable diameter at a height of 4.5 feet (Table 2.). From those measurements stem volume was calculated using the square of diameter at breast height multiplied by the total height (d^2h). The stem volume in the intense plots at the North Carolina Coastal Plain installation averaged 0.4 cubic inches for most varieties except for the open pollinated trees. In the operational plots, stem volume averaged half that of the intense plots, but there was no significant silviculture effect found. This can be likely be attributed, in part, to considerable variation in this metric following only two growing seasons. However, such a degree of variation, even found within the intense plots underscores the early importance of microsite conditions on growth in somewhat poorly to poorly drained soils. There were significant differences by variety in stem volume: clone 2 had significantly more volume than all others except clone 1 and clone 3. The open pollinated variety had significantly less volume than all other varieties except clone 4. There were overall density differences as well, but no discernable trends.

At the Virginia Piedmont installation over 80% of the trees had a measurable diameter at a height of 4.5 feet, but there was no location effect between the Virginia Piedmont and North Carolina Coastal Plain for stem volume. There was a significant silviculture effect on stem volume at the Virginia Piedmont installation. In the intense plots, stem volume averaged about 0.5 cubic inches for the clonal varieties compared to only about 0.3 cubic inches in the operational plots. There were no significant differences amongst the 4 clones in the piedmont, but the 4 clones did have significantly more stem volume than the control pollinated variety which, in turn, had significantly more stem volume than the open pollinated variety. There were significant differences in stem volume attributed to density, but again no clear trends for those density effects at the time of measurement. At both the Virginia Piedmont and North Carolina Coastal Plain installations there were no significant differences in stem volume amongst clones of the same ideotype. As at the North Carolina Coastal Plain installation, there was considerable variation in stem volume at the Virginia Piedmont installation.

CONCLUSIONS

Although two growing seasons is far from an adequate length of time to draw meaningful conclusions from a study designed to address questions that may take a full rotation to fully explore, there are some interesting trends evident early in the life of this study. The impact of increasing genetic uniformity has highlighted the considerable amount of variation in growth that can be expressed early in the life of a stand. This variation is likely largely due to microsite effects. Interestingly, through two growing seasons the performance of the seedlings at Virginia Piedmont installation has exceeded that of the North Carolina Coastal Plain installation. As this study matures this condition is expected to reverse. Subsequent fertilization treatments will likely remedy any innate phosphorous deficiencies, and improved soil aeration from a lowering water table will likely allow the North Carolina Coastal Plain installation to express the greater expected potential growth rates compared to the Virginia Piedmont installation. Following two growing seasons, among clones of the same ideotype performance has been largely consistent. There were no significant differences for tree height, height growth, live crown length, diameter at breast height, or stem volume found amongst clones of the same ideotype; however, there were some significant differences in crown volume and crown width.

This report does not attempt to address the results following two growing seasons in relation to each previously stated study objective. However, it is expected that subsequent work by a team of international collaborators as this study matures will yield meaningful results that address not only longstanding, unanswered biological questions, but also timely issues concerning the future of intensive plantation management.

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Table 1—Mean crown width measured following the second growing season of the study for each variety, initial planting density, silviculture level, and installation location. Crown widths are reported to the nearest tenth of a foot

Variety	North Carolina Coastal Plain						Virginia Piedmont					
	Intense silviculture			Operational silviculture			Intense silviculture			Operational silviculture		
	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa
	feet (std. err.)											
c1	3.6 (0.7)	3.5 (0.8)	3.7 (0.7)	2.7 (0.6)	2.4 (0.5)	2.1 (0.5)	3.4 (0.5)	3.6 (0.5)	3.4 (0.4)	2.9 (0.4)	2.6 (0.4)	2.9 (0.4)
c2	4.0 (0.8)	3.7 (0.9)	3.8 (1.0)	2.5 (0.6)	2.3 (0.7)	2.3 (0.6)	4.3 (0.6)	3.8 (0.7)	3.6 (0.6)	3.3 (0.4)	3.3 (0.4)	3.3 (0.5)
c3	3.3 (0.8)	3.1 (0.8)	3.1 (0.7)	2.2 (0.5)	2.6 (0.6)	2.6 (0.5)	3.6 (0.4)	3.6 (0.5)	3.5 (0.5)	2.8 (0.4)	3.0 (0.4)	3.1 (0.4)
c4	3.3 (0.7)	3.5 (0.7)	3.5 (0.7)	2.6 (0.6)	3.5 (0.7)	3.2 (0.8)	4.3 (0.4)	4.3 (0.3)	4.1 (0.5)	3.6 (0.4)	3.3 (0.3)	3.5 (0.4)
mcp	3.4 (0.8)	3.3 (0.8)	3.3 (0.9)	2.2 (0.5)	2.3 (0.6)	1.9 (0.5)	3.2 (0.5)	2.9 (0.5)	3.1 (0.5)	2.4 (0.4)	2.7 (0.3)	2.6 (0.3)
op	2.4 (0.6)	3.3 (0.7)	2.4 (0.6)	1.9 (0.6)	2.3 (0.5)	1.9 (0.5)	3.2 (0.6)	3.2 (0.6)	3.0 (0.6)	2.6 (0.4)	2.6 (0.4)	2.7 (0.4)

Table 2—Mean stem volume calculated using the d^2h method following the second growing season of the study for each variety, initial planting density, silviculture level, and installation location. Stem volumes are reported to the nearest tenth of a cubic inch

Variety	North Carolina Coastal Plain						Virginia Piedmont					
	Intense silviculture			Operational silviculture			Intense silviculture			Operational silviculture		
	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa	250 tpa	500 tpa	750 tpa
	inches^3 (std. err.)											
c1	0.5 (0.3)	0.4 (0.2)	0.4 (0.2)	0.2 (0.1)	0.2 (0.1)	0.1 (0.1)	0.5 (0.2)	0.5 (0.2)	0.5 (0.2)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)
c2	0.5 (0.3)	0.6 (0.3)	0.6 (0.4)	0.2 (0.2)	0.3 (0.2)	0.2 (0.1)	0.6 (0.3)	0.5 (0.2)	0.5 (0.2)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)
c3	0.4 (0.2)	0.5 (0.3)	0.3 (0.2)	0.2 (0.1)	0.3 (0.2)	0.3 (0.2)	0.6 (0.2)	0.5 (0.2)	0.6 (0.2)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)
c4	0.3 (0.1)	0.3 (0.2)	0.3 (0.2)	0.1 (0.1)	0.3 (0.2)	0.2 (0.1)	0.5 (0.2)	0.6 (0.2)	0.5 (0.2)	0.3 (0.1)	0.2 (0.1)	0.2 (0.1)
mcp	0.4 (0.3)	0.4 (0.3)	0.4 (0.3)	0.2 (0.1)	0.2 (0.1)	0.1 (0.0)	0.3 (0.2)	0.3 (0.1)	0.3 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.0)
op	0.1 (0.1)	0.2 (0.1)	0.1 (0.0)	0.2 (0.1)	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)

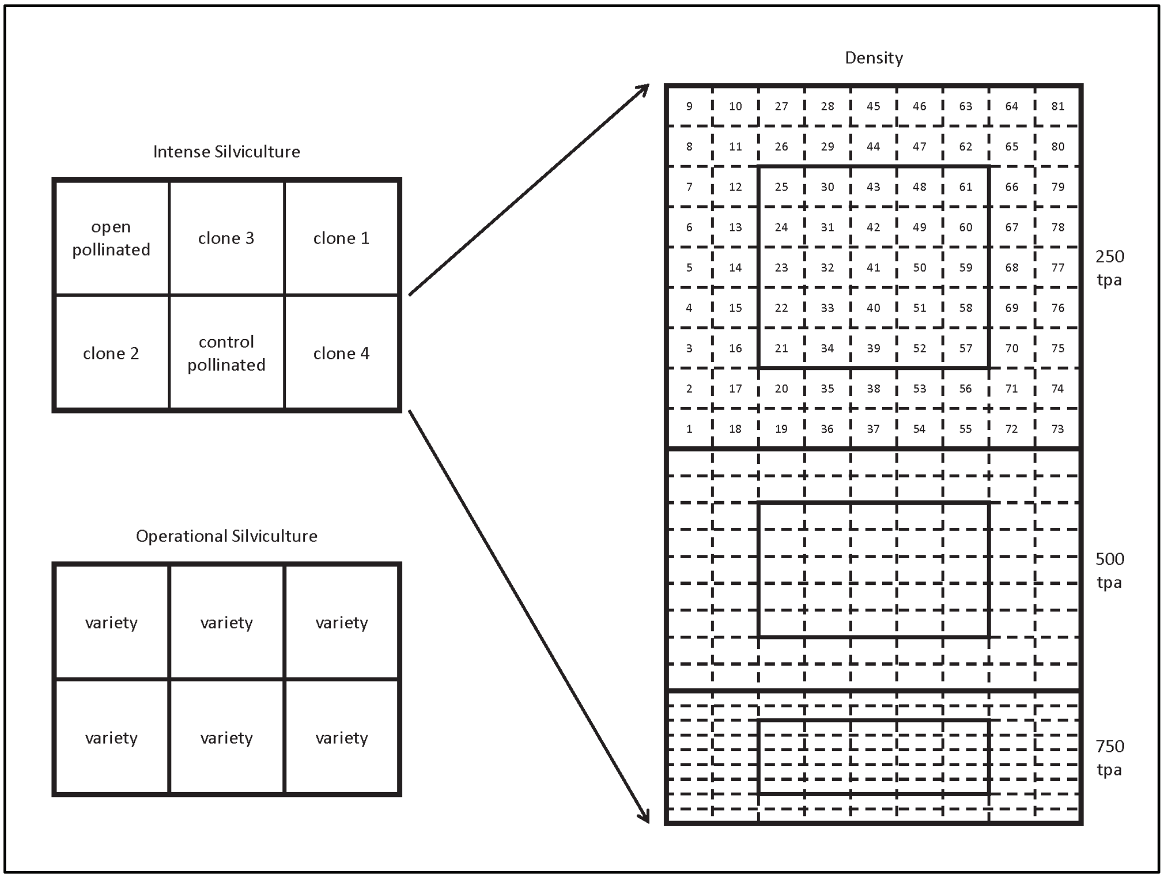

Figure 1—Hypothetical layout of a full replication of the split-split plot study design including two levels of silviculture as the main plot treatments, six different varieties as the split plot treatment, and three initial planting densities as the split-split plot treatment