Growth and yield of unthinned Honduras Pine grown to small sawlog sizes[1]

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ABSTRACT

Unthinned spacing of Honduras pine (*Pinus caribaea* var. *hondurensis* Morelet) ranging in age from 23.3 to 25 years, was evaluated at four installations in Puerto Rico on the basis of survival, growth, and yield. Results showed that marked significant differences existed in means of survival, diameters, and heights of trees in spacings ranging from 1.5 × 1.5 m to 4.3 × 4.3 m. However, because of decreasing diameter and height growth and increasing mortality in the narrower spacings (1.5 m, 2.1 m), and continued rapid diameter growth in the wider spacings (3.0 m, 4.3 m), there were no significant differences in basal area, total inside bark volume, and mean annual volume increment among spacings. Wide spacings are recommended where early thinnings are not possible.

Key words: *Pinus caribaea* var. *hondurensis* Morelet, spacing, mean annual volume increment, survival

RESUMEN

Crecimiento y rendimiento del pino hondureño sin entresacar

A base de sobrevivencia, crecimiento y rendimiento, se evaluó el espaciamiento, sin entresacar, de pino hondureño (*Pinus caribaea* var. *hondurensis* Morelet) con edades de 23.3 a 25 años en cuatro rodales en Puerto Rico. Los resultados demostraron diferencias significativamente marcadas entre los promedios de sobrevivencia, diámetro y altura de árboles en rodales con espaciamientos que fluctuaron desde 1.5 × 1.5 m a 4.3 × 4.3 m. Sin embargo, debido a la disminución de crecimiento en diámetro y altura y al aumento en la mortalidad en los rodales de espaciamientos más estrechos (1.5 m y 2.1 m), y al crecimiento rápido en diámetro en los rodales con espaciamientos más anchos (3.0 m y 4.3 m), no hubo diferencias significativas entre tratamientos en área basal, volumen total bajo la corteza y promedio de incremento de volumen anual. Se recomiendan espaciamientos anchos en plantaciones donde no sean posibles los entresaques tempranos.

INTRODUCTION

Individual trees of most species attain best growth at wide spacing (Bennett, 1963). To maximize total yield, it is necessary to grow trees with a minimum of space between crowns. However, once a site is fully

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utilized, the total yield over a range of stocking does not change much (Smith, 1962). Spacing trials of Honduras pine (*Pinus caribaea* var. *hondurensis* Morelet) were needed to document yields at various planting densities and to understand the effects of lag time to full site occupancy, growth response to competition, and the effect of crowding on mortality.

In a spacing trial of Honduras pine in Puerto Rico, Whitmore and Liegel (1980) and Liegel et al. (1985) found that in narrow (1.5-m) spacings, mean annual height and diameter increments peaked between ages three and seven. The narrow spacings produced a higher total volume per hectare by age 12 than did wider spacings. Mean annual increments of over 50 m^3/ha/yr were observed on some individual plots. By age 19, the narrowly spaced trees had fallen behind in diameter at breast height (dbh), total height, and survival but still maintained total volume per hectare comparable to that of the plots at wider planting densities. The study here presented is a continuation of the spacing trial described above.

If small stems are an acceptable product and high yield is the primary goal, narrow spacings are advisable. However, small-diameter material is usually less desirable than larger roundwood for several economic reasons. Consequently, many pine stands go unthinned until the first sawlog harvest. This study lends itself as a model for growth and yield as affected by initial spacing in unthinned Honduras pine plantations.

MATERIALS AND METHODS

Honduras pine of the Mountain Pine Ridge provenance of Belize was planted at four Puerto Rican installations, Guzmán, Caracoles, Utuado, and Lares, between late 1961 and late 1963. All sites were in uplands, 300 to 520 m in elevation, with rainfall of 2,000 mm or more per year and mean annual temperatures between 22 and 26°C. The soils were tested and ranged in pH from 4.4 to 5.4 and were variable in depth and texture. For efficiency of site utilization, a triangular spacing (offset) layout was used. The layout placed each interior tree equidistant to six other trees. Spacings used were 1.5, 2.1, 3.0 and 4.3 m, or 2.32, 4.55, 9.28, and 18.22 m^2 per tree with stocking equivalent to 4,304; 2,197; 1,077 and 549 trees per hectare, respectively. Plots consisted of 60 trees, 48 trees placed in two border rows to reduce the edge effect and the 12 interior trees for measurement. Plots of each spacing were replicated twice at each planting location. However, one plot of the 1.5-m spacing at Utuado was badly damaged by a storm and could not be used.

Measurements for this evaluation were made between September 1986 and February 1987, resulting in installation ages of 24.0, 25.0,

24.3 and 23.3 years. Heights were measured with an altimeter and dbh with a diameter tape. Volumes inside bark were calculated by two models: Model 1, the Hussain model (Hussain, 1987), was developed by using pines grown in Puerto Rico. Model 2, the Voorhoeve model (Voorhoeve, n.d.), was developed in Surinam and was included to give continuity with previous publications on this study. Because installation ages differed slightly, for the analysis of variance (Snedecor and Cochran, 1967), adjustments were made to dbh, total standing volume, and mean annual volume increment to project them to a standard 24 years old. However, no adjustments were made to survival, total height, and basal area because mortality was progressing at different unknown rates and because height growth in all densities had slowed to a fraction of its former rate. The general linear model for each dependent variable was tested (SAS Institute, 1988), entering site as a class

TABLE 1.—*Survival, diameter, height, and basal area of unthinned Honduras pine planted at four spacings at each of four locations.*[1]

Location	Spacing[2]	Age	Survival	DBH[3]	Height[3]	Basal area
	m × m	yr	%	cm	m	m²/ha
Guzmán	1.5 × 1.5	24.0	41.7	20.8 ± 2.5	22.3 ± 2.2	81.7
	2.1 × 2.1	24.0	75.0	22.6 ± 2.2	23.4 ± 2.1	89.8
	3.0 × 3.0	24.0	83.3	27.9 ± 1.8	26.2 ± 1.0	69.3
	4.3 × 4.3	24.0	79.2	33.3 ± 1.7	29.3 ± 0.7	46.7
Caracoles	1.5 × 1.5	25.0	58.3	17.5 ± 2.0	16.8 ± 2.0	85.0
	2.1 × 2.1	25.0	70.8	22.4 ± 1.7	19.8 ± 1.5	78.1
	3.0 × 3.0	25.0	75.0	32.0 ± 1.6	23.2 ± 0.8	79.7
	4.3 × 4.3	25.0	83.3	34.4 ± 1.6	23.0 ± 1.2	52.6
Utuado	1.5 × 1.5	24.3	12.5	17.3 ± 3.2	17.8 ± 3.1	38.4
	2.1 × 2.1	24.3	45.8	24.6 ± 2.5	23.4 ± 2.0	68.2
	3.0 × 3.0	24.3	70.8	24.5 ± 1.7	26.0 ± 2.0	51.9
	4.3 × 4.3	24.3	70.8	37.2 ± 1.4	30.8 ± 1.7	58.5
Lares	1.5 × 1.5	23.3	62.5	17.0 ± 1.7	17.0 ± 1.4	86.6
	2.1 × 2.1	23.3	83.3	20.9 ± 1.4	20.7 ± 1.5	81.7
	3.0 × 3.0	23.3	83.3	26.6 ± 1.2	25.6 ± 1.5	75.8
	4.3 × 4.3	23.3	95.8	36.5 ± 1.5	29.8 ± 1.3	67.2

[1]Each entry is the mean of two plots except for the 1.5 × 1.5-m-spaced plots at Utuado, where the second replication was destroyed by a storm.

[2]Triangular spacing made on slope distances; basal areas adjusted for true planar area.

[3]Including standard error.

variable and spacing (m^2 per tree) as a continuous variable. The parameters for a linear model were calculated for those dependent variables that proved significant at a probability of error of 5%.

RESULTS AND DISCUSSION

Table 1 gives means of survival, dbh, total height, and basal area per hectare, by spacing and installation. Table 2 lists total inside bark volumes per hectare and mean annual volume increments per hectare for the various spacings and installations, each calculated by two volume equations. Table 3 presents the means of the above-mentioned measurements across the four installations. Spacing expressed as area

TABLE 2. — *Total volumes and mean annual increments as estimated by two models for unthinned Honduras pine plots planted at four spacings at each of four locations.*[1]

			Total inside bark volume		Mean annual volume increment	
	Spacings[2]	Age	Model 1	Model 2	Model 1	Model 2
Location	m × m	yr	------- m^3/ha -------		------ m^3/ha/yr ------	
Guzmán	1.5 × 1.5	24.0	779	1,000	32	42
	2.1 × 2.1	24.0	940	1,206	39	50
	3.0 × 3.0	24.0	704	903	29	38
	4.3 × 4.3	24.0	555	712	23	30
Caracoles	1.5 × 1.5	25.0	744	871	30	35
	2.1 × 2.1	25.0	656	795	26	32
	3.0 × 3.0	25.0	724	910	29	36
	4.3 × 4.3	25.0	505	637	20	26
Utuado	1.5 × 1.5	24.3	282	362	12	15
	2.1 × 2.1	24.3	656	841	27	35
	3.0 × 3.0	24.3	543	704	23	29
	4.3 × 4.3	24.3	676	868	28	36
Lares	1.5 × 1.5	23.3	751	878	32	38
	2.1 × 2.1	23.3	738	926	32	40
	3.0 × 3.0	23.3	856	1,078	37	46
	4.3 × 4.3	23.3	773	987	33	42

[1]Each entry is the mean of two plots except for the 1.5 × 1.5-m-spaced plots at Utuado where the second replication was destroyed by a storm.

[2]Triangular spacing made on slope distances; volumes per hectare adjusted for true planar area.

TABLE 3.—*Means of various measurements of growth and yield for Honduras pine at various spacings*

Measurement[1]	Means for spacings (m × m)[2]			
	1.5 × 1.5	2.1 × 2.1	3.0 × 3.0	4.3 × 4.3
D.b.h. (cm)	18.1	22.5	27.6	35.2
Height (m)	18.5	21.8	25.2	28.2
Survival (percent)	43.8	68.7	78.1	82.3
Basal area (m^2/ha)	72.9	79.4	69.2	56.2
Total yield (m^3/ha)	636.0	744.0	704.0	626.0
Total yield (m^3/ha)	775.0	938.0	897.0	799.0
Mai (m^3/ha/yr)	26.5	31.0	29.5	26.0
Mai (m^3/ha/yr)	32.5	39.2	37.2	33.5

[1]The first rows of total yields and mean annual volume increments (mai) are by model 1 and second rows are by model 2. Slight differences in the means of volumes derivable from Table 2 are due to a projection of all volumes to a standard 24 years old.

[2]Treatment (spacing) was not significant in the analysis of variance for basal area, total yield, and mai.

per tree (treatment in the analysis of variance) significantly affected dbh, height, and survival, but not basal area, total volume, or mean annual volume increment. The outcome of the least squares analysis of variance, using dbh, total volume, and mean annual volume increment as dependent variables, was not changed by adjustments to project each plot to a standard 24 years old. Mean dbh for the 4.3-m spacing was nearly twice as great as that for the 1.5-m spacing. Heights were also dramatically affected by spacing. Survival was lower in the narrowest spacing but did not change much in the three widest spacings. Basal area, total yield, and mean annual volume increment for the 2.1-m spacing were numerically greater than those measurements for the other spacings.

Trees at the widest spacing had heavier limbs and less natural pruning than did trees in narrower spacings. Form was similar for all spacings. A few trees had died because of snapped foxtails, but most of the mortality was apparently the result of a slow decline caused by suppression. At the time of this study, no significant insect or disease problems had yet been observed in Honduras pine in Puerto Rico.

The mean dbh, height, and survival of unthinned Honduras pine at small sawlog sizes were strongly affected by initial spacing. The widest spacing allowed 94% greater diameter growth and 52% greater height growth than the narrowest spacing. Narrow spacing seriously reduced survival. Basal area, total inside bark volume, and mean annual vol-

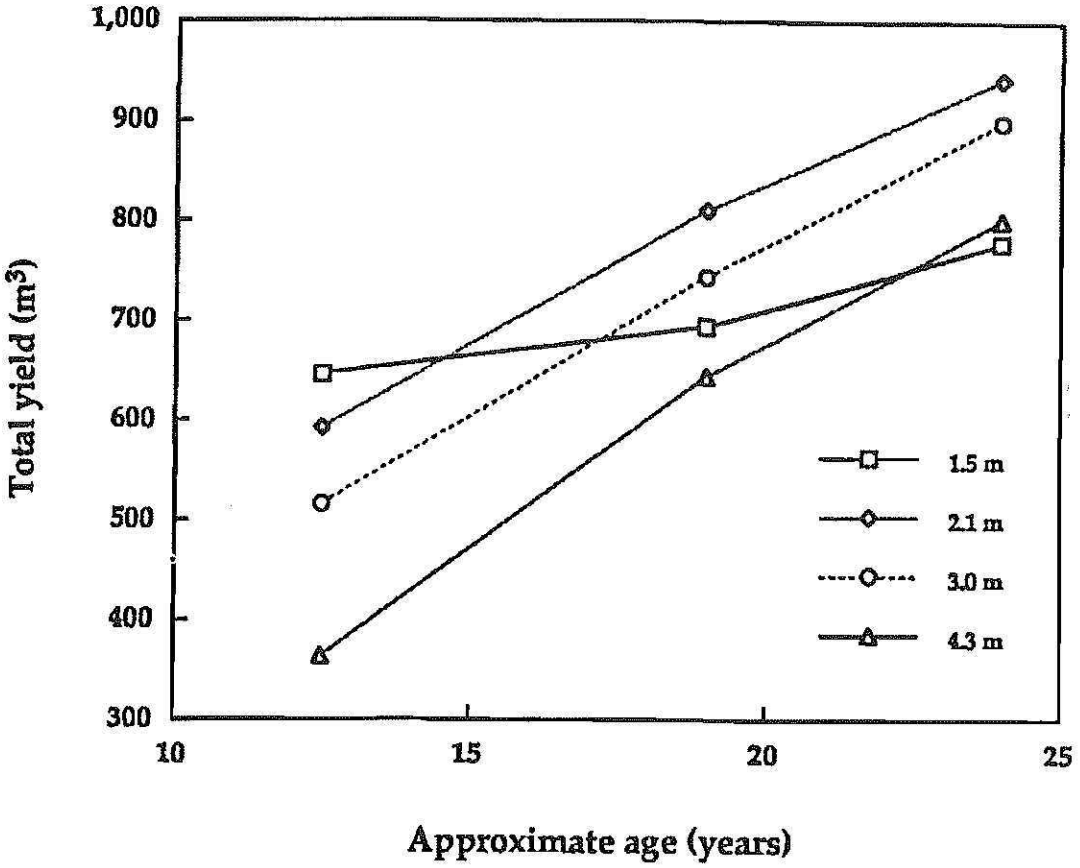

FIGURE 1. Mean total yield per hectare as projected by the Surinam volume table at three ages (approximate) and four planting densities.

ume increment per hectare, which had previously been greater at narrow spacings, were not significantly affected by spacing because of greater mortality and slower growth at the narrow spacings. The response of dbh and height to spacing appeared to be linear whereas the response of survival appeared to be curvilinear because of poor survival at the closer spacings. The R-squared values for the models of survival, dbh, and height were 0.69, 0.84, and 0.90, respectively. Figure 1 illustrates the relative changes in total volume (Surinam model) for the four spacings across all installations for ages 12 to 24 (Liegel et al., 1985; unpublished data). As theory suggests, at some point in the rotation of Honduras pine in Puerto Rico (between 19 and 24 years in these tests), differential height, diameter growth and mortality level the yields across a wide range of stocking rates.

Before stands of Honduras pine are grown to small sawlog sizes (mean dbh of 18 to 35 cm), decisions about spacing should be made on the basis of establishment cost and desired final product size. If commercial thinnings for pulpwood or posts are not possible, narrow spacings, such as 1.5 by 1.5 m should not be used because the extra

trees needed to make the density high will be lost through mortality before trees reach small sawlog size. The mortality rate in dense plantings could be even higher in areas where pines have insect and disease problems.

As of this writing, Puerto Rico does not have a significant market for pine wood, sawn or round. Older pine planted with commercial intent continues to grow into sawlog sizes, and Honduras pine continues to be planted for soil and watershed protection. The species may someday provide commercial products. Honduras pine is an important producer of wood products in other areas of the West Indies and the humid tropics.

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