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CEDRELA PROVENANCE TRIAL IN PUERTO RICO AND ST. CROIX: ESTABLISHMENT PHASE[2]

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RESUMEN

Tres años después de plantación, se evaluó un ensayo de procedencia de cedro español. Ninguno de los cinco sitios considerados probó ser apropiado para plantaciones de esta especie. De las siete procedencias experimentadas, ninguna creció satisfactoriamente en ninguno de los sitios. Ninguna resultó resistente al barrenador de la caoba, *Hypsipyla grandella.* La importancia relativa de los dos problemas mayores en el establecimiento de plantaciones de cedro español (sensibilidad al sitio y ataque del barrenador) es discutida aquí.

SUMMARY

Three years after outplanting, a provenance trial of Spanish cedar was evaluated. Of the five sites considered, none proved appropriate for plantations of this species. Of the seven provenances tested, none grew satisfactorily on any of the sites. None proved resistant to the mahogany shoot borer, *Hypsipyla grandella.* The relative importance of the two main problems of Spanish cedar plantation establishment (site sensitivity and borer attack) is discussed.

Retrieval Terms: Meliaceae, Spanish cedar, *Hypsipyla grandella,* tropical silviculture.

Spanish cedar (*Cedrela* spp.[3]), a tree of the mahogany family and native to most of the humid neotropics, produces a cabinet wood popular for both local use and export. In view of the commercial importance of and interest in this species, the Commonwealth Forestry Institute (CFI) provided several research stations with seedlots of cedar provenances (see Burley and Lamb 1971, Melchior and Quijada 1972, and Omoyiola 1972 for details). The Institute of Tropical Forestry (ITF) in Puerto Rico received eight of these seedlots, which were sown in August and September 1969 and outplanted in July and October 1970. The nursery phase of this study was described earlier (Whitmore, 1971). This report covers the establishment phase (the 3 years immediately after the nursery phase).

The establishment of cedar plantations has long been a problem. Most attempts have failed, apparently because of internal soil drainage and the species' site sensitivity. Concurrent tests

[1] In cooperation with the University of Puerto Rico.

[2] Revised from a paper presented at the I Congreso Brasileiro de Florestas Tropicais, Vicosa, October 1974.

[3] This report deals with *Cedrela odorata* L. (*sensu lato*). Specific epithets of *Cedrela* are confusing, however, and use of geographic origin is recommended until the taxonomy of the genus is better understood.

which supplement this provenance trial are being conducted to examine this regeneration problem. Other recent studies attempt to provide alternative species with similar wood characteristics (Otárola *et al.* 1976, Sánchez *et al.* 1976).

A second problem in cedar plantations is the attack of the shootborer, *Hypsipyla grandella* Zeller. There are several recent studies on this plant-insect relationship (Grijpma 1973, Whitmore 1976 a & b). This trial served as a preliminary attempt to find provenances that might help overcome either or both of these problems under growing conditions in Puerto Rico and St. Croix, Virgin Islands.

ESTABLISHMENT PHASE PROCEDURES

Seedlings were raised in two nurseries, one in Puerto Rico and one in St. Croix. Mean height, branching tendency and mortality varied among provenances at the beginning of the field phase (Table 1).

Seven sites were planted, three in Puerto Rico and four in St. Croix. One site in Puerto Rico was destroyed by highway construction and one in St. Croix was abandoned after the second year due to poor growth, so this report deals with the remaining five sites (Figure 1). Because of problems in the nurseries (reported in Whitmore, 1971), no site was planted with all eight provenances (Table 2).

A randomized complete block design was used with four-tree plots and 16 replications at each site. The four-tree plot, laid out 1 x 4 with the axis parallel to the slope, was considered a suitable compromise between the highly efficient one-tree plot and the longer-term, CFI-recommended 100-tree plot. This decision was based on Line's (1976) definition of first-stage provenance research, on the argument of Wright and Freeland (1961) that plots with fewer trees are more efficient, and on the facts of high labor cost and unavailability of large tracts for research in Puerto Rico and St. Croix.

Each site in Puerto Rico, planted with six provenances and a total of 384 trees at 3 m spacing, occupies 0.23 ha. Each site in St. Croix, with five provenances and 320 trees, occupies 0.19 ha. At Corozal and Guajataca cedars were planted under overstory vegetation. Corozal was a former coffee site with a dense shade of *Inga laurina* (Sw.) Willd., and Guajataca was a 35-year-old *Swietenia mahagoni* Jacq. plantation with a high, sparse canopy. The other three sites were not shaded.

During the first year, the plantings were weeded as necessary to keep mortality low. On two sites, Bog of Allan and Estate Thomas, all competing vegetation was kept mowed year-round on 4 of the 16 replications in order to test the theory that weed competition limits cedar height growth. The remaining 12 replications on these sites, as well as the 16 on each of the other sites, were not weeded after the first year.

Three years after outplanting, results were evaluated according to height, mortality, branches, and attack by the shootborer. Analyses of variance and multiple range tests were used to evaluate the height data.

RESULTS AND DISCUSSION

Height growth (Table 3)

In Puerto Rico the C source outgrew the others by a large margin, averaging 0.88 and 1.10 m in annual height growth. The G and E sources were next, ranging from 0.46 to 0.94 m, and the D, A and F sources followed with 0.24 to 0.64 m per year. At St. Croix sites, where C was not planted, G outgrew the others (0.59 to 0.93 m per year) except at Ham Bluff where it was equaled by D On these three sites, D and E averages ranged from 0.45 to 8.84 m; A and B grew least with 0.31 to 0.69 m annual height increment.

There was a very low correlation between tree height during the first 12 months (nursery stage) and height 3 years after outplanting. One cannot expect the tallest trees in the nursery to necessarily be the tallest at the end of 3 years in the field.

Cedar plantations often stagnate before the fifth year as the growth rate levels off, but this has not yet happened with any of these provenances. In each provenance, growth rate dropped slightly after the 18-24 month period, but has maintained a rather steady pace (Figure 2).

Measuring the crop tree, the tallest in each 4-tree plot, can sometimes give a better estimate of the genetic potential of a provenance than height growth means because the effect of non-genetic

defects and accidents is minimized. In this study, crop tree performance of provenances remained comparatively the same as plot means in height growth, but rates are substantially greater. The C source crop trees, for example, grew an average of 1.14 and 1.32 m annually (Guajataca and Corozal) compared with the 0.88 and 1.10 m averages for all C source trees, a difference of 20 to 30%.

Even so, initial height growth is not satisfactory. Considering the problem of weed growth and the threat to slow-growing trees by the form-ruining shootborer, the performance of 1.1 to 1.3 m per year shown by the best trees of the best provenance is disappointing. Lamb (1968), for example, described a *Cedrela odorata* L. plantation in Nigeria which, 29 months after outplanting, was 6.1 to 7.6 m in height with excellent form. Furthermore, natural cedar regeneration on abandoned slash-burn agricultural land in the Urabá region of Colombia produced trees 30-40 cm dbh at age 13 years, when they were harvested. Form was good and wood quality excellent. The effects of shootborer attack were overcome by rapid growth (Arturo Romero, Silviculturist, Medellin, Colombia: Personal Communication). Also, a cedar plantation in the San Carlos region of Costa Rica had, at age 14 years, trees up to 53 cm dbh, straight, tall stems of high quality, harvestable wood, in spite of early shootborer attack. These examples demonstrate the potential of *Cedrela* on optimum sites and the goal to which we must aspire in cedar plantation research.

Though Corozal, Ham Bluff, and Estate Thomas proved better for cedar height growth than Guajataca and Bog of Allan, performance was basically poor for all sites, and no conclusions can be drawn from this limited study to compare these sites to optimum growing conditions.

Weed Competition, Mortality, and Branching Tendency (Table 4)

In St. Croix, the Bog of Allan mowed vs. unmowed plots showed mean heights of 1.4 and 2.1 m respectively, after three years of growth: the trees with more weeds and less maintenance grew faster in height. The Estate Thomas site showed no difference: 2.3 m for mowed and 2.3 for unmowed. Another mowed-unmowed trial at Estate Thomas had means of 1.2 and 1.6 m, again indicating that weed competition can induce height growth. These results do not support the theory that elimination of weedy competition would produce taller cedars.

Adaptability of a provenance can be measured by survival and height growth. In this trial, survival and height growth were directly correlated: those provenances that grew fastest generally had least mortality. Of the fastest growing provenances, mortality was less than 20%, which is quite acceptable. Overall mortality of trees planted on sites in the subtropical moist forest life zone (Table 2) was 25%, but only 18% on sites in the subtropical dry forest life zone. This tends to support the belief that cedar resists drought well but cannot tolerate excessive moisture.

At the end of the nursery phase, the C provenance seedlings had 9 times more branches (2.7 per seedling) than any other provenance. The tentative conclusion was that, if this branching tendency was indicative of later form, the C provenance would prove unacceptable. Three years later, we now see that the C source is the most promising in height growth and has excellent form. The tendency for early branching was apparently an expression of vigor.

The trees on the three St. Croix sites grew in the open and tended to branch more than trees in Puerto Rico, although, the trees in Puerto Rico branched more during the nursery phase (Table 1). The nursery in Puerto Rico was unshaded and the one in St. Croix was heavily shaded. Therefore, the number of branches three years after outplanting is probably related to whether the seedlings are shaded or not. It is also apparently related to height growth: faster growing sources tend to have more branches.

Shootborer attack (Table 4)

To obtain accurate information on shootborer attack, trees must be inspected once every two months and preferably more often. In this study, recent attacks were recorded once a year at the time of height measurement, a highly unsatisfactory evaluation of borer damage.

Nevertheless, the 1973 borer data from St. Croix sites indicate a weak, but direct relation between height growth and borer attack: the borer tends to attack trees that grow faster. Borer attack influenced branching: when the borer kills the terminal shoot several side shoots grow and

later persist as branches. Borer data from the Puerto Rico sites are confounded with the factor of shade from overstory, thus are not included here. In general, these shaded trees were attacked less than those growing in the open. No provenance proved exceptionally more resistant to attack except when related to height growth.

Gara, *et al.* (1973) observed that the borer selects the tallest trees that have fresh, green growth. This observation is supported by the present study. To the contrary, however, Lamb (1968) found that borer attack failed on the most vigorous trees due to a heavy resin flow which entraps or otherwise discourages the insect. The apparent anomaly suggests that (1) studies of this feature in stands which are not vigorous (i.e. Gara *et al.* and the present study) may be misleading, (2) cedar growing under optimum conditions will not be bothered by borer attack, from either a biological or commercial point of view, and (3) the problem must be met silviculturally by identifying and providing optimum growing conditions.

Interaction

It should be noted that the above mentioned items, while listed separately, are definitely interrelated. Mortality, branching tendency and shoot-borer attack are all correlated with height growth. The interaction between branching and borer attack is the more obvious: the borer kills the terminal shoot thus causing several side shoots to grow which later persist as branches. Also, there is a strong site/provenance interaction for each of the parameters.

CONCLUSIONS

1. Height growth of the most promising provenance, on the most promising site, was at best disappointing. C (Turrialba, Costa Rica) is by far the fastest provenance in height growth on the sites in Puerto Rico. G (Belize) was the fastest in height growth on St. Croix. D (Campeche, Mexico) and E (Cuba) were intermediate on both islands. A (Guanacaste, Costa Rica), B (Jamaica) and F (Argentine) grew poorly. Weeding after the first year provided no stimulus to height growth.

2. Mortality of the faster-growing provenances was low and could be lowered even more by further site adaptability research. Cedar resists drought well: mortality was lower on dry sites than on moist sites.

3. Branching and borer attack were both more common on the open sites than on the shaded sites. No provenance stood out as borer-resistant.

4. Provenance research, as with borer research, is of limited value if none of the trees grow at maximum potential. Until we can define and provide optimum site and growing conditions for cedar, borer and provenance studies will only tell us what happens to a tree growing under an unknown handicap.

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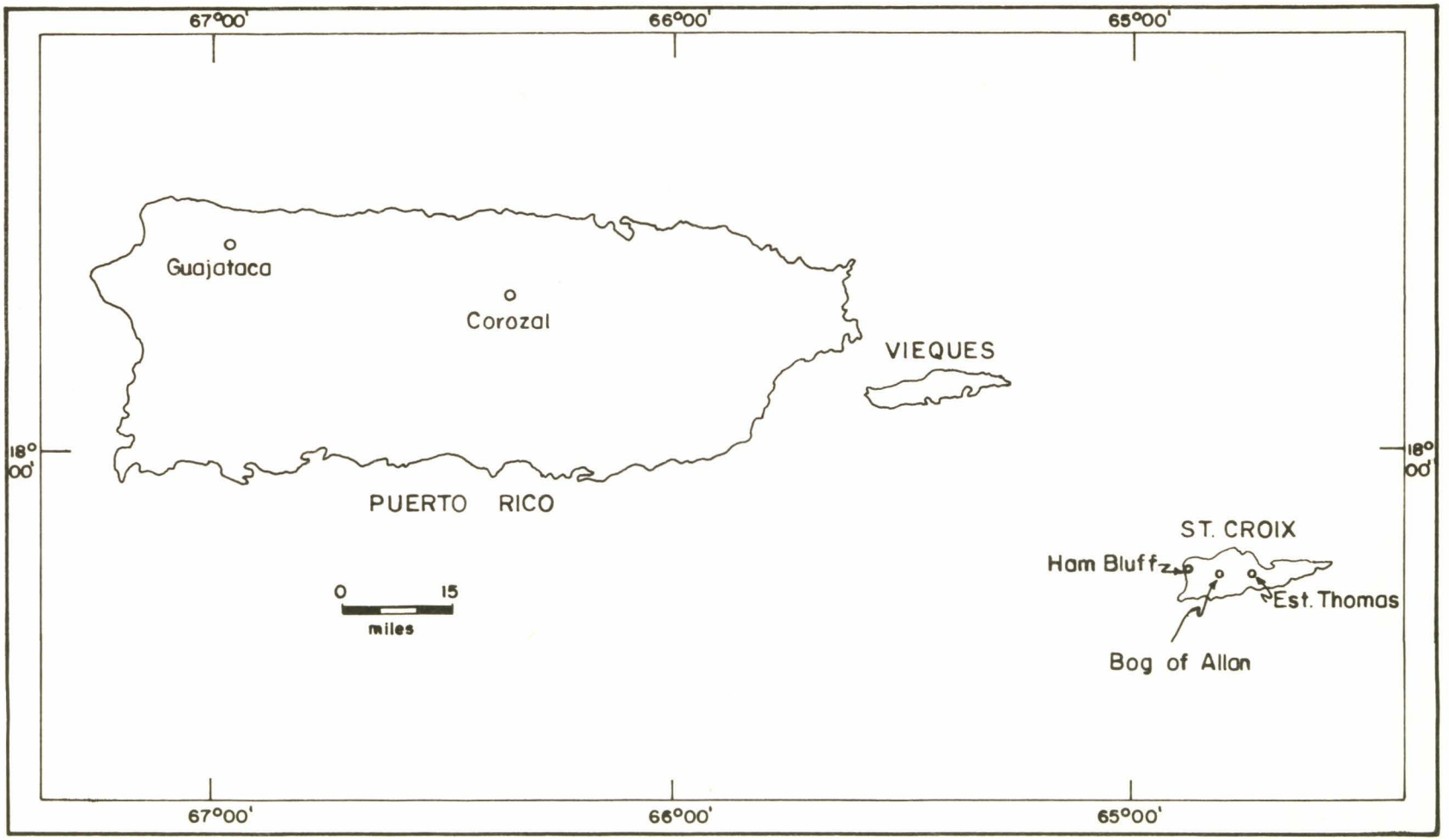

Figure 1. Position of the five sites of the Puerto Rico — St. Croix Cedrela provenance trial.

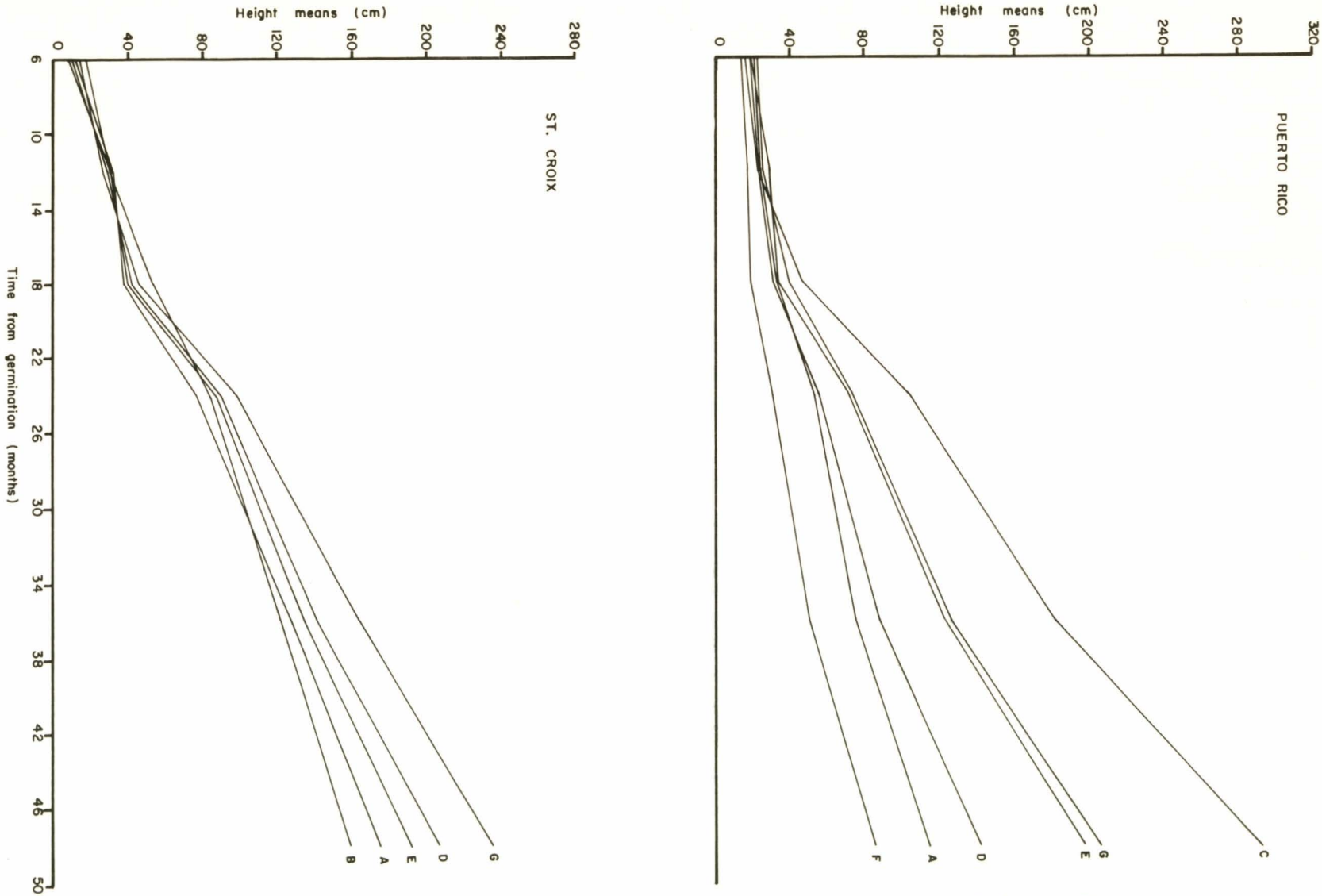

Figure 2. **Cedrela** provenance trial height data summary. Means of two sites in Puerto Rico, and three in St. Croix, according to provenance. Time scale expressed in months after germination (Puerto Rico germination August 1969, St. Croix September 1969)

Table 1. Description of *Cedrela* provenances and height, branching and mortality means of *Cedrela* provenances at age 11 months (Puerto Rico) and 12 months (St. Croix). These figures refer to the end of the nursery phase (Whitmore, 1971).

ITF Code	CFI Code	Origin	Specific epithet*	Height** (cm)	Branching (#/100 seedlings)	Mortality (%)
				Puerto Rico		
A	67 (7286) Oxon 1	Guanacaste, Costa Rica	*odorata*	A 25.5 a	D 5.0	A 0.0
				E 24.5 ab	E 12.5	E 0.0
B	67 (7292) Oxon	Enfield, Jamaica	*odorata*	G 24.2 ab	F 17.5	G 0.5
				C 23.6 ab	G 17.5	C 1.0
C	67 (7286) Oxon 2	Turrialba, Costa Rica	*odorata*	D 22.4 b	A 30.0	D 2.0
				F 17.6 c	C 272.5	F 5.1
D	67 (7263) Oxon	Campeche, Mexico	*mexicana*			
				St. Croix		
E	67 (729) Oxon	Cuba (plantation)	*odorata*			
				A 32.3 a	D 0.0	A 3.1
F	68 (8273) Oxon	Misiones, Argentina	*tubiflora*	B 30.1 b	E 2.5	D 3.1
				D 29.0 bc	A 2.5	E 3.1
G	67 (7282) Oxon 1	Belize	*mexicana*	G 27.9 cd	G 7.5	G 3.9
				E 27.0 d	B 27.5	B 7.4
H	67 (7282) Oxon 2	Belize	*mexicana*			

* Specific epithets are those in use at place of origin.

** Means followed by the same letters are not significantly different ($P < 0.01$).

Table 2. Sites planted, with provenances, altitude, rainfall, life zone, soil type and date planted.

Site	Sources tested	Altitude (m)	Mean annual rainfall (mm)	Life zone*	Soil**	Date planted
Puerto Rico						
Corozal	A,C,D,E,F,G	152	1994	moist	Lares clay old, well drained terrance	July 1970
Guajataca	"	200	1952	moist	Tanama stony clay rocky limestone slope	"
St. Croix						
Bog of Allan	A,B,D,E,G	90	990	dry	Descalabrado clay loam shallow, igneous origin	Oct. 1970
Estate Thomas	"	120	985	dry	Sion clay loam deep black soil between limestone hills	"
Ham Bluff	"	30	1194	moist	San Anton clay loam deep, well drained, igneous origin	"

* Moist = Subtropical moist forest life zone; dry = Subtropical dry forest life zone (Ewel & Whitmore, 1973).

** Roberts (1942) and Rivera *et al.* (1970).

Table 3. Means for height and crop tree height three years after outplanting. Those means followed by the same letter are not significantly different ($P < 0.05$).

Each provenance, by site

Site	Height (cm)	Crop tree height (cm)
Corozal	C 329 a	C 396 a
	G 282 b	G 359 ab
	E 248 b	E 329 b
	D 192 c	D 236 c
	A 157 cd	A 210 c
	F 114 d	F 140 d
Guajataca	C 263 a	C 341 a
	E 156 b	E 218 b
	G 137 b	G 214 b
	D 100 c	D 151 c
	A 78 c	A 97 c
	F 71 c	F 94 c
Bog of Allan	G 176 a	G 245 a
	D 140 b	D 193 b
	E 134 b	E 193 b
	A 128 b	A 169 b
	B 92 c	B 117 c
Estate Thomas	G 278 a	G 325 a
	D 229 b	D 295 b
	E 223 bc	E 271 b
	B 201 cd	B 238 c
	A 189 d	A 233 c
Ham Bluff	D 252 a	D 298 a
	G 250 a	G 296 a
	E 219 b	E 269 b
	A 207 b	A 253 b
	B 184 c	B 218 c

Each site, by provenance

Provenance*	Site	Height (cm)	Crop tree height (cm)
A	Ham Bluff	206 a	252 a
	Estate Thomas	189 a	232 a
	Corozal	154 b	206 ab
	Bog of Allan	124 b	167 b
	Guajataca	57 c	72 c
D	Ham Bluff	250 a	297 a
	Estate Thomas	228 a	294 a
	Corozal	188 b	232 b
	Bog of Allan	135 c	181 bc
	Guajataca	93 c	141 c
E	Corozal	245 a	326 a
	Estate Thomas	223 a	270 a
	Ham Bluff	218 a	268 a
	Guajataca	150 b	208 b
	Bog of Allan	136 b	197 b
G	Corozal	279 a	355 a
	Estate Thomas	278 a	325 a
	Ham Bluff	251 a	295 ab
	Bog of Allan	177 b	248 bc
	Guajataca	130 b	205 c

* Only provenances common to all sites are listed.

Table 4. *Cedrela* data three years after outplanting, according to island and provenance. Numbers represent means of two sites in Puerto Rico and three in St. Croix.

	Height (cm)	Mortality (%)	Branches (#/live tree)	Borer attack (#/live tree)
Puerto Rico				
C	292	8	0.8	
G	205	16	1.1	
E	198	12	0.8	No
D	141	30	0.7	data
A	115	50	0.5	
F	90	58	0.1	
St. Croix				
G	235	13	3.1	0.77
D	207	12	2.9	0.73
E	192	12	1.9	0.74
A	175	16	2.3	0.70
B	159	30	2.2	0.66