Spacing and Twelve-Year Growth of Slash Pine

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Abstract. Comparison at age 12 of eight spacings of old-field planted slash pine (*Pinus elliottii* Engelm.) shows average tree diameter is positively correlated with spacing. Through the seventh year relationship is linear; beginning in the eighth and intensifying through the twelfth year the relationship is curvilinear. Beginning with the eleventh year, tree height is positively correlated with spacing, although the trend is not entirely consistent. There is a positive curvilinear relationship between crown ratio and spacing. Configuration—square versus rectangular spacings—has not affected diameter growth; merchantable cubic volume yield does not yet show a clear relationship to spacing.

ALTHOUGH the general nature of the effects of spacing of trees on growth is fairly well understood, the magnitude of these effects on individual species is still uncertain. To help clarify the relationship between growth and spacing of planted slash pine, a series of spacing plots was established in 1952 on the George Walton Experimental Forest, Dooly County, Ga.

A previous paper (*2*) presented growth of these plots through age 7. This report describes their condition at the end of 12 growing seasons.

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Methods

The study was established in a field that had been under cultivation the previous year, a site typical of much of the middle coastal plain region with loamy sand soils of the Gilead and Lakeland series. Soil site index (25-year basis) of the field is 65 feet (*4*).

Seedlings were planted in three-quarter-acre plots arranged in a randomized block design. Two blocks were established, each block consisting of one plot for each of eight spacings. These spacings, all of which have at some time been used for slash pine, are: 6 × 6, 6 × 8, 5 × 10, 8 × 8, 6 × 12, 10 × 10, 7½ × 15, and 15 × 15 feet. Good soil moisture conditions and care in handling and planting the seedlings resulted in 97 percent survival at the end of the fourth growing season. Mortality since then has been light. A check at the end of the twelfth year showed a survival of 93 percent for the study as a whole.

Results

Diameter growth.—Diameter growth was consistently favored by the wide spacings (Table 1). A trend first became evident at the end of five growing seasons when tests showed that trees were significantly larger in the plots spaced 10 × 10 feet and wider. Bennett (*2*) is of the opinion that this development marked the beginning of competition for growing space.

Absolute diameter growth of trees declined steadily over the years in all spacings, but the differences in growth from spacing to spacing increased annually since the fifth year. Through the seventh year the difference among spacings was such that the relationship between diameter and stand density was linear—diameter increasing uniformly per unit decrease in density (Fig. 1). During the eighth year a curvilinear trend developed—each unit reduction in density resulting in an increased rate of diameter growth. This effect has intensified through the twelfth year. Data given by Bennett et al. (*1*) indicate that this curvilinear relationship will hold at least through age 20.

Difference in diameter growth among spacings can be explained by variation in crown size. Expressed in terms of crown ratio, crown size is related to stand density in the same way as diameter (Fig. 2). The crown ratio level of each spacing has dropped about 20 percentage points during the last 5 years. The rate of reduction is slightly greater in the closer spacings. However, trees in the closer spacings began to lose their lower branches several years before those in the widest spacings.

The loss of crown in the wide spacings in the absence of competition for light during the early years helps explain declining growth rates of these plots. Heavy loss of crown during the first 12 years in the medium to dense spacings indicates the need for early thinning in these stands if diameter growth is to be maintained at a high level.

Competition for soil moisture was not a factor in growth differences among spacings. Intensive sampling during the seventh and eighth years showed no correlation between soil moisture and stand density (*3*). The lack of difference in moisture among spacings was ascribed to heavy vegetative ground cover in the wider spacings removing water from the soil as fast as the trees in the narrow spacings.

Through age 8, analyses of variance indicated that configuration —square versus rectangular spacings—had no significant effect on tree diameters. Beginning in the ninth year this factor was significant at the 5 percent level. However, when square and rectangular spacings were adjusted to common densities through covariance analysis, configuration was no longer significant. Whether or not this change in the ninth year indicates the beginning of a configuration effect remains to be seen.

Height growth.—Height growth through age 12 averaged 3.1 feet annually. This is slightly above average for young slash pine on old-field sites in the area. Between the age of 2 and 9 there were no significant differences in average height among spacings. At the end of the tenth year significant differences developed. Since the tenth year the pattern has strengthened until it now appears as shown in Table 2.

Trees in the wide spacings were somewhat taller than those in the narrow spacings, but the pattern is not consistent. For instance, the average height in the 15 × 15 spacing is the shortest of the four wider spacings and is not significantly different from the average height in the 6 × 8 spacing. Variation in soil site quality is a probable explanation for this inconsistency. For example, a part of one of the 6 × 6 plots is on a shallow Susquehanna clay soil. The trees on this plot average 2.1 feet shorter than those on the other 6 × 6 plot, which is on Gilead, a deeper soil. A covariance analysis of total height adjusted for site (depth to a fine textured horizon) was used to eliminate some of the soil site quality variation. This analysis showed adjusted heights to be significantly different beginning with

Table 1.—Average Diameter and Diameter Growth by Age and Spacing

Age	Item	Spacing (feet) 6 × 6	6 × 8	5 × 10	8 × 8	6 × 12	10 × 10	7½ × 15	15 × 15	Average
Years		*Inches*								
4	Diameter	1.49	1.39	1.38	1.31	1.40	1.62	1.52	1.55	1.46
	Growth	......	......	......	......	......	......	......	......	......
5	Diameter	2.45	2.70	2.69	2.55	2.67	2.93	2.82	3.02	2.73
	Growth	0.96	1.31	1.31	1.24	1.27	1.31	1.30	1.47	1.27
6	Diameter	2.97	3.37	3.34	3.49	3.59	3.86	3.73	3.96	3.54
	Growth	0.52	0.67	0.65	0.94	0.92	0.93	0.91	0.94	0.81
7	Diameter	3.39	3.96	4.02	4.07	4.11	4.47	4.45	4.74	4.15
	Growth	0.42	0.59	0.68	0.58	0.52	0.61	0.72	0.78	0.61
8	Diameter	3.79	4.34	4.22	4.47	4.60	5.00	5.03	5.44	4.61
	Growth	0.40	0.38	0.20	0.40	0.49	0.53	0.58	0.70	0.46
9	Diameter	4.09	4.68	4.48	4.82	5.02	5.45	5.50	6.09	5.03
	Growth	0.30	0.34	0.26	0.35	0.42	0.45	0.47	0.65	0.42
10	Diameter	4.28	4.91	4.73	5.14	5.34	5.90	5.92	6.67	5.36
	Growth	0.19	0.23	0.25	0.32	0.32	0.45	0.42	0.58	0.33
11	Diameter	4.45	5.10	4.90	5.45	5.60	6.30	6.20	7.20	5.66
	Growth	0.17	0.19	0.17	0.31	0.26	0.40	0.28	0.53	0.30
12	Diameter	4.61	5.32	5.15	5.66	5.89	6.58	6.61	7.66	5.94
	Growth	0.16	0.22	0.25	0.21	0.29	0.28	0.41	0.46	0.28

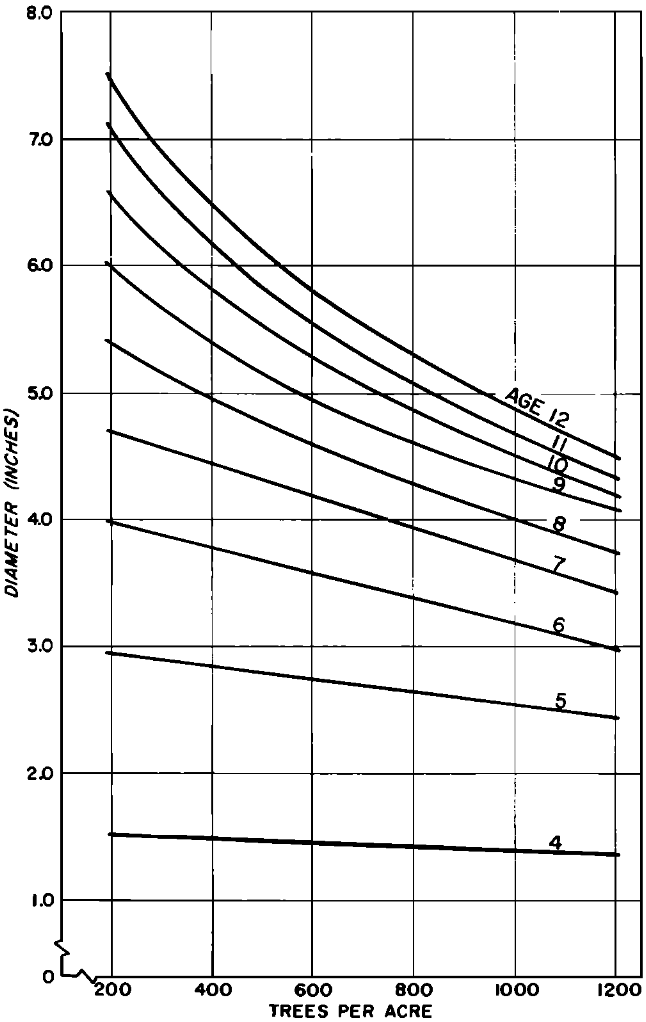

Fig. 1.—*(Left)* Average diameter by age and density.

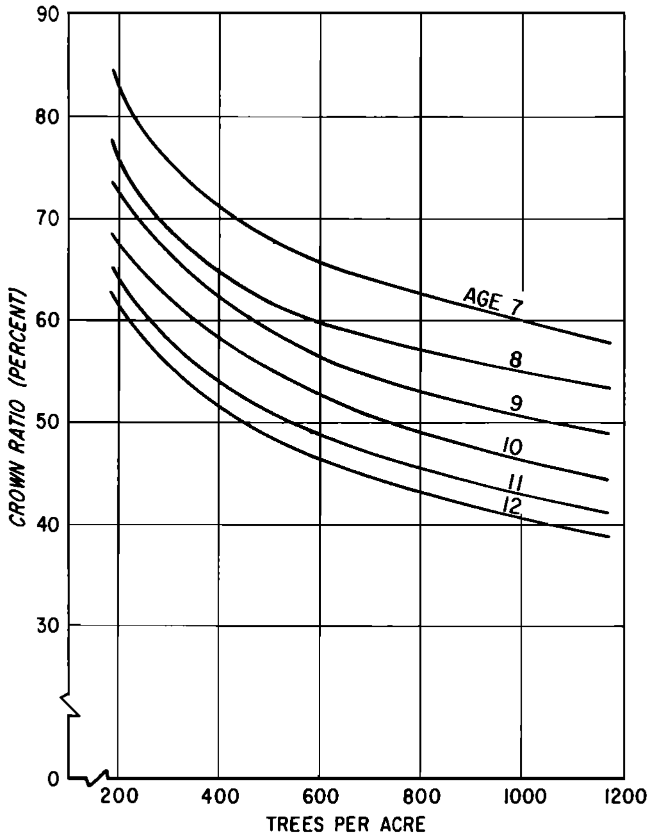

Fig. 2.—Crown ratio percent in relation to trees per acre and age.

the eleventh year. The difference is even more pronounced after the twelfth year, although the significance level still remains at 5 percent.

After adjustment by covariance analysis for site differences, the effect of stand density on dominant height (6 to 8 tallest trees per plot) was not significant, although the *F* ratio was just below that required for significance at the 5 percent level. A more meaningful test, from the management viewpoint, would involve 75 to 100 of the tallest trees per acre. The present height sample did not permit this test, but indications are that the density effect might prove significant with a new height sample of the 75 to 100 tallest trees per acre.

Cubic volume and basal area.—Merchantable cubic-foot volume yield does not vary greatly among stockings of 400 to 900 trees per acre—the 5 × 10 spacing being the only exception (Table 3). Since this spacing is below the 6 × 8 spacing in average height and diameter, a below-average site is apparently responsible for the disparity in yield. Heavy competition has held down the number of trees reaching merchantability in the 6 × 6 spacing and consequently its yield is low. For example, only 58 percent of the 6 × 6 trees have reached merchantability as opposed to 85 percent for the 6 × 8 spacing. Ingrowth will greatly influence the 6 × 6 yield, as well as that of all the closer spacings, within the next few years. Thus, with increasing

Table 2.—Average Height in Feet at Age 12 in Ascending Order[1]

6 × 6	5 × 10	6 × 8	8 × 8	15 × 15	6 × 12	10 × 10	7½ × 15
34.3	35.3	36.6	36.6	37.3	37.5	37.9	38.7

[1]On the basis of Duncan's new multiple range test, values not underscored by the same line are significantly different at the 5-percent level.

Table 3.—Number of Trees, Merchantable Cubic-Foot Volume and Basal Area by Spacing at Age 12

Spacing	Trees per acre: Planted	Surviving	Merchantable[1]	Merchantable trees	Merchantable volume per acre[2]	Total basal area per acre
Feet	*Number*			*Percent*	*Cu. ft.*	*Sq. ft.*
6 × 6	1,210	1,132	655	58	1,041	136
6 × 8	907	835	708	85	1,439	132
5 × 10	871	820	661	81	1,233	122
8 × 8	681	651	588	90	1,398	116
6 × 12	605	541	506	94	1,355	105
10 × 10	436	393	383	97	1,367	95
7½ × 15	387	362	353	98	1,281	88
15 × 15	194	183	183	100	975	60

[1]4.6 inches d.b.h. or greater.
[2]Volume to a 4-inch top, outside bark.

age, yield in relation to spacing can be expected to assume a more normal pattern—the greater densities producing the greater yields.

Basal area in relation to spacing shows a very consistent pattern—increasing as number of trees per acre increases. However, the relationship is asymptotic, leveling off sharply at basal area yields between 800 and 1,200 trees per acre. This illustrates the progressively depressing effect of the higher densities on diameter growth (Table 3).

In summary, diameter increased uniformly per unit decrease in density through the seventh year. From the eighth to the twelfth year the trend changed and each unit of reduction of density resulted in an increased rate of diameter growth. This effect has intensified through the twelfth year and is greatest in the denser spacings. The changes in crown ratios with age and density follow a similar pattern, the decline in crown ratio is the obvious explanation for the declining diameter growth. Basal area yields level off sharply between densities associated with 800 to 1,200 trees per acre. Merchantable cubic foot volume has not yet developed a definite pattern. The higher densities appear to have a depressing effect on height growth, although the trend is not yet consistent.

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HARDWOOD REGENERATION—THE DANISH APPROACH

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Abstract. Danish hardwood silviculture is based upon several tenets developed over more than two centuries with species having counterparts with similar silvical characteristics in America. These include, the desirability of even-aged stands, need for abundant stocking, and the importance of genetics. Natural beech regeneration is achieved by a passive program without soil preparation that depends upon openings in the overstory to encourage reproduction or active measures that include soil disturbance during a good seed year. Plantations typically contain about 8,000 seedlings per acre with nurse trees or standards. Oak is regenerated almost exclusively by artificial means planted at the rate of about 4,800 per acre. Ash and the maple may be planted about 2,700 seedlings per acre. Mixed plantations of conifers with hardwoods are sometimes made to gain early revenue from the sale of Christmas trees and greens and small fence poles. Hardwood regeneration procedures are expensive, but even so, the Danes are willing to make this investment on good sites in order to develop productive high-yielding hardwood stands.

ALL OF THE commercially important indigenous tree species in Denmark are hardwoods. Although exotic conifers have been introduced into the country to satisfy the considerable demand for softwood materials, hardwoods still constitute about one-half of the timber harvest. European beech (*Fagus sylvatica* L.), popularly regarded as the national tree of Denmark, is by far the most important, but oaks (*Quercus pendunculata* Ehrh. and *Q. sesseliflora* Ehrh.), European ash (*Fraxinus excelsior* L.), and sycamore maple (*Acer pseudoplatanus* L.) contribute significantly to the Danish timber economy.

The existence of second and even third generations of managed stands reflect the ability of Danish foresters to successfully grow hardwoods. In many instances intensive management dates back to turn of the 19th century. On Sorø Forest District 1 management records were started in the 15th century and at Wedellsborg and Frederiksgave there have been only three district foresters in 118 years. Thus, in a sense present forests are "man made." A review of the techniques employed so successfully by the Danes in hardwood reproduction provide American foresters with much valuable information especially in view of our frequent lack of success in regenerating these species.

Danish hardwood silviculture is based upon several tenets developed from long-standing experience. First is the almost complete agreement about the desirability of even-aged hardwood stands. Second is the very real concern for quality in hardwoods reflected in the large number of seedlings per acre that is sought in reproduction. Measures routinely taken to protect regeneration and young stands from animals, harsh weather conditions, and grass competition are also very much related to the concern for quality. Third is the importance assigned to genetics. Time

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