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Growth of Teak, Mahogany, and Spanish Cedar on St. Croix, U.S. Virgin Islands[1]

P.L. Weaver, J.K. Francis**

ABSTRACT

Plantation growth of mahogany (*Swietenia* spp.) and teak (*Tectona grandis*), and the performance of teak and Spanish cedar (*Cedrela* spp.) provenances located in subtropical dry and moist life zones, are summarized for St. Croix, U.S. Virgin Islands. Hybrid mahogany (*S. macrophylla* x *S. mahagoni*) from St. Croix had the best form and growth rate of all tree species tested. The mean trunk volume growth of a 30-year old mahogany hybrid at Bodkin was 8.1 m^3 ha^{-1} yr^{-1}, mean dbh growth was 0.78 cm yr^{-1}, and mean height growth was 0.47 m yr^{-1}. Comparable growth figures for 30-year-old teak at Estate Thomas were 3.9 m^3 ha^{-1} yr^{-1}, 0.76 cm yr^{-1} and 0.51 m yr^{-1}, respectively. West Indies mahogany (*S. mahagoni*), after 25 years at Estate Thomas, averaged 6.0 m^3 ha^{-1} yr^{-1}, 0.86 cm yr^{-1}, and 0.44 m yr^{-1}. Pacific Coast mahogany (*S. humilis*) at Estate Thomas, in contrast, averaged only 2.0 m^3 ha^{-1} yr^{-1}, 0.83 cm yr^{-1}, and 0.39 m yr^{-1} after 25 years. Testing of seven Spanish cedar provenances was confounded by mortality losses in the nursery and fire after outplanting. The surviving five provenances showed 39 and 59 percent survival at 16 years in Estate Thomas and Hams Bluff, respectively. Growth rates for the Belize provenance at Estate Thomas and the Mexican provenance at Hams Bluff were superior to others; their survival rates were 66 and 89 percent, respectively. Testing of six provenances of teak showed significant differences in dbh and height, with the Tamilnadu, India provenance growing most rapidly, but having the highest mortality.

COMPENDIO

Se resume el crecimiento de caoba (*Swietenia* spp.) y de teca (*Tectona grandis*) en plantaciones, y el comportamiento de procedencias de teca y de cecro (*Cedrela* sp.), localizadas en las zonas de vida de bosque seco subtropical y bosque húmedo subtropical, en San Cruz, Islas Vírgenes, EE.UU. El híbrido de caoba (*S. macrophylla* x *S. mahagoni*), de Santa Cruz, mostró la mejor forma y tasa de crecimiento de todas las especies probadas. El crecimiento promedio del volumen de los fustes de caoba híbrida de 30 años de edad, en Bodkin fue 8.1 m^3 ha^{-1} $año^{-1}$; el crecimiento promedio del dap fue 0.78 cm $año^{-1}$ y el crecimiento promedio en altura fue 0.47 m $año^{-1}$. Cifras comparables de crecimiento para teca en Estate Thomas, durante 30 años, fueron 3.9 m^3 ha^{-1} $año^{-1}$, 0.76 cm $año^{-1}$ y 0.51 m $año^{-1}$, respectivamente. La caoba de las Indias Occidentales (*S. mahagoni*), después de 25 años, en Estate Thomas, promedió 6.0 m^3 ha^{-1} $año^{-1}$, 0.86 cm $año^{-1}$, y 0.44 m $año^{-1}$. La caoba de la costa del Pacífico (*S. humilis*), en Estate Thomas, en contraste, promedió solamente 2.0 m^3 ha^{-1} $año^{-1}$, 0.83 cm $año^{-1}$, y 0.39 m $año^{-1}$ después de 25 años. La prueba de siete procedencias de cedro resultó confusa por pérdidas debido a la mortalidad en el vivero y a un incendio forestal ocurrido después de plantarse en el campo. Las cinco procedencias sobrevivientes mostraron 39– y 59–por ciento de supervivencia después de 16 años, en Estate Thomas y en Hams Bluff, respectivamente. Las tasas de incremento de la procedencia de Belize, en Estate Thomas, y la procedencia de México, en Hams Bluff, fueron superiores a las otras; sus tasas de supervivencia fueron 66 y 89 por ciento, respectivamente. La prueba de seis procedencias de teca mostró diferencias significativas en dap y en altura, con la procedencia de Tamilnada, India, creciendo más rápidamente aunque mostrando la mortalidad más alta.

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INTRODUCTION

St. Croix, one of the U.S. Virgin Islands (Fig. 1), was discovered by Columbus on his second voyage in 1493. Between 1700 and 1850, most of the Island was cleared and planted with sugar cane and cotton. By the late 1920's, the local wood-using

industries were confined to charcoaling, bay oil extraction, and small-scale cabinet making (14). In 1950, 30 percent of the Island was again covered with trees, including 120 ha of previously introduced, naturally regenerated West Indies mahogany (*Swietenia mahagoni*) trees (21).

In early 1955, the USDA Forest Service implemented a forestry program on St. Croix. The objectives included forest management and utilization, promotion of wood-using industries, and production of local planting stock. Cooperation with private landowners was aimed at timber production, soil and water conservation, and the establishment of windbreaks and shade trees in pastures and along roadsides.

Forestry research began in 1958. Teak (*Tectona grandis*) was introduced, and species adaptability trials, growth studies, and provenance trials of teak and Spanish cedar (*Cedrela* sp.) were iniatied. Plantations of hybrid mahogany, a natural cross between West Indies mahogany and Honduras mahogany (*Swietenia macrophylla* x *S. mahagoni*), first discovered at Davis Bay where both species had been planted in the early 1900's, were established at Estate Thomas, Bodkin, and Sion Farm. From 1955 through 1972, the forestry program was credited with establishing about 250 000 mahogany, teak, and Spanish-cedar trees on 110 ha in St. Croix (25), averaging 6.5 ha yr^{-1} of successfully regenerated forest. By the early 1970's the Island had an estimated 500 000 board feet of merchantable mahogany in roadside, streambank, urban, and research plantings as well as mahogany plantations.

Because more than 40 percent of the forests located within tropical latitudes are dry (3), and many of these areas are currently experiencing wood shortages, there is a need to identify useful tree species and provide information on their survival and performance. The purpose of this study was to summarize plantation growth of mahogany and teak and to assess provenance trials of Spanish cedar and teak.

Environmental background

The island of St. Croix occupies 220 km^2 of land area, with Mt. Eagle in the northwest being the highest point at a 355 m elevation (Fig. 1). The mountainous areas of the north and east are flanked by a rolling plain in the south-central and western parts of the Island. Intermittent streams are found in both ranges.

Geology. The oldest rocks on St. Croix are of late Cretaceous age and were eroded from volcanic rocks and deposited as sand beds by turbidity currents deep on the ocean floor (30). Mountain building forces during the Oligocene, when St. Croix was emerging from the sea, compressed the Island's two mountain ranges causing folds and a thrust fault. The mountain ranges formed two islands joined by a large coral reef during the lower Miocene, and later were joined by continual uplift. In recent times, alluvium and beach deposits formed at the edges of the marl formation and in coastal areas.

Soils. The Island's soils were derived from basic, volcanic rocks, formed in sediments derived from soft limestone or volcanic rocks (23). Seventy different soils and land use types have been mapped, and six soil associations (Fig. 1) have been recognized (19). The soils have been further classified into woodland suitability groups based on their suitability for wood crops, production potential, and management requirements (23).

Climate. Mean rainfall ranges from < 760 mm yr^{-1} at the eastern tip of the Island to $> 1\,270$ mm yr^{-1} in the northwest (Fig. 1). September through November are wetter than the remaining months, and February and March are drier (Fig. 2). Temperatures fluctuate between 21 and 32°C and are characterized by more diurnal than annual variation (4).

Although infrequent, hurricanes influence forestry. The last storm to directly hit St. Croix was San Felipe of 1928. Similar storms with trajectories close to or directly over Puerto Rico have caused considerable damage in both plantations (16) and natural forests (5, 27, 28).

Natural vegetation. The natural vegetation of St. Croix was classified into two Holdridge (12) life zones. The subtropical dry forest comprises 83 percent of the Island; the subtropical moist forest, located in the northwest, occupies the remainder (6). Ten ecosystem types are also recognized: semi-evergreen forest, deciduous forest, thorn woodland, thorn scrub, mangrove swamp, littoral woodland, beach strand vegetation, and three vegetation types derived from human activity (7).

The original species composition of St. Croix's forests has been drastically altered (8). Changes began with the indigenous groups before Columbus' arrival. Clearing and burning for agricultural production and the introduction of species for agriculture and forestry continue today.

Study sites

Plantings on five sites were studied. The Annaly (Hams Bluff), Bodkin, and Mahogany Road sites are

in subtropical moist forest (Fig. 1) and receive an average rainfall of 1 140 to 1 270 mm yr^{-1}. The soils are in the Descalabrado-Jacana association (**Inceptisols**) (18), which are characterized as well-drained on steep slopes, with clay loam to clay subsoils. The Estate Thomas and Sion Farm sites are in subtropical dry forest where rainfall averages about 1 000 mm yr^{-1}. The soils are in the Aguilita-Fredensborg-Sion association (**Mollisols**), which are characterized as sloping and well drained, with shallow clay loam or silty clay loam subsoils, located over soft, marly limestone.

METHODS

In early 1986, six previously unmeasured plantations and two provenance trials were surveyed. West Indies mahogany planted along Mahogany Road and naturally regenerated at Estate Thomas was also assessed. Tree diameters were measured to the nearest 0.1 cm at breast height (dbh) with a diameter tape. Total heights and merchantable heights to a top diameter of 10 cm or the point of major bifurcation were estimated to the nearest 0.1 m with an optical rangefinder. The point of measurement for top diameter was determined with a pentaprism. Trunk volume in the growth studies was estimated by the relationship: volume = 0.5 x basal area x height (20). Merchantable volume was calculated by the relationship: volume = 0.5 (basal area top + basal area bottom of log) x length. All calculations were based on outside bark measurements.

The plantations included two plots of West Indies mahogany, a plot of Pacific Coast mahogany (*S. humilis*), three plots of hybrid mahogany, and a plot of teak. In the plantations, all trees intercepted by a basal area prism (BAF = 2.5 m^2 ha^{-1}) were measured. Crown classes (1), slope positions, and aspect were noted for most of the plots. To determine volumes on the prism plots, the actual basal area and volume of each intercepted tree was calculated. The actual basal area of each tree was then divided into the BAF factor to estimate the number of trees of that size class per hectare. Tree numbers were then multiplied by their respective volumes, and these data were summed to derive plot volumes per hectare. Mean diameter and height growth were also derived with the same weighting.

The Institute of Tropical Forestry teak provenance trial had been established in October of 1975 on St. Croix to compare the performance of five seed sources (Thailand, Ghana, Indonesia, and two from India) with seed collected from Sabana, Puerto Rico. At Bodkin, 272 stumps were planted. Four-tree rows were replicated 12 times with five provenances at a spacing of 3 by 3 m, with provenances assigned at random within each replication. Only eight replications of the Thailand provenance were available. They were planted around the margin of the other provenances. Height and dbh, stem form, and the number of trees producing seeds were recorded on all surviving trees at Bodkin. Tree dbh and height were compared among provenances using the Tukey-Kramer test (34).

The Commonwealth Forestry Institute Spanish cedar provenance trial had been established in August

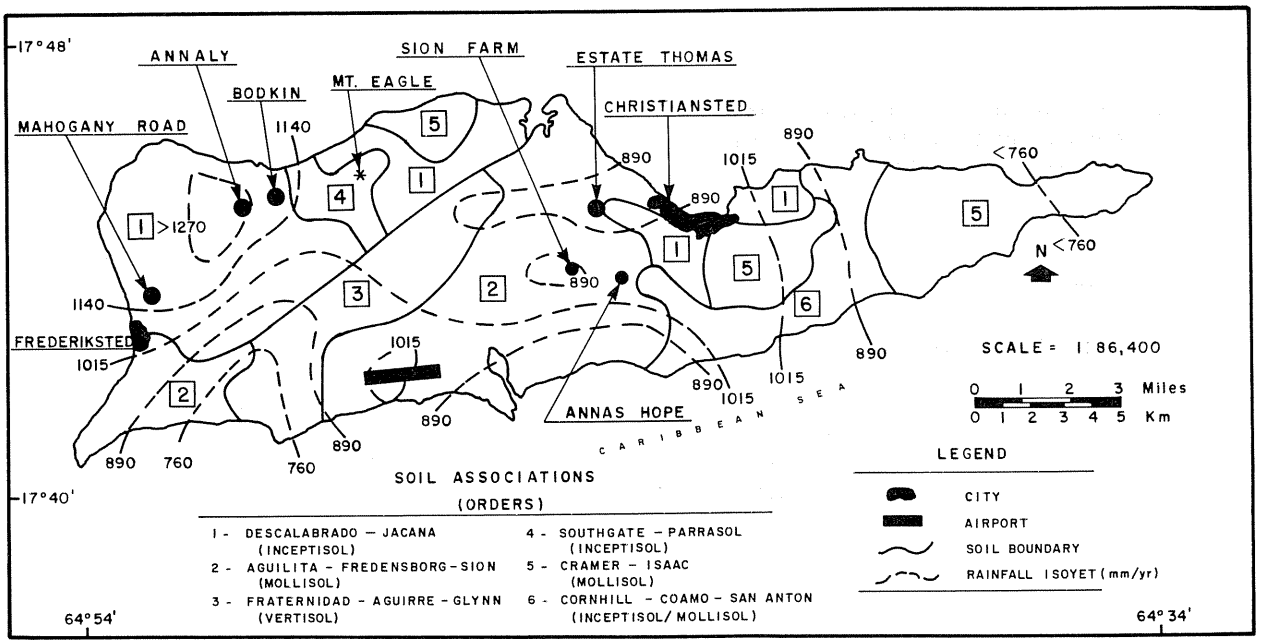

Fig. 1. Soil associations, soil orders, rainfall distribution, and location of study plots on St. Croix, U.S. Virgin Islands.

and September of 1969 at Estate Thomas, Hams Bluff, and two other sites on St. Croix that were subsequently lost by fire. On each site, 320 trees were planted (four trees per treatment, five treatments per replication, and 16 replications per site). Eight seed sources from Costa Rica, Jamaica, Mexico, Cuba, and Belize were included in the adaptability trials. The main objective was to determine the best sources for planting in the areas tested based on survival, growth rates, form, and phenology. All surviving trees on Estate Thomas and Hams Bluff were measured. Because mortality was high, data on survival, height, and dbh were inappropriate for analysis. Therefore, the data were converted to the sum of the main stem volumes per plot which were compared using Tukey's Omega procedure (26).

RESULTS

(1) West Indies mahogany (Mahogany Road). The sample of 20 mahogany trees planted along Mahogany Road ranged in dbh from 92.5 to 190.0 cm with heights between 16.8 and 25.1 m. The trees had a mean dbh of 125.7 ± 5.8 cm and a mean height of 22.4 ± 0.4 m. Estimated trunk volumes ranged from 6.4 to 29.4 m^3 per tree with a mean value of 14.6 ± 1.5 m^3. Although the age of these trees is uncertain, it appears that they were planted about 1790. An estimate of mean dbh growth, assuming an age of 200 years, is 0.63 cm yr^{-1}.

(2) West Indies mahogany regeneration (Estate Thomas). The naturally regenerated Estate Thomas mahogany stand, located on lands abandoned in 1928 after having been used for agriculture, was situated mainly on midslopes with north and south aspects. Mahogany trees accounted for 87 percent of the 176 stems tallied on 14 prism plots. Most sample plots contained mahoganies that varied considerably in size. Some trees dated to the time of abandonment and others were recent regeneration. Records indicate that much of the area had been thinned in the 1960's. The mean basal area in 1986 was 27 m^2 ha^{-1} and the mean trunk volume was about 109 m^3 ha^{-1} (Table 1).

The largest trees in the natural regeneration were found on the north-facing slopes. Detailed calculations were not merited because neither the age nor the effect of recent silvicultural treatments were known.

Table 1. Summary of studies conducted on St. Croix, 1986, with estimated basal areas and volumes for plantation species.

Study number and species[1]	Plots[2] (number)	Trees (number)	Year established	Parameters (mean ± SE)[3] Basal area (m^2/ha)	Trunk volume (m^3/ha)	Merchantable volume (m^3/ha)	Location
Growth:							
(1) *Swietenia mahogani*[4]	–	20	1 790	–	–	–	Mahogany Road
(2) *S. mahogani*[5]	14	176	1928	27.3 ± 3.8	108.9 ± 12.4	–	Estate Thomas
(3) *S. mahogani*[6]	5	51	1960	25.5 ± 1.4	146.2 ± 6.8	39.4 ± 2.2	Estate Thomas
(4) *S. humilis*	5	31	1961	39.5 ± 1.4	47.3 ± 6.8	18.0 ± 2.2	Estate Thomas
(5) *S. hybrid*[7,8]	7	51	1971	18.2 ± 1.0	90.5 ± 6.6	–	Sion Farm
(6) *S. hybrid*[7,8]	6	53	1971	22.1 ± 2.0	124.8 ± 14.5	–	Sion Farm
(7) *S. hybrid*[7]	5	66	1956	32.0 ± 2.1	239.7 ± 14.0	153.8 ± 14.1	Bodkin
(8) *Tectona grandis*	8	50	1956	15.3 ± 0.7	116.5 ± 5.9	79.1 ± 9.3	Estate Thomas
Provenance:							
(9) *T. grandis*	–	272	1975	–	–	–	Bodkin
(10) *Cedrela* spp	–	314	1969	–	–	–	Estate Thomas Hams Bluff

1 Study numbers are coded to text.
2 Plots in growth studies are prism plots (BAF = 2.5 m^2).
3 Basal area equals number of trees intercepted by a prism. Volume determined by relationships outlined in methods.
4 Assumed planting date about 1790.
5 Natural forest on land abandoned in 1928. Basal area plots also intercepted 23 trees of other species. Aspect was recorded.
6 "Plum pudding" variety of West Indies mahogany.
7 *Swietenia macrophylla* x *S. mahogani*.
8 U.S. Park Service plantings.

(3) West Indies mahogany (Estate Thomas). West Indies mahogany selected from seed sources with an attractive wood grain configuration, locally called "plum pudding" variety, was planted on level land on Estate Thomas in 1960. Basal area, trunk volume, and merchantable volume increment were satisfactory (Table 1). Mean volume growth rate averaged 6.0 m^3 ha^{-1} yr^{-1}. Mean dbh and height growth rates for all 51 trees sampled on five prism plots were 0.86 cm yr^{-1} and 0.44 m yr^{-1}, respectively. Ratios of diameter and height growth by crown class are shown in Table 2. The growth of dominant and co-dominant stems indicate the potential for trees when there is adequate space.

(4) Pacific Coast mahogany (Estate Thomas). The Pacific coast mahogany plantation, located on level ground in Estate Thomas, was established in 1961. Mean trunk volume was about one-third that of West Indies mahogany (Table 1) and averaged 2.0 m^3 ha^{-1} yr^{-1}. Mean dbh and height growth rate of the 31 trees recorded in five rows were 0.83 cm yr^{-1} and 0.39 m yr^{-1}, respectively.

(5) Mahogany hybrid (U.S. Park Service Planting No. 1). The mahogany hybrid, planted at Sion farm in 1971 and thinned in 1981, was located on mid-slopes that faced south. The mean basal area and mean trunk volume are shown in Table 1. Mean annual volume increment was 6.2 m^3 ha^{-1} yr^{-1}, excluding thinnings. Mean dbh and height of the 51 trees sampled on seven prism plots are shown in Table 2; mean rates of growth were 1.19 cm yr^{-1} and 0.66 m yr^{-1}, respectively.

(6) Mahogany hybrid (U.S. Park Service Planting No. 2). The second Park Service plantings of mahogany hybrid, also established in 1971 at Sion Farm, were located on mid-slopes with a north aspect, and on bottomlands. They were thinned once at an unknown date. The mean basal area and mean trunk volume are about 20 and 40 percent greater, respectively, than those on the first site. Mean dbh and height of the 53 trees sampled on six prism plots are shown in Table 2. Rates of growth for dbh and height were 1.16 cm yr^{-1} and 0.72 m yr^{-1}, respectively.

(7) Mahogany hybrid (Bodkin). The mahogany hybrids planted in Bodkin in 1956 were located on midslopes. Mean basal area, mean trunk volume and mean merchantable volume are shown in Table 1. Mean volume growth was 8.1 m^3 ha^{-1} yr^{-1}. Mean dbh and height of the 65 trees sampled on five prism plots are shown in Table 2. Mean dbh and height growth rates were 0.78 cm yr^{-1} and 0.47 m yr^{-1}, respectively.

(8) Teak (Estate Thomas). The teak planted in 1956 on Estate Thomas was located on level terrain and did not show much variation in stem size. Mean basal area, mean trunk volume and mean merchantable volume are shown in Table 1. Mean trunk volume growth rate was 3.9 m^3 ha^{-1} yr^{-1}. Mean dbh

Table 2. Relationships of tree diameters and heights by crown class in the sampled plantations.

Study number and species[1]	Diameter (cm)					Height (m)				
	Mean ± SE	Ratio[2]				Mean ± SE	Ratio[2]			
		D	C	I	S		D	C	I	S
(3) *Swietenia mahogani*[3]	22.05 ± 0.88	1.52	1.15	0.85	–	11.31 ± 0.29	1.08	1.06	0.95	–
(4) *S. humilis*[4]	20.2 ± 1.22	1.87	1.14	0.84	0.70	9.45 ± 0.33	1.44	1.05	1.01	0.80
(5) *S. hybrid*[5]	17.34 ± 1.69	1.30	1.08	0.82	0.44	9.64 ± 0.54	1.11	1.03	0.93	0.81
(6) *S. hybrid*[6]	16.91 ± 1.70	1.99	1.32	0.83	0.47	10.45 ± 0.58	1.26	1.11	0.93	0.80
(7) *S. hybrid*[7]	23.05 ± 1.04	1.77	1.39	0.83	0.57	13.75 ± 0.40	1.23	1.16	0.91	0.84

1 Study numbers coded to text.
2 Ratios for dominant (D), codominant (C), intermediate (I), and suppressed (S) stems. Ratios are a function of weighted mean values except for *S. humilis*, which was sampled in rows. To determine mean growth for any crown class, multiply overall mean by the ratio.
3 Total stems sampled, 51: D = 3, C = 33, and I = 15.
4 Total stems sampled, 31: D = 2, C= 13, I = 8, and S = 8.
5 Total stems samples, 51: D = 4, C = 43, I = 2, and S = 2.
6 Total stems sampled, 53: D = 2, C = 45, I = 4, and S = 2.
7 Total stems sampled, 65: D = 7, C = 32, I = 19, and S = 7.

and height growth rates of the 50 trees sampled on eight prism plots were 0 76 cm yr^{-1} and 0 51 m yr^{-1}, respectively

(9) Teak provenances. The teak provenances at Bodkin, located on gently sloping lands, were established in October, 1975 Survival ranged from about 80 percent for the Tamilnadu, India provenance, to about 95 percent for the remaining provenances (Table 3).

The best mean values for dbh and height were 13 8 cm and 10.5 m, respectively, attained by the Tamilnadu, India provenance; these values were significantly greater than dbh and height values for any of the remaining provenances. This provenance still had not produced seed and had an intermediate amount of forking. The Puerto Rico provenance showed comparatively poor dbh and height growth, averaging 11.0 cm and 9 3 m, respectively

(10) Spanish cedar provenances. The Spanish cedar provenances planted in August and September of 1969 were on level ground at Estate Thomas and on gently sloping lands at Hams Bluff. High mortality on both sites and the loss of two other plantations by fire altered the approach to data analysis specified in the original study.

Survival and dbh growth for all provenances combined were greater at Hams Bluff; height growth was better at Estate Thomas (Table 4). At Estate Thomas, the best volume growth was attained by the Belize provenance, whereas at Hams Bluff, the Mexico provenance performed best. Incidentally, these same provenances performed best in each of the three criteria tested: survival, height growth, and dbh growth.

DISCUSSION

Plantations

Mahogany and teak. The wood properties of mahogany and teak (17) make these species desirable for planting on St Croix The 30-year growth of the hybrid mahogany was the best of all species tested The 25-year growth of West Indies "plum pudding" mahogany was similar in dbh increment, but averaged only 80 and 75 percent of the height and volume increment, respectively, of the hybrid growth rates. The 25-year growth of the Pacific Coast mahogany averaged only 90 percent of the dbh and 83 percent of the height growth and about one-third of the trunk volume growth of West Indies mahogany. Initial survival in all plantations appears to have been high, although some stems were subsequently thinned or lost through competition.

Naturally occurring hybrid mahogany has been reported in Puerto Rico, St Croix, and Martinique (15). Moreover, hybrid mahogany has been planted with success in the subtropical wet life zone of the Luquillo Mountains in Puerto Rico (29). The hybrid has a finer wood texture when compared with typical Honduras mahogany, yet shows a more rapid growth rate when compared with the West Indies

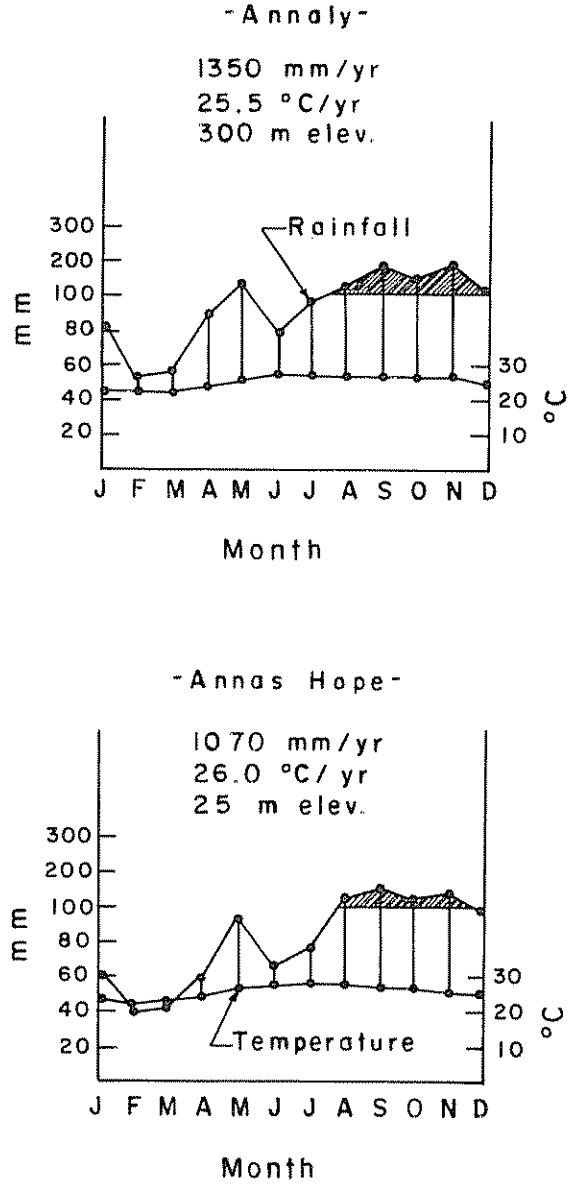

Fig. 2. Climatic diagrams for Annaly and Annas Hope, St Croix

Table 3. Comparison of teak provenance trials at Bodkin on St. Croix.

Provenance	Survival (%)	Mean ± SE[1] dbh (cm)	Mean ± SE[1] height (m)	Seed production (%)	Forking (%)
3040 (Ban Pha Lai, Thailand)	94	10.7 ± 0.7 a	7.8 ± 0.3 a	3	19
A (Sabana, Puerto Rico)	96	11.0 ± 0.3 a	9.3 ± 0.2 b	17	17
3044 (Jema, Ghana)	96	11.7 ± 0.3 a	9.2 ± 0.2 b	52	46
3049 (Ngliron, Java, Indonesia)	96	12.2 ± 0.4 ab	9.8 ± 0.1 bc	21	27
3021 (Nilambur, Kerala, India)	96	12.5 ± 0.5 ab	9.5 ± 0.3 b	4	13
3017 (Mt. Stuart 1, Tamilnadu, India)	79	13.8 ± 0.6 b	10.5 ± 0.2 c	0	19

1 Statistical differences at the 95% level within columns are indicated by different letters.

mahogany (15). It also has more drought resistance than Honduras mahogany (22), and grows faster than either parent on some sites (2). These favorable characteristics led to its planting in the Virgin Islands (10). The hybrid may also be more resistant to shoot borer attack than Honduras mahogany, and adaptability testing throughout the tropics has been encouraged (33).

The 27-year growth of teak at Estate Thomas was also satisfactory, given the Island's environmental conditions, which are not ideal for this species. The best sites for teak are on flat or slightly sloping terrain, with deep, well-drained, homogeneous, alluvial loam soils (13, 24). Moreover, the area should have a 3- to 6-month dry season with 50 mm or less of accumulated rainfall, yet receive annual precipitation in excess of 1 500 mm. Neither the edaphic nor the climatic conditions of St. Croix meet these environmental requisites. Furthermore, the top height of teak should average 24 m at 50 years (regional site class II) to achieve the best returns (13). This would mean that at 27 years, teak would be slightly more than 20 m tall, or about 6 m in excess of the top height of trees produced in Bodkin (Table 4). The growth of teak on St. Croix places it in regional site class IV (Table 4; 13).

Two other comments can be made based on the above studies. First, the size and growth rate of the West Indies mahogany trees on Mahogany Road probably approach the maximum that could be expected on St. Croix. The trees are growing in the open in the subtropical moist forest life zone, and their roadside position provides access to runoff during rainstorms. Second, microsite is a critical factor for tree growth in dry environments. The naturally regenerated West Indies mahogany on Estate Thomas appeared to develop better on the north aspect, which is shaded, and therefore more humid, than on the south aspect.

Provenance Trials

Teak. According to an unpublished progress report, the germination was good for all provenances used in this study. It was also noted that the Indonesia and Ghana provenances were growing most rapidly and that the latter provenance produced flowers in the fourth year. After 10 years, however, the best growth rates were shown by the Tamilanda, India, provenance. The Ghana provenance continued to show the greatest percentage of trees with seed production as well as demonstrate the highest amount of forking, substantiating the observation that early flowering of teak often results in poor form (11).

The dbh and height growth rates of teak at Bodkin after 10 years were more rapid than those at Estate Thomas. Although none of the sites where teak was planted on St. Croix meet the species' requisites well, it appears that the Bodkin site is better, probably because of greater annual rainfall.

Spanish cedar. The Belize provenance performed best at Estate Thomas, and the Mexican provenance performed best at Hams Bluff. In the nursery phase of these same trials, the Guanacaste, Costa Rica, Mexico, and Belize sources were above average when considering all measures of performance (height and dbh growth, branching tendency, percent mortality, and shoot borer attack), whereas the Turrialba and Argentina sources suffered heavy mortality due to slugs (31). At three years, or the establishment phase, none of the provenances was judged satisfactory and none had proven resistant to the mahogany shoot borer (32). Although some authors feel that Spanish cedar showed enough potential to justify more testing (9), tree form and growth of mahogany and teak are far superior to Spanish cedar and those species should be favored in future plantings.

Table 4. Comparisons in Spanish cedar provenance trials on St. Croix.

Provenance[1]	Mean ± SE dbh (cm)	Mean ± SE ht (m)	Volume[2] (m^3)	Survival (%)
Block 06 (Estate Thomas)				
A (Costa Rica)	12.4 ± 1.2	9.8 ± 0.6	0.049 a	12
B (Jamaica)	10.7 ± 1.8	9.0 ± 1.1	0.020 a	9
B (Mexico)	12.6 ± 1.1	9.7 ± 0.5	0.161 ab	47
E (Cuba)	8.1 ± 0.7	7.4 ± 0.4	0.067 a	56
G (Belize)	13.6 ± 0.6	10.7 ± 0.3	0.240 b	66
Mean	11.5 ± 0.4	9.3 ± 0.2	0.064	39
Block 07 (Hams Bluff)				
A (Costa Rica	9.1 ± 4.9	7.1 ± 2.2	0.083 ab	59
B (Jamaica)	4.7 ± 1.1	4.8 ± 1.3	0.002 a	11
D (Mexico)	14.5 ± 7.0	9.1 ± 2.5	0.387 c	89
E (Cuba)	11.2 ± 5.9	8.3 ± 2.6	0.171 ab	68
G (Belize)	12.5 ± 6.1	8.8 ± 2.8	0.230 bc	70
Mean	11.8 ± 6.4	8.2 ± 2.7	0.175	59

1 Commonwealth Forestry Institute codes for provenances: A = 67 (7286) Oxon 1, Guanacaste, Costa Rica; B = 67 (7292) Oxon, Enfield, Jamaica; D = 67 (7263) Oxon, Campeche, Mexico; E = 67 (729) Oxon, Cuba (exotic plantation); G = 67 (7282), Oxon 2, Belize. The following provenances were eliminated from the study because of poor germination or mortality: C, 67 (7286) Oxon 2, Turrialba, Costa Rica; F, 68 (8273) Oxon, Missiones, Argentina; and H, 67 (7282) Oxon, Belize (Whitmore 1971).

2 Sum of volume per four-tree plot. Statistical difference at the 95%level within columns is indicated by different letters.

Another interesting point derived from these provenance trials is that the short-term observations of performance, although generally informative with respect to growth, did not coincide with the long-term observations of best growth. Many provenance trials are designed to report on performance for just a few years. As in evident in these studies, short-term observations may not indicate the best performers in the long run.

In summary, the research and reforestation effort on St Croix has provided information on the survival and growth of commercial tree species and has created a valuable forest resource on lands that had no higher priority use. Although growth rates on the Island are not as rapid as in areas with higher rainfall, quality timber is now available for local wood-using enterprises and may be supplied in limited quantities on a sustained yield basis.

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Reacción de Algunos Cultivares de Cacao a la Inoculación Manual con *Moniliophthora roreri*[1]

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ABSTRACT

In field trials established at Turrialba, Costa Rica (22.5°C-87%), sixty-day-old pods were sprayed with 9 to 15-day-old monilia spores in a solution of 10^5 spores/ml. After innoculation, fruits were protected with clear plastic bags, perforated at the bottom to allow drainage of excess humidity. Readings taken weekly, from weeks five through fifteen, evaluated external damage on a scale of 0 to 10. Internal reaction was rated from 0 to 5 depending on degree of decomposition of beans. Cultivars demonstrating resistance were characterized by low incidence ($\bar{x}$ = 29%) of moniliaisis and slight external ($\bar{x}$ = 1, 2) and internal ($\bar{x}$ = 2.0) damage. Best results were obtained with cultivars 'CC-210', 'EET-48', 'EET-59', 'CC-266'. Most susceptible were: 'UF-667, 'UF-650, 'UF-4, 'UF-654', 'Pound-7', 'SGU-69' and 'UF-29', as evidenced by high ($\bar{x}$ = 91%) incidence and severe external ($\bar{x}$ = 4.6) and internal ($\bar{x}$ = 4.0) damage.

COMPENDIO

En Turrialba, Costa Rica, (22.5°C - 37%), se determinó la reacción de algunos cultivares de cacao a la inoculación manual de *Moniliophthora roreri*. Se utilizaron frutos de 60 días de edad de 33 cultivares, los cuales se asperjaron con conidios de 9 a 15 días de edad. Se usó una concentración de 10^5 conidios/ml; los frutos se protegieron con una bolsa plástica transparente y perforada en su base. A las cinco semanas de la inoculación, se iniciaron las lecturas de reacción externa y se continuaron una vez por semana hasta la décima quinta. Para estas lecturas se usó una escala de 0 a 10, según el tipo de síntoma que se observó. También, se calificaron internamente con base a una escala de 0 a 5, según el grado de descomposición que presentaron las almendras. De los resultados obtenidos se consideraron como resistentes o promisorios, por su baja incidencia ($\bar{x}$ = 29%) y severidades externa ($\bar{x}$ = 1.2) e interna ($\bar{x}$ = 2.0), a los cultivares: 'CC-210', 'EET-48', 'EET-59' y 'CC-266'. Como muy susceptibles, dada su alta incidencia ($\bar{x}$ = 91%) y severidades externa ($\bar{x}$ = 4.6) e interna ($\bar{x}$ = 4.0), a los cultivares 'UF-667, 'UF-650, 'UF-4, 'UF-654', UF-29', 'Pound-7' y 'SGU-69'.

INTRODUCCION

La moniliasis del cacao (*Theobroma cacao* L.), conocida también como pudrición acuosa, mal palúdico, mal de Quevedo, pringue, ceniza, pasmo, polvillo, helada, hielo, etc. (5, 10), es una enfermedad causada por el hongo *Moniliophthora roreri* (Cif. y Par. Evans), que ocasiona considerables pérdidas en cacaotales de Sur y parte de Centro América. Apareció con características epifitóticas en Ecuador en el año 1916 y de allí se extendió a Colombia y Venezuela. También se encuentra al extremo sur-este de Panamá (10) y en 1978 se registró por primera vez en Costa Rica (6) donde invadió toda el área cacaotera de la zona atlántica en menos de dos años. A fines de 1980, ya se encontraba en plantaciones del sur y también del norte, en la frontera con Nicaragua (Brenes, O. Comunicación personal, Turrialba, Costa Rica, C.A., 1981).

Hasta el presente, se sabe que el hongo sólo ataca el fruto de varias especies de los géneros Theobroma y

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