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FOUR PINE SPECIES GROWN AT FOUR SPACINGS ON THE EASTERN HIGHLAND RIM, TENNESSEE, AFTER 30 YEARS

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Abstract—In 1966, four pine species [loblolly pine (*Pinus taeda* L.), Virginia pine (*P. virginiana* Mill.), shortleaf pine (*P. echinata* Mill.) and eastern white pine (*P. strobus* L.)] were planted at four spacings (6 x 6 foot 9 x 9 foot 12 x 12 feet and 15 x 15 feet) on the eastern Highland Rim near Tullahoma, Tennessee, to evaluate their growth and development. Survival for all species at 6 x 6 foot in 1996 was significantly lower (39 percent) than at the other three spacings (58 to 64 percent). Eastern white pine had significantly higher stand cubic foot volume and economic value than the other three species. Loblolly pine had significantly higher stand volume and economic value than shortleaf pine and Virginia pine. Volume for loblolly pine was highest at 6 x 6 feet (8,820 cubic feet per acre) and lowest at 15 x 15 feet (4,807 cubic feet per acre). Long-existing markets have favored loblolly pine, although markets have recently developed in the area of this study for eastern white pine.

INTRODUCTION

“The Barrens” is an area on the Eastern Highland Rim southeast of Nashville and northwest of Chattanooga. Estimates of its area range from a quarter to a half million acres (Clebsch and Pyne 1995, Shanks 1958). Its forests are predominately hardwoods and are generally low in volume and poor in quality. The dominant species include scarlet oak (*Quercus coccinea* Muenchh.), chestnut oak (*Q. prinus* L.), post oak (*Q. stellata* Wangenh.), blackjack oak (*Q. marilandica* Muenchh.), and southern red oak (*Q. falcata* Michx. var. *falcata*), with a few hickories (*Carya* spp.), elms (*Ulmus* spp.), and ash (*Fraxinus* spp.). Forest composition and appearance reflects a combination of natural factors, particularly a fragipan at 20 to 30 inches, and human causes, including fire, both Native American and settler, grazing, and high grading. In 1961, the University of Tennessee acquired a 860 acre tract in the Barrens southeast of Tullahoma, which became the Highland Rim Forestry Experiment Station (HRFES). During the next few years, Dr. Eyvind Thor established a number of pine evaluation studies at this location, including the species-spacing study reported in this paper.

METHODS AND MATERIALS

The topography of the HRFES is flat to gently rolling. The climate typically is warm humid summers and mild winters. Annual precipitation is 57.6 inches, with 12.5 inches during July and 6.2 inches in January. Average winter temperature is 42 °F, while average summer temperature is 71 °F. There are 196 frost-free days. The soil of the site is Dickson silt loam (fine-silty, siliceous, thermic Glassic Fregindults), which is typical in the Barrens area. As indicated above, it has a fragipan which limits permeability to air, water, and roots. Soils are acidic with low organic matter content and nutrients.

In this study, four species (loblolly pine, shortleaf pine, Virginia pine and eastern white pine) were planted at four

spacings (6 x 6, 9 x 9, 12 x 12, and 15 x 15 feet) in a split-plot design with four replications. In each replication, species were randomly assigned to 2-acre square plots. The main plots were divided into four ½-acre square plots to which each of the four spacings was randomly assigned.

In 1965, the native forest on the site was harvested, cull trees injected with 2,4-D and the area mist-blown to kill the herbaceous vegetation. In the late winter of 1966, 2-0 eastern white pine seedlings and 1-0 seedlings of the other species were planted. The eastern white pine and shortleaf pine seedlings were from TVA's Clinton, Tennessee, nursery, while the loblolly pine and Virginia pine seedlings came from Hiwassee Land Company's Rose Island nursery.

Measurements were taken on trees in the interior ¼-acre plot to minimize edge effects. To have about the same number trees measured for each spacing, all trees in the ¼-acre plots were measured in the 15 x 15-foot spacing, while in the three closer spacings only trees in systematically selected rows were measured. Diameter was measured with a diameter tape; height was measured with a clinometer and 100-foot tape on surviving trees.

Individual tree volume was calculated with equations developed by Clark and others (1991). Coefficients for the upper Coastal Plain were used for loblolly pine, shortleaf pine, and Virginia pine, while coefficients for the Appalachian Mountains were used for eastern white pine. Value was estimated by getting sawtimber and topwood volume for trees 10 inches and larger d.b.h. Sawtimber volume between a ½-foot stump and a 6-inch upper-stem diameter and topwood volume between a 6-inch and a 4-inch upper-stem diameter were calculated. For pulpwood trees with d.b.h. less than 10 inches, volume from a ½-foot stump to a 4-inch upper-stem diameter was calculated. Volumes were converted using 160 cubic feet per thousand board feet

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(MBF) and 90 cubic feet per cord (Toennisson and Hadden 1992). Pulpwood value was calculated using 1998 delivered price of \$66.88 per cord (Tennessee Department of Agriculture Forestry Division 1998). Sawtimber values were determined using \$200 per MBF for yellow pines and \$280 per MBF for eastern white pine (Tennessee Department of Agriculture Forestry Division 1998).

Plot values were calculated for each variable with SAS Proc MEANS. A mixed model ANOVA was performed with SAS to determine interactions of main effects and compare differences between the means of subplots across blocks using pairwise contrasts. Tukey-Kramer's test was performed for all variables with a probability level of $P < 0.05$.

RESULTS AND DISCUSSION

Survival

Results from 22 years (1988) and 30 years (1996) after establishment are compared and reported. Survival did not differ significantly among species at 22 years or 30 years (table 1). Although significant differences would be expected, given the range in survival, there was considerable variation among the plots. Survival for trees at 6 x 6 foot was significantly less than at the other three spacings for both measurements. Although not significantly less, survival at 9 x 9 foot was numerically less than the two wider spacings at 30 years, perhaps due to increased competition.

The effect of spacing on survival varied among species. No trend was seen for shortleaf pine at either measurement (table 1). Survival for Virginia pine was not affected by spacing at 22 years but had a significant difference between the 6 x 6 foot spacing and the other spacings at 30 years. Survival in eastern white pine and in loblolly pine decreased with spacing for both measurements. The low survival for loblolly pine at 15 x 15 feet at each measurement was influenced by very poor survival in one plot.

Tree Characteristics

The mean height of eastern white pine was significantly higher than loblolly pine, and both were significantly taller

than shortleaf pine and Virginia pine (table 2). There were small, although significant, differences among mean heights by spacing within species; however, there was no trend with spacing within species. The d.b.h. of loblolly pine and eastern white pine were significantly larger than that of shortleaf pine and Virginia pine (table 2). For all species there was a marked increase in d.b.h. as spacing increased. Individual tree volume followed the trends of d.b.h. (table 2). Loblolly pine and eastern white pine were significantly larger than shortleaf pine and Virginia pine. Within each species, individual tree volume increased as spacing increased.

Individual tree value for eastern white pine was significantly higher than for the yellow pines (table 2). Loblolly pine was significantly higher than shortleaf pine and Virginia pine. This is the result of a greater price per MBF for eastern white pine and larger individual trees for eastern white pine and loblolly pine. Again, individual tree value for each species increased as spacing increased.

The only difference in 22 year results for individual tree means is that eastern white pine and loblolly pine were not different in height. At 22 years, the mean height of eastern white pine was 63 feet, while loblolly pine was 61 feet. At age 30, the heights were 78 and 73 feet, respectively.

Stand Characteristics

At 22 years, eastern white pine and loblolly pine had significantly more stand volume than shortleaf pine and Virginia pine (table 3). Stand volume decreased as spacing increased for all four species. The decrease in number of trees per acre with increasing spacing had a greater impact on stand volume than the increase in individual stem volume with increasing spacing.

The value of eastern white pine was significantly greater than the other three species. Loblolly pine was significantly more valuable than shortleaf pine and Virginia pine (table 3). Stand value decreased as spacing increased for all species, except eastern white pine where it peaked at 9 x 9 foot. This was due to considerably more eastern white

Table 1—Least squares estimates of percent survival by species and spacing 22 years and 30 years after planting for the species-spacing comparison near Tullahoma, TN

Species	Years since planting	Spacing (feet) ^a				Mean
		6 x 6	9 x 9	12 x 12	15 x 15	
Loblolly pine	22	54.90ef	62.50abcde	76.00abcde	64.95abcde	64.59A
	30	43.14efg	56.77abcde	73.00ab	64.40abcd	59.33A
Shortleaf pine	22	54.90bcde	67.19abcd	49.35ef	53.15cdef	56.15A
	30	65.36abcde	70.23abcde	66.87abcde	64.36abcde	49.51A
Virginia pine	22	65.36abcde	70.23abcde	66.87abcde	64.36abcde	66.70A
	30	29.26f	57.58abcde	62.34abcde	59.09abcde	52.07A
Eastern white pine	22	52.94def	75.52abcd	80.50ab	87.05a	74.00A
	30	40.20fg	63.02bcde	74.50ab	80.80a	64.63A
Mean	22	57.03B	68.86A	68.18A	67.38A	
	30	39.30B	58.40A	64.03A	63.79A	

^a Lower case letters indicate significant differences among spacings and species within years since planting. Upper case letters indicate significant differences among species or among spacings.

Table 2—Mean tree dimensions by species and spacing 30 years after planting for the species-spacing comparison near Tullahoma, TN

Species	Tree dimension	Spacing (feet) ^a				Mean
		6 x 6	9 x 9	12 x 12	15 x 15	
Loblolly pine	Height(feet)	73c	70d	70d	73d	72B
	DBH(inches)	9.0gh	10.1ef	11.7bc	13.5a	11.1A
	Vol.(cubic ft)	17.2ef	21.1d	27.2c	38.4a	26.0A
	Value(\$)	16.13fgh	22.36e	31.05d	45.70b	28.81B
Shortleaf pine	Height(feet)	60f	61ef	58gh	57gh	59C
	DBH(inches)	7.5i	8.6h	9.5fg	9.8fg	8.9B
	Vol.(cubic ft)	11.2hi	14.4fg	17.4def	17.6de	15.1B
	Value (\$)	8.49i	12.33ghi	17.79efg	17.96ef	14.14C
Virginia pine	Height(feet)	62ef	63e	59fg	57h	60C
	DBH(inches)	69i	8.6h	10.0f	10.6de	9.0B
	Vol.(cubic ft)	8.8i	13.1gh	16.8ef	18.2de	14.2B
	Value(\$)	6.45i	10.78hi	17.20efg	19.59ef	13.51C
Eastern white pine	Height(feet)	78ab	79ab	77b	79a	78A
	DBH(inches)	9.3fgh	11.0cd	12.2b	13.9a	11.6A
	Vol.(cubic ft)	18.2def	25.1c	31.4b	40.4a	28.8A
	Value(\$)	22.90e	37.73c	49.86b	66.18a	44.17A

^a Lower case letters indicate significant differences among spacings and species. Upper case letters indicate significant differences among species.

Table 3—Mean stand dimensions by species and spacing 22 years after planting for the species-spacing comparison near Tullahoma, TN

Species	Stand dimension	Spacing (feet) ^a				Mean
		6 x 6	9 x 9	12 x 12	15 x 15	
Loblolly pine	Volume ^b	6656a	4643c	4205cd	2915fg	4605A
	Value ^c	4923cd	4100de	4401d	3322f	4186B
Shortleaf pine	Volume	4442cd	3207f	1860hi	1331i	2710B
	Value	3214efg	2240hij	1594ijk	1144k	2025C
Virginia pine	Volume	4529cd	3390ef	2483gh	1628 l	3007B
	Value	3027fgh	2374ghi	2136ij	1480jk	2254C
Eastern white pine	Volume	6139ab	5680b	4270cd	3943de	5008A
	Value	5635bc	7070a	6132b	6119b	6239A

^a Lower case letters indicate significant differences among spacings and species within years since planting. Upper case letters indicate significant differences among species.

^b Stand volume is in cubic feet per acre to a 4 inch dob.

^c Stand value is for sawtimber, topwood and pulpwood in \$ per acre.

pine trees being of sawtimber size at the 9 x 9 foot spacing than at 6 x 6 foot.

Eastern white pine and loblolly pine again had significantly more stand volume than shortleaf pine and Virginia pine at 30 years (table 4). Stand volume decreased as spacing increased for three species. Virginia pine had significantly less volume at the 6 x 6 foot spacing than at the 9 x 9 foot spacing because of large mortality in three of the four replications.

At 30 years, as at 22 years, eastern white pine had the highest value, followed by loblolly pine and then shortleaf pine and Virginia pine (table 4). Stand value decreased with increasing spacing for loblolly pine and shortleaf pine.

For eastern white pine and Virginia pine, value peaked at the 9 x 9 foot spacing. As at 22 years for eastern white pine, this was due to the number of sawtimber size trees in the 9 x 9 foot spacing. The drop in value for Virginia pine at the 6 x 6 foot spacing was due to the large mortality noted under stand volume.

Fiber from eastern white pine sawtimber tree tops and from pulpwood trees is used for products such as OSB, but not for pulp. Therefore, the values cited above may not be appropriate for locations that do not have eastern white pine pulpwood markets. Removing the value of eastern white pine pulpwood results in a considerable decrease in value at the 6 x 6 foot spacing and small decreases at the other three spacings (table 4).

Table 4—Mean stand dimensions by species and spacing 30 years after planting for the species-spacing comparison near Tullahoma, TN

Species	Stand dimension	Spacing (feet) ^a				Mean
		6 x 6	9 x 9	12 x 12	15 x 15	
Loblolly pine	Volume ^b	8820a	6471bc	6014c	4807d	6528B
	Value ^c	8245c	6857de	6863d	5715ef	6920B
Shortleaf pine	Volume	5980c	4369d	2452ef	1785f	3647C
	Value	4530fg	3736gh	2503ef	1830j	3150C
Virginia pine	Volume	3056e	4045d	3173e	2118f	3098C
	Value	2223hij	3317ghi	3249ghij	2275ij	2766C
Eastern white pine	Volume	8908a	8518a	7097b	6347c	7718A
	Value	11217b	12798a	11290b	10404b	11427A
	ST value ^d	7990	11241	10454	9884	9892

^a Lower case letters indicate significant differences among spacings and species within years since planting. Upper case letters indicate significant differences among species.

^b Stand volume is in cubic feet per acre to a 4 inch dob.

^c Stand value is for sawtimber, topwood and pulpwood in \$ per acre.

^d Stand ST value is only for sawtimber in \$ per acre; no statistical differences were calculated on sawtimber values.

RECOMMENDATIONS

Based on this study, loblolly pine and eastern white pine are recommended for planting on the Barrens of Tennessee. They had superior survival and growth when compared to shortleaf pine and Virginia pine. The choice between eastern white pine and loblolly pine needs to be based on markets. Although eastern white pine had more volume and may bring more money per MBF, markets for it are not as numerous as those for loblolly pine. Thus, the geographic location of the site to be planted and its proximity to markets can have a great impact on the choice of species.

Recent southern pine beetle infestations in east Tennessee have spread to the Eastern Highland Rim. They have totally infested the three yellow pine species in this study and also have started to infest the eastern white pine. Although eastern white pine is infested in severe southern pine beetle outbreaks, it is less likely to be affected in moderate infestations. This lower risk for eastern white pine should also be considered when selecting a species to plant.

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