VOLUME AND CROWN CHARACTERISTICS OF JUVENILE LOBLOLLY PINE GROWN AT VARIOUS RATIOS OF BETWEEN AND WITHIN ROW SPACINGS

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Abstract—In plantation forestry, several silvicultural treatments can be row oriented. When rows are treated individually, planting trees in wider rows may result in lower silvicultural treatment cost, facilitate future operations, such as thinning and fire fighting, and provide a longer period with open canopy conditions. All these scenarios could provide benefit to landowners, depending on management objectives. Few studies have considered the effects of asymmetrical spacing on tree growth, stand yield, or wood quality. This study examines tree and stand attributes for loblolly pine (*Pinus taeda* L.) grown at five rectangular spacings for a common stand density. The treatments include spacings of 9 by 8 feet, 12 by 6 feet, 15 by 4.8 feet, 18 by 4 feet, and 24 by 3 feet; these planting arrangements represent between-row to within-row spacing ratios of 1 to 1, 2 to 1, 3 to 1, 4 to 1, and 8 to 1, respectively. Tree and stand volumes and branching characteristics after the ninth-growing season are presented.

INTRODUCTION

Initial planting density of trees has long been of interest to managers of plantation forests; however, the spatial arrangement has not received the same degree of study. Many "spacing" studies for southern pines have focused on the volume response and stand dynamics of plantations grown at various densities. Only a few studies have reported the response of plantations to various spacing arrangements.

The literature addressing asymmetrical arrangement (rectangularity) of southern pine plantations is limited (Lock 1977). Some agroforestry applications provide insight although the extremely rectangular spatial arrangements would possibly be beyond practical limits for commercial timber operations. Lewis and others (1985) report no statistical differences between an 8- by 12-foot and a 4- by 24-foot spacing for survival, height, diameter, and volume in 13-year-old slash pine (*Pinus elliottii* Engelm). It should be noted that these stands were in a very early stage of development with approximately 50 square feet of basal area. Sharma and others (2002) report survival, height, diameter, basal area, and volume were not statistically different nor were the distributions of height and diameter between a nominal 1-to-1 and 3-to-1 spacing ratio at age 16 years in loblolly pine (*P. taeda* L.) stands located in the Southeastern United States. At age 19 years results from the project previously cited indicate that rectangularity had no significant effect on potential timber products. The 3-to-1 spacing ratio did have a larger maximum branch size but this was not attributed to spacing arrangement (Amateis and others 2004).

Rectangularity comparisons have been published with other forest tree species, as well. Rectangular arrangements at 1-to-1 and 4-to-1 ratios with half-sib maritime pine (*P. pinaster* Ait.) in southwestern France showed no statistical differences in height, diameter, or basal area at age 16 years (von Euler and others 1992). In Lithuania, rectangularity of 4 to 1 or 5 to 1 had an insignificant influence on stem quality of *Pinus sylvestris* (Malinauskas 2003). With *Eucalyptus nitens* (Deane and Maiden), no differences in growth or the size of the largest branch in the lower 6 m were detected between square and rectangular spacing ratio up to 2.5 to 1 (Gerrand and Neilsen 2000). An objective of this study was to test the effects of varying spatial arrangement on tree and stand level attributes of plantation-grown loblolly pine trees.

METHODS

Site Description and Study Establishment

This study was established in December 1999 on an old field site located in Randolph County, GA. Soils are of the Lakeland sand and Lucy loamy sand series with slopes of <3 percent. Prior to study establishment, the site had been fallow for a number of years and had no hardwood trees. Site preparation consisted of a broadcast fertilization with 500 pounds per acre of 10-10-10 fertilizer including micronutrients and subsoiling in two directions at 90-degree intersections on 3-foot centers. Spacing treatments included 9 by 8 feet, 12 by 6 feet, 15 by 4.8 feet, 18 by 4 feet, and 24 by 3 feet. These planting arrangements represent between-row to within-row spacing ratios of 1 to 1, 2 to 1, 3 to 1, 4.5 to 1, and 8 to 1, respectively. All of these spacing ratios represent 605-trees-per-acre density. All treatments were replicated four times in a randomized complete block design, with blocking around soils series.

Two seedlings of a half-sib Atlantic Coast loblolly pine family were planted at each planting location within the study. In July of the first growing season, one seedling was randomly removed where both seedlings survived. Herbaceous weed control was applied in 6-foot bands during March 2000 and broadcast in March 2001. An additional fertilization treatment was broadcast applied in August 2002 with 47, 20, and 39 pounds per acre of nitrogen, phosphorus, and potassium, respectively.

Measurement and Analysis

During the ninth dormant season, all trees were measured for total height; diameter at breast height; and the presence of stem rust, sweep or crook, forked, and broken tops. A subset

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of 10 healthy trees was randomly selected in each plot for crown and branch measurements, consisting of crown length, crown width across and along rows, number of branches (live and dead) in the first 17.5 feet, and the diameter of the 2 largest branches in the first 8 feet. Means were calculated for each variable and subjected to polynomial regression. Trees with broken tops were excluded from the analysis for height means. Cubic-foot-volume was calculated for each tree using equations for site-prepared loblolly pine developed by Burkhart and others (1987). Individual tree volumes were summed by plot and expanded to estimate per-acre volumes.

RESULTS

Stem and Volume Attributes

Mean height did not differ among spacing treatments and averaged 30.5 feet (table 1). Mean diameter ranged from 5.21 inches for the widest spacing to 5.66 inches for the square spacing. Individual tree volume increased from 2.4 cubic feet to 2.8 cubic feet per tree as spacing ratios decreased. Volume per acre ranged from about 1,400 cubic feet at wider spacing ratios to over 1,600 cubic feet in the square spacing treatment.

Branching and Crown Attributes

The number of branches in the first log averaged 40 per tree and was not different among spacing treatments (table 2). Basal diameter of the largest branch did not differ among treatments and averaged 1.44 inches. The second largest branch diameter was largest for the 18- by 4-foot spacing but this was only 0.03 inches larger than for the 9- by 8-foot spacing.

Crown width between rows differed by treatments; the widest spacing had the widest between-row crown width. Both between-row and within-crown width differed by treatment, yet differences were not directly proportional to row spacing; similar results were reported by Sharma and others (2002). Crowns were longest in the widest row spacing and decreased as row spacing decreased.

DISCUSSION

Establishing plantations with greater rectangularity may provide economic, operations, and nontimber advantages over planting on more square spacing. Plantation establishment often includes treatments applied to rows. As the space between planting rows is increased the cost associated with establishment can be reduced (VanderSchaaf and South 2004).

In locales with strong pulpwood markets thinning operations provide the benefit of intermediate income. Contemporary commercial thinnings in plantations generally include some form of row removal and selection from the remaining trees. Rows are removed at specific intervals to allow access to inferior trees within the remaining rows, leaving trees of superior quality. In row thinnings, potential higher value trees are removed in proportion to the row removal interval. Plantations established using wider row spacing may offer the ability to access inferior trees without removing an entire row. Nontimber related advantages to wider row spacing include a delay in crown closure and the prolonged presence of early successional vegetation, as well as less soil disturbance on sites with potential for erosion.

Table 1—Stem and volume attributes for trees grown at different degrees of rectangularity

Spacing	D.b.h.	Height	Volume per tree	Volume per acre
	inches	*feet*	-------------------- *cubic feet*	--------------------
9 by 8 feet	5.66	31.1	2.8	1,628
12 by 6 feet	5.52	30.3	2.6	1,514
15 by 4.8 feet	5.41	30.3	2.5	1,396
18 by 4 feet	5.42	30.3	2.6	1,434
24 by 3 feet	5.21	30.5	2.4	1,413
Polynomial contrast	------------------------------- *probability of a greater F-value* -------------------------------			
Linear	0.0085	0.7208	0.0442	0.1206
Quadratic	0.4751	0.2595	0.3518	0.1339
Cubic	0.5458	0.4576	0.4065	0.5412
Lack of fit	0.8212	0.9131	0.8698	0.5892

D.b.h. = diameter at breast height.

Table 2—Branch and crown attributes for trees grown at different degrees of rectangularity

Spacing	Between-row crown width	Within-row crown width	Crown length	Number of branches	Largest branch	Second largest branch
	---------- *feet* ----------				---------- *feet* ----------	
9 by 8 feet	10.3	9.7	21.6	40.2	1.40	1.21
12 by 6 feet	11.8	9.0	21.9	41.1	1.52	1.21
15 by 4.8 feet	13.1	8.58	23.3	41.9	1.43	1.20
18 by 4 feet	14.6	8.43	23.7	38.5	1.45	1.24
24 by 3 feet	15.4	8.1	23.6	38.4	1.38	1.04
Polynomial contrast	---------- *probability of a greater F-value* ----------					
Linear	0.0001	0.0169	0.0074	0.1484	0.4048	0.0076
Quadratic	0.0004	0.1562	0.0252	0.8403	0.4599	0.0829
Cubic	0.3928	0.6284	0.4990	0.1502	0.4066	0.4711
Lack of fit	0.7573	0.9900	0.3604	0.3986	0.2609	0.5397

Preliminary results in this study show volume per acre to be slightly lower with wider rows. However, the establishment cost savings and possibility of pure selection thinning for all rows may outweigh the slight volume loss at age 8. As more data are available from plantations with wider row spacings, managers can determine the benefits based on their management objectives.

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