STATUS, GROWTH, AND DEVELOPMENT OF UNTHINNED HONDURAS PINE PLANTATIONS IN PUERTO RICO*/

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Resumen

Más de 70 plantaciones no manejadas de pino hondureño, que cubren unas 128 ha, fueron identificadas en un inventario en Puerto Rico en 1976. El incremento anual promedio de altura y diámetro fue de 1.5 m y 1.8 cm respectivamente en 28 de las plantaciones de 4 a 14 años, localizadas en cinco regiones variables, en cuanto a suelo. El incremento medio anual de volumen con corteza fue de 29 m³/ha. Las diferencias en altura, diámetro, incremento anual y volumen fueron significativas a nivel de 0.05 entre regiones. El mejor crecimiento se encontró en suelos Ultisoles localizados sobre 300 m en relación a Inceptisoles o Ultisoles encontrados a menos de 300 m.

Las diferencias en porcentajes de árboles con cola de zorro, biforeados, torcidos, inclinados o superiores en cada plantación no fueron significativas entre regiones. La vegetación del soto-bosque resultó diversa y profusa en la mayoría de las plantaciones con una profundidad de hojarasca que fluctuó entre 18 y 112 m. Algunas plantaciones mostraron evidencia de haber sido dañadas por fuego y viento; no se encontró mortalidad causada por insectos o enfermedades. El manejo inadecuado fue el factor limitante más común en reducir tanto el potencial de crecimiento biológico como el potencial económico de inversión de las plantaciones estudiadas.

Introduction

Pinus caribaea Morelet var. *hondurensis* Barr. & Golf., known locally as Honduras pine, pino hondureño, or pino caribaea, grows well throughout most of Puerto Rico. The species was added to island reforestation programs in the mid 1960' after adaptability plantings showed that it outperformed most other pine and hardwood species. Besides protecting soils from erosion, Honduras pine[1] offers a potential local source of raw material for posts, poles, and sawtimber when planted on land unsuited for crops or other land uses.

Most *P. caribaea* plantations have not been managed or thinned since establishment. Few data are available on their size and location or on volume growth on different sites. Information is also lacking on extent of seed and cone production, disease, form, and other stand development characteristics. This report summarizes findings from an island-wide inventory made from 1975-76 to assess growth and development of Honduras pine plantations.

Study areas

Climate

Seasonal changes in prevailing easterly-northeasterly winds and dissected local topography cause considerable rainfall and temperature variation within the five study regions (Table 1). Rainfall usually exceeds 1 700 mm, with mountainous areas receiving from 2 000 to 2 800 mm or more. Pronounced wet and dry seasons are absent, but there are usually dry periods of 3 or 4 months when rainfall is 50 mm or

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1 In this report, Honduras pine will always refer to variety *P. caribaea* var. *hondurensis*

less in all regions. Summer temperatures of 30° to 34°C may prevail for several days or up to 2 weeks or more in the lowlands; in the mountains, temperatures stay between 22° and 26°C. Subtropical moist and subtropical wet are the dominant life zones in four regions; lower montane wet occurs in one region (Table 1).

Soils and geology

Climatic, geologic, and topographic influences have produced great soil diversity on the island. Some 164 classified soil series are known (14), representing 9 of the 10 soil orders recognized in the USAD Soil Taxonomy classification system (25). Inceptisols and Ultisols are the principal soil orders within the study areas (Figure 1, Table 2).

Soils in each region have high amounts of clay in the surface horizons, low pH, and good to moderate drainage and permeability (Table 3). Parent material for the lowland and highland sands are granodiorite, quartz diorite, or residuum of plutonic rocks. Soils in the other three regions are derived from residuum or colluvium of basic volcanic rocks (1). On limestone soils, generally Mollisols, pine plantings are limited to a few small research plots. Limestone areas were excluded from the inventory, because soil depth is a limiting factor preventing their suitability for commercial forestry.

Methods

Puerto Rico Department of Natural Resources (DNR) field personnel helped locate individual plantations. Seed sources for all plantations were not known. They were probably from Mountain Pine Ridge, Belize, the most common source planted throughout the Caribbean in the 1960's (8).

One or more variable-sized rectangular growth plots, between 0.02 and 0.04 ha, were established in each plantation where mortality or site disturbance was not severe. Diameter at breast height (dbh) was recorded for all individuals, usually ⩾ 30, within a plot. Total heights and outside bark upper stem diameters at 5.0 cm intervals along the bole were taken, using a relaskope, on the first and every fourth sample tree thereafter in each 2.5 cm diameter class. Height to first live limb, bark thickness at breast height (from opposite bole faces), and crown class were also recorded. From collected field data, an existing computer program (13) was used to calculate total plot basal area (BA) and volumes, and to summarize plot mean height and dbh, live crown ratios, bark thickness, and crown class data.

Other stand development data were collected. Tree form quality factors in each plot were assessed by counting the number of forked, crooked, leaning, foxtail (term applied to individual pine trees that have

Table 1. Climatic data for inventoried regions containing *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantations in Puerto Rico.

Region	Mean Annual Temperature (C)	Rainfall (mm)	Elevation (m)	Life Zone[1]
Lowland sands	24.0 – 25.5	2 030 – 2 540	0 – 300	mf–S wf–S
Highland sands	22.0 – 24.0	1 520 – 2 030	250 – 1 000	wf–S
Shallow clays	22.0 – 24.0	1 520 – 2 290	0 – 700	mf–S wf–S
Lowland deep clays (⩽300 m)	23.5 – 25.5	1 780 – 2 290	0 – 500	mf–S wf–S
Highland deep clays (⩽300 m)	20.0 – 23.5	2 290 – 2790	500 – 1 200	wf–S wf–LM

1 As determined from J. J. Ewel and J. L. Whitmore. 1973. The ecological life zone of Puerto Rico and the U.S. Virgin Islands. USDA Forest Service Res. Pap. ITF-18. Institute of Tropical Forestry. Rio Piedras, Puerto Rico:
mf–S = subtropical moist forest, wf–S = subtropical wet forest and wf–LM = lower montane wet forest.

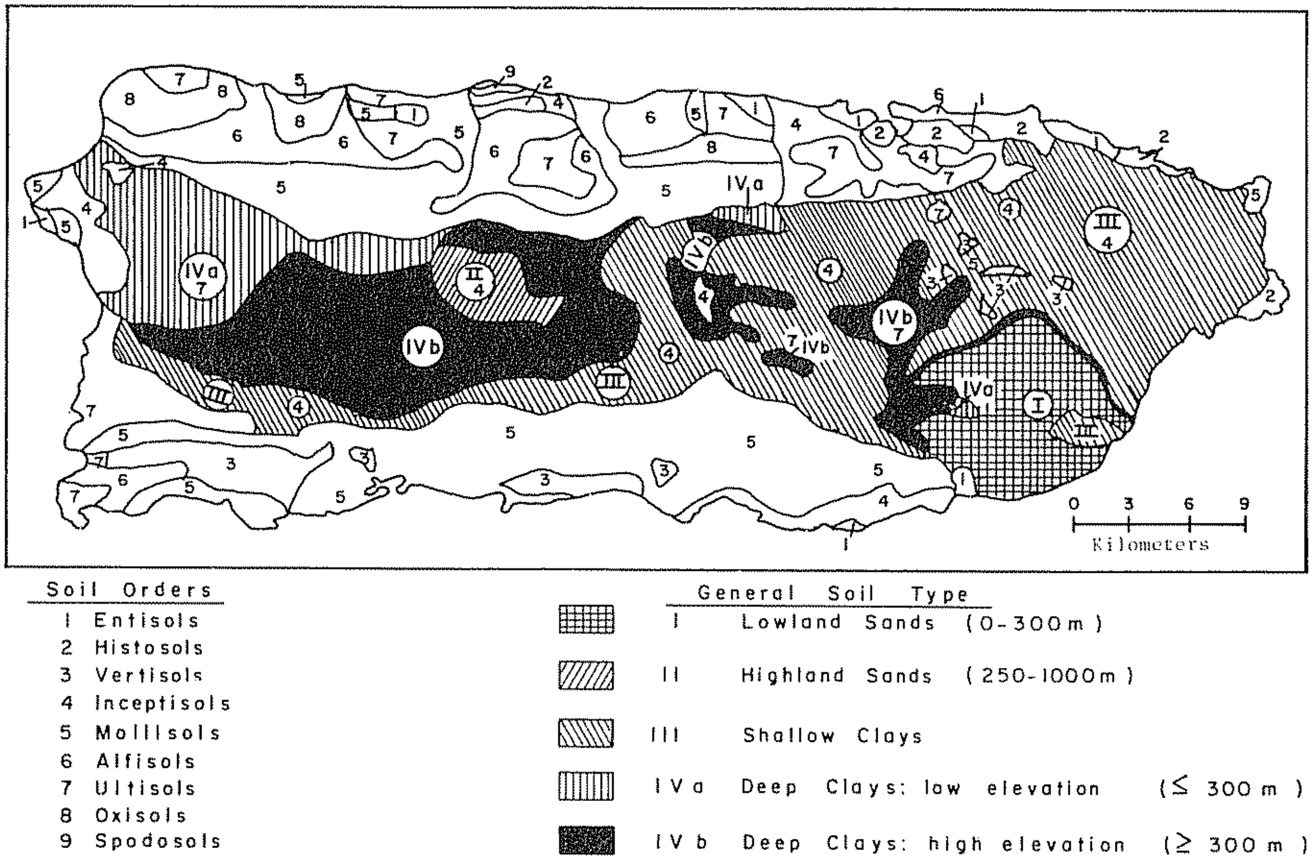

Fig. 1. Map of Puerto Rico showing major soil orders and general soil types included in an inventory of *Pinus caribaea* var. *hondurensis* plantations; it is adapted from U. S. Department of Agriculture Soil Conservation Service, San Juan, Puerto Rico.

Table 2. Number of *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantings inventoried in Puerto Rico, 1976, and their associated.

Region	TOTAL		No. of Growth Plots Established	Predominant Soil	
	Plantations Found	Estimated Area (ha)		Series	Orders
Lowland sands	10	9	6	Pandura, Teja, Utuado, Lirios	Inceptisols
Highland sands	12	9	3	Pandura, Teja, Utuado, Pellejas	Inceptisols
Shallow clays	5	15	2	Caguabo, Malaya Múcara	Inceptisols
Lowland deep clays	20	40	6	Consumo, Daguey Humatas	Ultisols
Highland deep clays	23	20	11	Consumo, Daguey Humatas	Ultisols
Totals	70	93	28		

an abnormal growth pattern, usually characterized by one or more branchless areas, on the main stem. In this study, the branchless foxtail area was ≥ 1.2 m in length), and superior trees. Cone production was assessed ocularly and with binoculars, counting maturing cones on opposite sides of individual trees and multiplying this figure by two; this method has been calibrated and values can be considered only relative. Branch angle was assessed ocularly. Understory vegetation was classified into one of five categories, ranging from bare ground covered only by needles to profuse grass or shrub cover. Litter thickness was the average of all measurements taken at the middle of a sampler, 30.5 x 30.5 cm, placed at 4.6 m centers along a line running through the plot center and parallel to the longest side.

Because initial spacing in all plantations was quite close, usually ≤ 1.8 x 1.8 m, most interior trees had experienced intense competition. Exceptions were trees at a plantation's edge; these trees had no competitors on one or more sides. Thus total height, dbh, and cone production for five edge trees in each plantation were assessed to obtain a relative measure of tree growth under better growing conditions, i.e., wider spacings and less competition.

Results and discussion

Area, location, owership

A total of 70 plantations covering 93 ha were located (Table 2). The majority on the western end of the island. Ages ranged from 4 to 14 yeras. Most plantings were about 0.5 ha in size; with an average size of 1.5 ha. The total area of Honduras pine plantings in Puerto Rico as of 1976 was estimated at 128 ha.

Approximately 30 percent of all plantations were found in Commonwealth or Federal forests; the rest were on private lands. The largest single plantation (16 ha), is within the Luquillo Experimental Forest Biosphere Reserve.

From the 70 plantations, 28 were chosen for estimating growth and performance. Each of the 28 plantings was large enough to accommodate one or more growth plots having at least three border rows around each side.

Table 3. Selected features of some soil series found in regions containing Honduras pine plantations in Puerto Rico.

Region	Soil Series	Depth[1] (cm)	pH[2]	Drainage	Permeability (cm/hour)	Parent Material
Lowland sands	Lirios silty clay	58	4.5 – 5.5	Well drained	1.6 – 5.1	Granodiorite or quartz diorite
Highland sands	Lirios silty clay loam	(Same features as above)				
	Pellejas	38	4.5 – 5.5	Somewhat excessively drained	5.1 – 16	Course textured residuum of plutonic rocks
Shallow clays	Múcara	31	5.6 – 6.5	Well drained	1.6 – 5.1	Fine residuum of basic volcanic rocks
Lowland deep clays	Consumo clay	51	4.5 – 5.0	Well drained	1.6 – 5.1	Residuum of basic volcanic rocks
	Humatas clay	81	4.5 – 5.0	Well drained	1.6 – 5.1	Residuum of basic volcanic rocks
Highland deep clays	Anones clay	33	4.2 – 4.6	Well drained	–	Colluvium from volcanic rocks
	Los Guineos clay	122	4.5 – 5.0	Moderately well drained	1.6 – 5.1	Fine residuum of basic volcanic rocks

1 Joint depth of A and B horizons 2 1:1 in H_2O

Overall growth performance

Regional differences in mean annual height increment (MAIH) and mean annual diameter increment (MAID) were statistically significant (Duncan's new multiple range test), respectively. at 0.01 and 0.05 (Table 4). Overall plot means for height and diameter growth were 1.5 m and 1.8 cm.

Across the 28 plantations there was a wide range in total BA (18 to 59 m^2/ha), total volumes (78 to 507 m^3/ha), and mean annual overbark volume increments (MAIV, 14 to 60 m^3/ha). This variability was caused by differences in age, number of surviving trees, and initial spacing at each planting. Total BA growth on highland sands was significantly lower than BA growth on highland deep clays (Table 5). Lowland sand and highland deep clay regions had significantly higher MAIV growth than did other regions. The island-wide MAIV growth was 29 m^3/ha.

There was some indication that individual sites within the broad regions differed in productivity

Table 4. Height and diameter growth summary for 28 unthinned *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantations studied in five regions in Puerto Rico.

			Mean Annual Increments			
		Age	Plot		Dominant	
Region	n	Range (years)	ht (m)	dbh (cm)	ht (m)	dbh (cm)
Lowland sands	6	10–14	1.5 b[1]	1.7 b[1]	1.6 b[1]	2.0 b[1]
Highland sands	3	4–14	1.5 b	1.7 b	1.5 c	1.8 c
Shallow clays	2	11–14	1.2 d	1.6 b	1.3 d	1.6 d
Lowland deep clays	6	9–13	1.4 c	1.6 b	1.5 c	1.9 b
Highland deep clays	11	4–12	1.6 a	2.1 a	1.7 a	2.2 a
Total Mean (n = 28)	28		1.5	1.8	1.6	2.0

Two-Way Analysis of Variance[2]

	Plots vs Dominant	Regions
Mean annual increment-height	*	**
Mean annual increment-diameter	NS	*

1 Values within columns having different letters are significantly different at 0.05 probability using Duncan's New Multiple Range Test.

2 F-test results:
NS – not significant at ≤0.05
* – significant at 0.05.
** – significant at 0.01.

potential. Within the lowland deep clay region, in two 11 year-old plantings of similar age and stocking, there was a 50 percent difference in MAIV growth. One planting had averaged 20 m^3 per year while the other averaged 30 m^3 in MAIV growth.

Island-wide plot tree averages of 1.5 m and 1.8 cm for height and diameter growth parallel observed growth rates reported for 11.5 to 13.6 year-old Honduras pine spacing trials in Puerto Rico (29). In the spacing trials, replicated at four sites, MAIH rates ranged from 1.2 to 2.0 m across triangular spacings of 1.2, 2.1, 3.0 and 4.3 m; MAID rates ranged from 1.0 to 2.5 cm.

Mean annual overbark volume growth in Puerto Rico, compares well to rates from other countries. They are actually higher than the MAIV growth figures of 3 to 37 m^3 reported by Lamb (8) and Sommer and Dow (24) for 16 countries. In Costa Rica, Salazar (18) found higher rates, ranging from 30.9 to 75.5 m^3, the average being 58.4 m^3 for 16 plantations. But those plantings were much younger, from 4.7 to 8.0 years old, and were located on more fertile, young, volcanic ash soils (Inceptisols).

Volume growth in Puerto Rico is as great or greater than that of native pines from the Southern United States, or for the same species planted as exotics in other countries. For example, MAIV growth of slash pine (*P. elliottii* Engelm var. *elliottii*) ranged from 6.4 to 19.3 m^3 in native environments (2, 3, 4) and from 7.0 to 23.4 m^3 in Australia and Brazil (5, 16). Expected MAIV yields from 15 year-old unthinned loblolly pine (*P. taeda* L.), growing on the best sites of the Western Coastal Plain of the United States and planted at 1.4 m spacing, were 26.2 m^3 (11). Similarly aged and spaced stand of shortleaf pine (*Pine echinata* Mill.) had expected MAIV yields of only 7.2 m^3 (23).

Correlation coefficients between plantation density and plot mean height and plot mean dbh were –0.7 and –0.8, both were statistically significant. Salazar (18) did not find any significant correlation between these parameters. But unlike the case in Puerto Rico where initial spacing was usually ≤ 2.0 m, all but two plantings that Salazar measured had original spacings ≥ 2.0 m. Whitmore and Liegel (29) also found that spacing influenced height and diameter growth of *P. caribaea* in Puerto Rico.

Table 5. Volume and basal area growth summary for 28 unthinned *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantations studied in five regions in Puerto Rico.

Regions	No.	Total		Mean Annual Increment	
		Volume[1] (m^3/ha)	Basal Area (m^2/ha)	Volume (m^3/ha)	Basal Area (m^2/ha)
Lowland sands	6	302	41 ab[2]	27 a[2]	3.7
Highland sands	3	228	29 b	22 b	3.3
Shallow clays	2	280	33 ab	22 b	2.6
Low elevation deep clays	6	251	34 ab	23 b	3.1
High elevation deep clays	11	348	45 a	36 a	5.1
Mean (n = 28)		300	39[3]	29[3]	4.0

1 Based on outside bark measurements and total height.

2 Values within columns having different letters are significantly different at 0.05 probability using Duncan's New Multiple Range Test

3 Analysis of variance F-test for regional differences significant at 0.05 probability

Bark thickness and diameter distributions

Mean ratio of inside to outside bark diameters ranged from 0.83 to 0.89 in age classes 9 to 14 years. There was no significant difference in ratios between the five regions. The island-wide mean was 0.86.

Diameter classes in all 28 plantations ranged from 2.5 to 39.9 cm. Plantations older than 9 years had greatest frequencies in the 15.0 to 24.9 cm classes, except for age 11 where greatest frequencies were between 10.0 and 19.9 cm. Across the five regions, plantations older than 9 years averaged 1 296 stems with dbh ≥ 10 cm and only 25 stems with dbh ≥ 30 cm (Table 6). In the spacing study of Honduras pine (29), the average number of stems per ha with dbh ≥ 10 cm was up to 60 percent greater than that found in the inventoried plantations. But the spacing trial plots had high overall survival and better tending care than did the 28 plantations located primarily on private land; triangular spacing also allows more stems per ha than does rectagular spacing.

Stand conditions

Foxtail percent

Foxtailing existed in all but two plantations. One of these was on lowland sands, the other on highland deep clays. There was no significant regional or age differences in foxtailing. The highest amount was 34 percent for a 12 year-old planting on highland deep clays; the island-wide mean was 14 percent (Table 7). Such foxtail percents are typical for Mountain Pine Ridge, Belize sources planted in Puerto Rico (12).

Foxtailing tended to increase with age in each region. However, the correlation coefficient between plantation age and foxtail percent was not significant (r = 0.2 at 0.05 probability). Musalem (15) also observed a trend for foxtailing to increase with age in 1 to 5 year-old *P. caribaea* plantings near Turrialba, Costa Rica. Wiersum (30) found that foxtailing varied on different soils as well as between varieties. Observations on 6 to 7 year growth performance of over 30 provenances covering the three varieties of *P. caribaea* and *Pinus oocarpa* Schiede indicate varietal and species differences for foxtailing in Puerto Rico, as shown by significant differences in mean maximum internode lengths (12).

The one anomaly in Puerto Rico was that the greatest amount of foxtailing occured in western Puerto Rico where total rainfall is lower and less evenly distributed (Tables 1, 7). This observation is contrary to a working hypothesis that expects greatest foxtailing in areas receiving more total rainfall that is well distributed (7). According to this hypothesis, a species is more prone to foxtail in those (exotic) environments where both moisture and nutrients are better than those found in native regions (22).

Form quality

Forking comprised 0 to 17 percent of individual plantations. Regional differences were small and not significant. The percentage of crooked and leaning trees was more variable on a regional and age basis (Table 7), but regional differences were not significant. The two regions with deep clay soils had lower percentages of individuals with epicormic branching, but again, regional differences were not significant.

Table 6. Diameter class distributions for unthinned *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantations in Puerto Rico.

Age[1] (years)	Number of Plantations	Diameter classes 2.5–9.9	10.0–14.9	15.0–19.9	20.0–24.9	25.0–29.9	30.0–34.9	35.0–39.9	Stems per ha: Sum	≥10 cm	≥30 cm
14	2	36	95	304	442	148	24	0	1 049	1 013	24
13	2	0	116	661	354	64	0	18	1 213	1 213	18
12	9	0	134	439	490	203	10	0	1 276	1 276	10
11	8	38	540	694	355	67	10	0	1 704	1 666	10
10	1	0	24	367	685	49	0	0	1 247	1 247	49
9	2	0	74	557	494	198	38	0	1 361	1 361	38
5	1	0	538	1 973	179	0	0	0	2 690	2 690	0
4	3	640	1 482	420	0	0	0	0	2 542	1 902	0

1 For plantations of similar age, the number of stems per ha in existing diameter classes were summed and then divided by the number of plantations having that diameter class to obtain a mean number (frequency) for each diameter class represented.

Overall, the number of forked, leaning, and crooked trees did not seem unacceptable for unthinned, unmanaged stands originally planted at very close spacings. However, stands in all regions were not growing at optimal levels as shown by live crown ratios (Table 7). The island-wide mean was almost 50 percent; regional differences were not significant. Usually live crown ratios of 40 percent or less are indicative of healthy, vigorous growth in plantations. Branch angles were usually between 45° and 60°C, although some trees had branch angles between 60° and 90°C.

Each plantation had one or more superior phenotypes from which cuttings could be obtained for future tree improvement work. Over 90 superior trees (Table 7) have now been identified on the island (10). Best form and growth was seen at two plantations within the Carite Commonwealth Forest. Of the 28 plantings studied, young ones might be used for temporary seed production areas if thinnings were made. Others could be used to study the effects of different thinning regimes on subsequent growth or to provide data for local volume and yield tables or biomass estimates.

Cone production, natural regeneration

Cone production was very low, even in plantings that were 12 to 14 years old. The greatest number of maturing cones, an average of 30 cones per tree, was found in plantations on lowland sand soils. Edge trees usually had two to three times as many cones as those in the plantation interior; sometimes they had cones when interior trees did not. Seven plantings older than 10 years had no maturing cones either on edge or on interior trees.

Causes of low cone and seed yields in Puerto Rico are not known. Venator and Sanabria (28) found that 65 percent of two seed lots from one 9 year-old planting in southeastern Puerto Rico had empty seed. However, germination of the full seed was 89 percent. Since pollen abortion averaged only 10 percent for 10 trees studied in 1970, Venator (27) concluded that previously observed low seed yields, as expressed by the number of seeds with endosperm, was not a result of aborted pollen.

Individual pine trees and species vary greatly in their ability to produce flowers and seeds (6). For

Table 7. **Summary of several stand parameters for 28 unthinned *Pinus caribaea* var. *hondurensis* Barr. and Golf. plantations studied in five regions in Puerto Rico.**

Regions	Foxtails	Forked	Crooked	Leaning	Epicormic Branching	Live Crown	Litter Thickness (mm)	DIB/DOB Ratio	No.[1] Superior Trees
	(%)								
Lowland sands	15	7	28	15	16	50	56	0.86	21
Highland sands	17	1	10	2	17	44	79	0.87	4
Shallow clays	17	3	13	8	13	52	90	0.87	4
Low elevation deep clays	18	8	21	2	5	51	56	0.85	20
High elevation deep clays	11	4	16	4	4	47	75	0.86	42
Means (n = 28)[2]	14	5	18	6	8	49	68	0.86	

1 Based on selection intensity criteria established by Ledig and Whitmore (10)

2 Analysis of variance F-test for regional differences not significant for logarithimic and arcsine transformations of percent and other data

example, one clone of *P. caribaea* in Queensland, Australia (17) flowered actively for four months and produced multiple whorls of flowers. Although male flowers have been seen as early as August in western and north-central Puerto Rico, no active flowering was seen during the main period of the inventory, from May to July 1976. Personal observations on over 40 trees around the Institute of Tropical Forestry in Rio Piedras between 1978 and 1980 showed greatest male flower production between October and February and female flower production between December and January.

Several climatic, site, and silvicultural factors influence seed production: temperature and evaporation shortly after pollination (9), moisture at time of ovule fertilization (20), soil moisture in the period before formation of flower primordia (21), intensive cultivation and fertilization of seed trees (19), and removal of competitors from crowded stands (31). Since the original planting densities of pine plantings in Puerto Rico were quite high, adequate nutrients and light may not be available to interior trees for seed production. Tendency for edge trees to produce more cones than interior trees supports this view. Also, the winter and spring (January to May) monthly rainfall averages were below normal in 1973 and 1974 across most of the island (26). These droughty conditions could have coincided with critical periods of flower initial formation, pollination, and or fertilization when greater moisture is needed for seed formation. Phenological observations over successive years and thinning studies are definitely needed to provide conclusive data about factors influencing Honduras pine seed and cone production in Puerto Rico.

Natural reproduction consisting of several seedlings 5 to 30 cm tall, sometimes over 100 cm, were usually seen around the edges of plantations over 5 years old. Few seedlings were seen within plantation interiors. Natural regeneration was limited to areas having exposed mineral soil, caused by sparse understory, light litter cover, or site disturbance such as fire. Winged Honduras pine seeds evidently fly quite well since seedlings have been found more than 40 m from the closest seed source.

Damage and other limiting factors

Twelve plantations had signs of frequent burning. Damage existed in only four and was limited to canker scars and actively exuding resin. According to landowners, fires are usually started by vandals and occur in a 3 to 4 month winter period when rainfall decreases to 50 mm or less per month. Because of Puerto Rico's high population density, pine plantings are rarely located in isolated surroundings; trespass and vandalism are common and almost every plantation has some fire and illegal cutting damage. Unless fires occur repeatedly, damage and mortality are not severe because the thick outer bark of pine is fire resistant after seedlings are 3 to 6 years old (8).

Seven plantations had windthrow damage. It was limited to less than 15 percent except in two 11 year-old plantations where overgrazing had caused accelerated erosion along cattle trails. Surface and subsurface roots were exposed in both plantings, thereby decreasing windthrow resistance. No mortality was attributed to insects or to other pathogens.

Mismanagement, caused chiefly by trespass cutting and failure to thin at the proper time, was the most widespread limiting factor to good Honduras pine growth. Height, diameter, and volume data obtained in this inventory indicate the tremendous potential for wood or biomass production in local pine plantings. Failure to provide adequate cleanings, thinnings, and other silvicultural treatments after plantation establishment has severely reduced both the full biological and economical potential of these plantings.

Forest floor, understory

Understory vegetation was quite variable at each site. In 15 plantations it consisted of sparse to well-scattered shrubs and vines. Invading shrubs and broad-leaved trees dominated the understory in nine plantings; grass and briars predominated in two. In the remaining two, the forest floor was limited to pine needle mulch, probably because frequent fires and/or grazing kept shrubs, vines, and trees from becoming established. In general, understory species diversity within densely-spaced pine plantations was high, being the rule rather than the exception. At most sites, undergrowth was so heavy that passage was made only by using machetes.

Litter thickness ranged from 18 to 112 mm. Regional and age differences were not statistically significant; the island-wide mean was 69 mm. The coefficient of correlation between litter thickness and age was not significant ($r = 0.3$ at 0.05 probability). Mycorrhizal fruiting bodies were found in four plantings; they all appeared to be from *Pisolithus tinctorius*.

Conclusions

1. Despite almost a quarter-century of local reforestation efforts with many introduced or native

species, the total area covered by pine plantings is only about 0.01 percent.

2. The location and size of existing Honduras pine plantations are now known and can be used to plant future research activities.

3. Overall growth and performance of Honduras pine was quite good across five broad soil regions, even in unthinned, unmanaged stands. Mean annual volume increments for the young plantations inventoried usually surpassed those reported from other tropical countries and exceed volume increment rates for most temperate zone conifers.

4. Observations on edge trees in this inventory and results from a local spacing trial show that Honduras pine height and diameter growth can be improved substantially if initial spacings ⩾ 2.0 m are used. Growth could also be improved by following better tending and management practices and by planting superior genetic stock obtainable by developing a local tree improvement program.

5. Lack of knowledge on factors affecting seed production hinders increased use of Honduras pine for reforestation. Phenological studies should be started quickly so that areas can be identified where Honduras pine seed production can be undertaken since seed now costs up to $ 300 per kilogram on the open market. Producing high quality seed for international markets could be more lucrative for some lucrative for some landowners than growing Honduras pine for wood products. Seed production may also be less affected by local wood market conditions.

6. The small and isolated nature of local Honduras pine plantations is probably the most important factor limiting damage by insects or disease. In densely populated rural areas, repeated man-made fires will reduce yields. Any future commercial reforestation efforts must include fire watch and suppression capabilities.

7. Any intensification of reforestation with Honduras pine or other pines must also be accompanied by substantial upgrading of technical and extension forestry assistance available to landowner. If plantations are not managed properly or suitable markets are not made available for wood products, then land scheduled for reforestation can revert to native forest naturally. Secondary forest succession costs nothing to establish, effectively controls erosion, and protects watersheds on steep slopes unsuited for agricultural crops.

Summary

Seventy plantations representing 93 ha were located in an island-wide inventory of Honduras pine plantations in 1976. Mean annual height and diameter growth for dominant trees in 28 plots averaged 1.6 m and 2.0 cm respectively; plantings were 4 to 14 years old and were located in five major soil regions. Data are summarized for several stand features, including volume, bark thickness, basal area, form, live crown, foxtails, seed and cone production, injury/disturbance, and nature of understory vegetation.

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