FOREST SERVICE RESEARCH PAPER ITF-17

JULY 1973

SEED SOURCE VARIATION IN PUERTO RICO AND VIRGIN ISLANDS GROWN MAHOGANIES

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SUMMARY

Seeds were collected from natural stands of *Swietenia macrophylla* and *Swietenia humilis* in eighteen areas from Mexico through Panama and seedlings from the seeds were planted at thirteen locations in Puerto Rico and the Virgin Islands. *Swietenia mahagoni* from naturalized stands in the Virgin Islands were included in the plantings.

Differences exist to varying degrees in seed pods, seedling characteristics, survival after field planting, susceptibility to shoot borer attack, growth rate and leaf characteristics between species and among seed sources within species. Differences between species were more important than differences among seed sources in the important characteristic of adaptability as a timber species. Planting location was also very important.

S. macrophylla is recommended for plantations in most of the Subtropical Moist and Wet Ecological Life Zones, but only on a small scale because of shoot borer and weed problems. The data suggest that native areas with the shortest dry season may be the best source of seed for *S. macrophylla* plantations in Puerto Rico. No mahogany is recommended for the coolest,. wettest portion of the Subtropical Wet Life Zone or the Subtropical Lower Montane Wet Zone. A hybrid, *S. macrophylla* x *S. mahagoni,* is the mahogany for planting for timber production in the Subtropical Dry and transitional area of the Subtropical Moist Zone.

O.D.C.232.12:176.1 *Swietenia:* (729.5)

RESUMEN

Se escogieron semillas de *Swietenia macrophylla* y *Swietenia hùmilis* de rodales naturales en 18 áreas desde Mexico hasta Panamá, y las plántulas de estas semillas fueron plantadas en trece sitios en Puerto Rico y las Islas Vírgenes. En estas plantaciones se incluyó *Swietenia mahagoni* de rodales naturalizados en Islas Vírgenes.

Hay diferencias, hasta cierto grado, en la forma de las bellotas, características de las plántulas, grado de supervivencia después de plantadas, susceptibilidad al ataque del barrenador, grado de crecimiento y características de la hoja, entre las especies y la procedencia de las semillas. Las diferencias entre especies resultaron más importantes que las diferencias entre procedencias, en su importante característica de adaptabilidad como especie maderable. También fué muy importante el sitio donde se plantaron.

S. macrophylla es recomendada para la mayoría de las plantaciones en Zonas de Vida Ecológica Muy Húmeda y Húmeda Subtropical, pero solamente en pequeña escala, debido a los problemas causados por el barrenador y los yerbajos. Los datos adquiridos sugieren que las áreas nativas que tienen una temporada de sequía corta podrían ser la mejor procedencia para plantaciones de *S. macrophylla* en Puerto Rico. No se recomienda ninguna caoba para la parte más fresca y más húmeda de la Zona Muy Húmeda Subtropical o para la Zona Muy Húmeda Montano Bajo Subtropical. Para la producción de madera en la Zona Seca Subtropical y en el área transitoria de la Zona Húmeda Subtropical la híbrida, *S. macrophylla* x *S. mahagoni* es la caoba más apropiada a ser plantada.

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INTRODUCTION AND METHODS

Seed was collected from natural stands of Honduras mahogany, *Swietenia macrophylla* King, and Pacific mahogany, *Swietenia humilis* Zucc., in eighteen areas from Mexico through Panama in 1964 and 1965 (Table 1, Figure 1). Mature seed pods were usually obtained by shooting them from the trees, and it was attempted to collect five pods from each of sixteen trees of normal appearance in each area. In collection HGA the seed had fallen and was collected from underneath the mother trees. The collection areas, mother trees, seed pods, and season of maximum seed ripeness are described in Appendixes I, II, and III.

The seeds were obtained in two trips approximately one year apart and the resulting two seed collections were sown as separate experiments. The first trip covered the northern part of the collection area (all the Mexico seed sources and one of *S. macrophylla* from Guatemala) and the second trip covered the southern part. Seedlings were produced by directly sowing soil-filled polyethylene bags. The seedlings of each mother tree were grouped together in the nursery and the groups were distributed in random order in the beds. No measurements were made of the seedlings from the northern collection, but height, number of simple leaves, and presence or absence of compound leaves were recorded for the five tallest seedlings from each mother tree from the southern collection five months after sowing.

Approximately seven-month seedlings of the nine seed sources from the northern collection were planted at eleven locations in Puerto Rico and two in St. Croix, U.S. Virgin Islands (Table 2). The locations are ranked in Table 2 in approximate order of decreasing temperature and increasing rainfall, so that Coamo is hot and very dry, and Guilarte cool and very wet. Added to the plantings, except at Estate Jealousy, were seedlings of West Indies mahogany, *Swietenia mahagoni* Jacquin, grown from seed collected in St. Croix, where this species has become naturalized. The initial plantings in St. Croix were destroyed by error and were replanted ten months later. The eleven locations in Puerto Rico were planted with approximately seven-month seedlings of the southern collection approximately a year after planting the northern seedlings. Usually the planting areas of the two collections were side by side within locations, although occasionally they had to be separated because of terrain. For example, at Guajataca in the limestone hills of northwestern Puerto Rico, the two collections were planted at the bottom of different sink holes. The plantings of the southern collection included ten seed sources, but one has been excluded from the report because all of its seedlings came from a single mother tree.

1/ In cooperation with the University of Puerto Rico

The planting design was the same at each location for each collection, and 2.4 meter square spacing was used throughout. The basic units were single tree plots arranged into 3 plot x 3 plot square blocks. Nine different seed sources were planted in each block. There were 32 blocks for each collection at each location and these were laid out in a 4 block x 8 block rectangle. It was attempted to plant the same number of seedlings from each of 16 mother trees at each location. However, this was not possible because of lack of seedlings for some mother trees, less than 16 mother trees of sources MHA and MPA, and the 9 cell instead of a 10 cell block. There was a considerable difference among seed sources in the broadness of the genetic base (Table 3). At one extreme source HMB was represented in the eleven Puerto Rico field plantings by only 7 mother trees and there was large variation in the number of seedlings planted from each of the seven. One mother tree alone was the source of 46% of the HMB seedlings. At the other extreme the number of seedlings planted from each mother tree of source HSA only ranged from 20 to 24.

The Puerto Rico locations except Coamo were planted within a period of six weeks with the seedlings from the northern collection. Coamo was planted six weeks later than any other. All Puerto Rico locations were planted within a period of four weeks with the southern seedlings. Most of the plantings occurred in the months of November and December of 1964 and 1965. Seedlings that died within the first few months of planting were replaced within eight months of the initial planting (or the complete replanting in St. Croix) and usually within four months. Five percent of the northern seedlings and six percent of the southern were replaced.

Field measurements have been made a number of times since planting. Recorded were survival, height and diameter breast height (DBH), and whether or not trees were attacked by the mahogany shoot borer, *Hypsipyla grandella* Zeller, during the preceding year. In this report survival and growth are based on measurements made during late March-early April 1971 in Puerto Rico and mid-February, 1971, in St. Croix. The trees of northern origin were then in their seventh year of growth (sixth year in St. Croix) and the southern trees were in their sixth year. The report on shoot borer is based primarily on data recorded during February and March of 1969, when it was still possible to distinguish the tip of the leader.

Measurements of leaf characteristics were also made in 1969 on a sub-sample of trees. The locations in Puerto Rico were stratified into three size classes based on height. From each stratum one location was selected at random, and at each location five sample trees of each seed source were randomly selected. From each tree one mature, undamaged leaf was selected from one of sixteen crown regions. Measured were lengths of petioles, rachises, leaflets, and petiolules; leaflet length; leaflet maximum width; and number of leaflets.

Statistical analysis of field survival and growth posed a problem because of the non-orthogonal field design, replantings, missing plots, differences in measured growth intervals, heterogeneity of variances, and interactions. Therefore, for many comparisons, no statistical analyses of variance were made. Mean annual height increment was used for many comparisons to adjust for the differences in measurement periods. On subsets of data on which analyses of variance were made the following was done: for survival, transformation to arc sin values and two-way anova; for height and DBH, multiple regression analysis ignoring differences in length of the measurement periods; the five percent confidence level was chosen for establishing statistical significance.

RESULTS

Seedling characteristics – southern collection

The nine southern seed sources varied in seedling height, number of simple leaves and number of compound leaves (Table 4). The superior height of seed sources MNB and MNA was later to be found in the field plantings. Except for this, nursery heights did not predict future field results. The number of simple leaves on a seedling was independent of species and seedling height, and there was no obvious relationship to geographic origin. The average seed source of *S. macrophylla* has few seedlings with compound leaves after five months growth in the nursery and those of *S. humilis* had many. However, few seedlings of seed source HGA had compound leaves and this resemblance of HGA to typical *S. macrophylla* was found in subsequent field analyses. HCA showed an intermediate response in seedlings with compound leaves, as it often did later in other characteristics.

Survival in field plantings

A much greater percentage of *S. macrophylla* (M) trees survived than trees of *S. humilis* (H) and *S. mahagoni* (WIM) when averaged over all planting locations (Table 5.). However, there was a major interaction in species survival with moisture regime of the planting location. At the drier planting locations, survival of *S. humilis* and *S. mahagoni* was greater than that of *S. macrophylla.* This difference on the drier sites was statistically significant in the plantings of the southern collection only. There was no difference in survival between *S. humilis* and *S. mahagoni.*

Within a species there was considerable variation in survival associated with seed source. On the wetter sites there were statistically significant differences among seed sources of *S. macrophylla* of both northern and southern collections, and among *S. humilis* seed sources of the southern, but not northern collection. However, on drier locations the only significant difference among seed sources within a species was that of *S. humilis* seed sources of the northern collection. The most outstanding variation associated with seed source was that of seed source HGA which survived in a pattern more typical of *S. macrophylla* than *S. humilis* (i.e., percentage survival was greater on wetter than on drier locations), and that of HCA which survived equally well on both wet and dry locations.

In addition to the distinction in survival between wetter and drier locations, there were significant differences in survival among locations within the two moisture classifications (Table 6). Very low survival occurred at Estate Jealousy, where there were maintenance problems in addition to drought; in the northern collection at Guilarte, where road building activity caused soil movement over some plots; in the southern collection at Coamo, where severe drought occurred during the establishment period; and among most seed sources of *S. humilis* and *S. mahagoni* on many of the wetter sites, especially at the three that were probably the coolest and wettest, Maricao, Matrullas, and Guilarte. There was no evidence that within the two moisture classifications the pattern of survival of any individual seed source from location to location differed from that of the overall species, including seed sources HGA and HCA.

Seven locations were selected for more intensive statistical analyses of survival on the basis of their lack of establishment problems, presence of both collections, and climatic suitability for mahogany culture. Seed sources of poor adaptability (*S. mahagoni* and all but one seed source of *S. humilis*) at these locations were excluded. There were statistically significant differences in survival associated with seed source and planting location (Table 7). But in general survival of all seed sources and at all planting locations was fair to good. There was little difference in survival between collections and there was a greater range in survival associated with planting locations than with seed source.

Shoot borer attack

As of January 1969, four and three years respectively after planting the northern and southern collections, shoot borer attacks were recorded at seven locations (Table 8). Unattacked were the two St. Croix locations, Guajataca, and the three coolest, wettest locations in Puerto Rico. Very few trees were attacked at Rio Abajo, while attack was heavy at Cambalache, Tract 105, and El Verde. By early 1971 all but Guajataca and Maricao of the borer-free locations in early 1969 were being attacked, some of them heavily, and attack at Rio Abajo had become heavy, as shown below:

Shoot borer attack in late 1970-early 1971 in previously unattacked locations

Location	Trees attacked (%)
JEAL	73
THOM	96
RABA	71
MATR	20
GUIL	41

In contrast at Coamo, Las Marias, and Guavate, almost no new attacks were recorded in 1970 and 1971, while at Cambalache, Tract 105, and El Verde, borer attack continued heavily. Shoot borer attack at the various locations could be classified as follows:

Extent of Shoot Borer Attack Problem

Serious	Minor	None
JEAL	COAM	GUAJ
THOM	LMAR	MARI
CAMB	GUAV	
T105	MATR	
RABA	GUIL	
EVER		

A greater percentage of *S. macrophylla* trees were attacked than *S. humilis* trees, and *S. mahagoni* showed no signs of attack (Table 8). There was no evidence of geographical variation in susceptibility to borer attack within *S. macrophylla*. Within *S. humilis* HGA and HCA, again showing characteristics of *S. macrophylla*, were attacked more than other seed sources.

Growth in field plantings

Height growth followed a pattern similar to survival. Trees of *S. macrophylla* grew more rapidly in height than trees of *S. humilis* and *S. mahagoni* (Table 9). Again there was an interaction with moisture regime of the planting location. Trees of *S. macrophylla* grew more rapidly on wetter sites than drier sites, while trees of *S. humilis* and *S. mahagoni* grew more rapidly on drier than wetter sites, but never more rapidly than trees of *S. macrophylla* (ignoring individual seed source variations). And again HGA and to some extent, HCA, exhibited characteristics typical of *S. macrophylla.* There was no difference in the rate of growth between *S. humilis* and *S. mahagoni.*

Growth of *S. macrophylla* was poorest at the driest (COAM) and the three coolest, wettest locations (MART, MATR, GUIL), and of the remaining locations growth of *S. macrophylla* was best at the three (GUAJ, LMAR, GUAV) where shoot borer attack wasn't a serious problem (Table 10). Statistical analysis of the six fastest growing seed sources (all *S. macrophylla* except for HGA) of each collection on the seven locations in Puerto Rico with the best growth revealed statistically significant differences associated with seed source and planting location (Table 11). The few months difference in the measured period of growth between locations was ignored for this analysis. Poorest growth in the northern collection was that of MMA and MME, although MME did relatively much better at the drier location (Table 9). The two southern most sources of *S. macrophylla* and the *S. humilis* source HGA grew poorest within the southern collection, although on drier sites they grew relatively better. *S. macrophylla* of the southern collection has grown faster than that of the northern collection, and seed sources MNB and MNA have grown outstandingly. At a moist site with only minor shoot borer attack (LMAR), these two seed sources grew at a rate of 1.75 meters a year. This superiority, however, did not occur on the drier sites.

Best height growth occurred at the three locations (LMAR, GUAV, and GUAJ) with little or no borer attack. Although not analyzed statistically growth was also good at the two St. Croix locations (1.0 m/yr.). DBH growth fitted in the pattern of height growth with the exception of the northern collection at El Verde, where DBH growth was relatively better than height, no doubt reflecting the greater impact of shoot borer on height.

Leaf dimensions

The leaves of *S. macrophylla* trees had more leaflets and were larger than those of *S. humilis,* which in turn were greater than those of *S. mahagoni* (Table 12). The numbers and sizes varied with seed source within a species, but there were no obvious geographical patterns nor important differences except for seed source HGA and to a lesser extent HCA. These exhibited characteristics typical of *S. macrophylla* instead of *S. humilis.*

Planting location had a greater effect on petiole and rachis length than seed source. For example, location variance accounted for 28% of the total variance in petiole length as opposed to 9% for seed source variance. However, the total length of the main leaf axis (petiole plus rachis) varied little from location to location, nor did leaflet number and leaflet dimensions.

DISCUSSION

Differences exist among seed sources of *Swietenia* in seed pods (Appendix III), seedling characteristics (Table 4). survival after field planting (Table 5), susceptibility to shoot borer attack (Table 8), growth rate (Table 9), and leaf characteristics (Table 12). These differences could not be related to a geographical pattern, although superficial examination might suggest one. For example, the northernmost seed source of *S. macrophylla,* MMA, survived and grew least of all the *S. macrophylla* seed sources. However, in addition to being the northernmost, it was also the one with the greatest variation in plantable seedlings produced per mother tree (Table 3), and the seed was collected in an area where considerable dysgenic selection apparently had occurred (Appendix I).

The greatest practical differences were those between species and those caused by planting location, the latter in turn influenced by shoot borer attack. *S. macrophylla* has grown faster than *S. humilis* and *S. mahagoni* on all types of sites, although the latter two are more drought resistant. *S. macrophylla* then is the species of choice for planting within most of the Subtropical Moist and Wet Ecological Life Zones of Puerto Rico. In Subtropical Dry and in the transitional area of the Subtropical Moist Zone, the hybrid, *S. macrophylla* x *S. mahagoni* should be planted (Geary, Nobles, and Briscoe, 1972). It has yet to be shown by experimentation whether the hybrid should also be preferred in wetter zones. Mahoganies do not seem adapted to the Subtropical Lower Montane Wet Zone or the wettest part of the Subtropical Wet Zone, nor to serpentine soils, the soil type of the Maricao location.

Shoot borer had a great impact on mahogany growth. It seems certain that the mahoganies at Tract 105, El Verde, Cambalache, and Río Abajo would have been much taller if they had not been attacked. The lack of attack at some locations is difficult to explain. Shade on the trees reportedly protects against attack (Marshall, 1939; Tropical Forest Experiment Station, 1953; Grijpma and Gara, 1970), and the mahoganies at Las Marías, Guavate, and Guajataca did have some shade from surrounding forest and poisoned overstory trees, while those at El Verde, Cambalache, and Rio Abajo were in open fields. However, trees at Tract 105 also had some shade on them. Nevertheless from past experience with mahogany culture it seems safe to conclude that the trees at El Verde, Cambalache, and Rio Abajo were severely attacked because they were in open fields. The low incidence of attack at Matrullas, Guilarte, and Maricao, the cessation of attack at Coamo, and the lower attack incidence of *S. humilis* certainly were partially related to poorer tree growth, since the moth stage of the borer is attracted to fresh foliage (Grijpma and Gara, 1970). Climatic effects on borer activity as well as some shade may also have contributed to the lower incidence at the coolest, wettest locations. Tree growth at Estates Thomas and Jealousy did not seem affected by shoot borer only because these attacks did not occur until after a period of initial very rapid height growth. In the years to come the effect should become more evident. The reason for the delayed attack at Estates Thomas and Jealousy, where the plantings are in open fields, no doubt was caused by adverse climatological factors and initially low levels of shoot borer population. Only *S. mahagoni* of all the seed sources studied showed immunity to attack.

If *S. macrophylla* is to be planted, then where should the seed come from? Selection of collection area based on climate as a criterion might be rational. There was an obvious interaction of seed source with moisture regime of the planting locations and this can be more or less related to the length of the dry season (Appendix I) of the seed collection areas. The fastest growing seed sources (MNA and MNB) at moist and wet locations originated in the areas with the shortest dry season, and the two poorest growers at the same locations were from areas with the longest dry season. At the drier locations this superiority of MNA and MNB did not exist. *S. humilis* seed source, HGA, came from an area with the shortest dry season for this species, and this might explain its better growth. However, there are obstacles to completely accepting this argument. Firstly, seed sources MMA and MME came from areas with a lot of dysgenic selection. Secondly, on the drier sites shoot borer attack may have tended to keep all seed sources at uniform height by killing back new shoots of all lengths. Thirdly, records were not kept of seedling yield from seed sown, or the percentage of seedlings used. It is possible that at least some of the seed source variation could be due to different selection intensities within the nursery (Geary and Barros, 1973).

Probably the most important question is whether mahogany plantations should be established. Experience has shown that weeds are a serious problem in mahogany culture in Puerto Rico and are expensive to control. Mahoganies maintain a narrow crown for many years, thus not suppressing weeds; and in moist and wet zones on fertile sites, vines are continuously suppressing the trees. On well cleaned sites, shoot borers often ruin the tree form and reduce growth. Therefore, we do not recommend mahogany plantations be established on a large scale in Subtropical Moist and Wet Zones. Individual landowners may be willing to do the required weeding effort with small plantations on nutrient rich sites to grow this fine quality cabinet wood. In the Subtropical Dry Life Zone and into the transitional area of the Subtropical Moist, planting of hybrid mahoganies has been recommended, mainly because it is for all practical purposes the only timber tree that can be recommended. Growers in the drier areas can keep brush around young trees to cast shade on the crowns to reduce borer attack and later when crowns emerge into full light, prune to single leaders following shoot borer attack. In moist and wet zones, landowners have a choice of pines, eucalypts, and teak, among other species, that are easier and cheaper to grow.

Priority research on mahoganies in Puerto Rico and the Virgin Islands should be on improving cultural techniques to reduce weeding costs, controlling shoot borer, and trying the hybrid in the moist and wet zones. More genecology would have lesser priority.

ACKNOWLEDGMENTS

We thank the following for their support: Harvlan, Inc. for land at Estate Jealousy; Mr. Jaime Enseñat for land in Las Marías; Mr. José Ismael Zayas for land in Coamo; the Puerto Rico Office of Conservation of Forest Resources for land in the Cambalache, Guajataca, Río Abajo, Guavate, Maricao, Toro Negro (Matrullas), and Guilarte State Forests; and Mr. M. Antoni of the University of Puerto Rico, Agricultural Experiment Station for statistical assistance.

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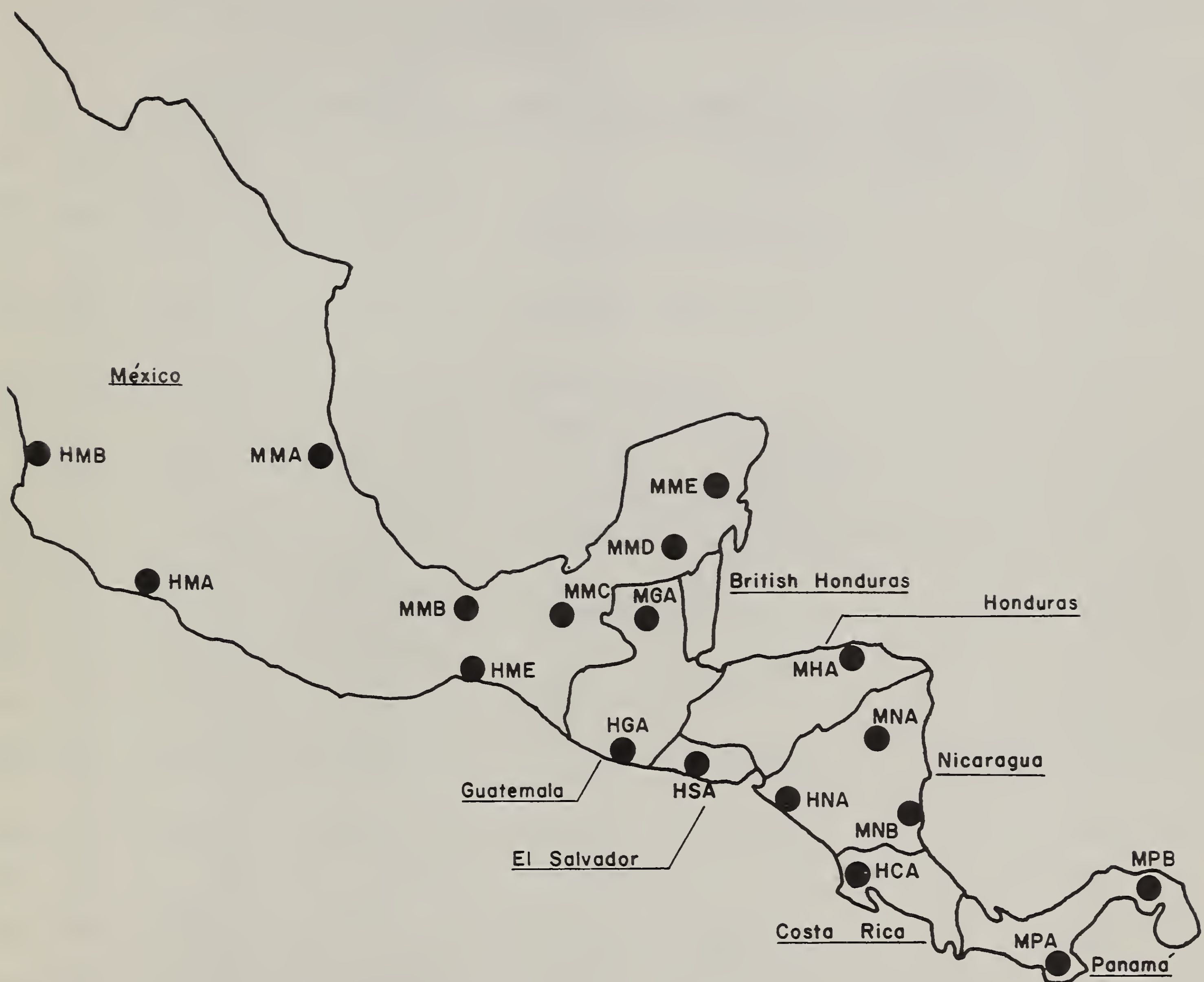

Figure 1. Seed collection areas in Mexico and Central America, codes as in Table 1.

Table 1.--Areas in which seeds of *Swietenia* species were collected.

Area No.	Seed source code	Species collected	Country	Geographical Coordinates[a/] North latitude	Geographical Coordinates[a/] West longitude	Mother trees (No.)	Collection date
1.	MMA	*macrophylla*	Mexico	20°30'	97°20'	16	Jan. 1964
2.	MMB	"	"	17°40'	94°55'	16	Feb. 1964
3.	MMC	"	"	16°55'	91°35'	16	Feb. 1964
4.	MMD	"	"	18°25'	89°25'	16	Feb. 1964
5.	MME	"	"	19°30'	88°05'	16	Feb. 1964
6.	MGA	"	Guatemala	17°00'	89°40'	16	Mar. 1964
7.	MHA	"	Honduras	15°50'	86°00'	7	Apr. 1965
8.	MNA	"	Nicaragua	13°40'	84°10'	16	Feb. 1965
9.	MNB	"	"	11°50'	83°55'	16	Feb. 1965
10.	MPA	"	Panama	7°35'	80°40'	15	Dec. 1964
11.	MPB	"	"	8°50'	78°00'	16	Dec. 1964
12.	HMA	*humilis*	Mexico	18°05'	102°15'	16	Jan. 1964
13.	HMB	"	"	22°20'	105°20'	16	Jan. 1964
14.	HME	"	"	16°20'	94°00'	16	Feb. 1964
15.	HGA	"	Guatemala	14°15'	90°50'	16	Feb. 1965
16.	HSA	"	El Salvador	13°40'	88°55'	16	Feb. 1965
17.	HNA	"	Nicaragua	12°10'	86°40'	16	Feb. 1965
18.	HCA	"	Costa Rica	10°40'	85°30'	16	Jan. 1965

a/ Estimated center of collection area to nearest five minutes.

Table 2.--Description of planting locations.

Location	Code	Ecological life zone[a]	Soil classification[b] and series[c]	Elevation (meters)
Coamo	COAM	STD	Typic or Udertic Arguistoll Like Coamo or Llanos clay	250
Estate Jealousy (St. Croix)	JEAL	STD	Udic Pellustert Aguirre clay	40
Estate Thomas (St. Croix)	THOM	STD	Typic Calciustoll Fredensborg clay	90
Cambalache	CAMB	STM	Tropeptic Eutrothox Bayamón sandy clay loam	50
Guajataca	GUAJ	STM	Tropeptic Haplorthox Coto clay	230
Tract 105	T105	STM	Vertic Eutropept Múcara silty clay	500
Las Marías	LMAR	STW	35% Orthoxic and 80% Typic Tropohumult 35% Daguey and 80% Humatas clay	220
Río Abajo	RABA	STW	Tropeptic Haplorthox Catalina silty clay	330
El Verde	EVER	STW	Tropeptic Haplorthox Comerio silty clay	100
Guavate	GUAV	STW	Epiaquic Tropohumult Los Guineos clay	600
Maricao	MARI	STW	70% Typic Eutropept[d] 70% Maresua silty clay loam	730
Matrullas	MATR	STW	Epiaquic Tropohumult Los Guineos clay	750
Guilarte	GUIL	LMW	Epiaquic Tropohumult Los Guineos clay	1050

a/ According to Holdridge(4). STD=Subtropical Dry; STM=Subtropical Moist; STW=Subtropical Wet; LMW=Subtropical Lower Montane Wet.

b/ By the 7th Approximation of a Comprehensive System of Soil Classification of the International Society of Soil Science.

c/ Soil series descriptions are available from the USDA Soil Conservation Service, Fort Worth, Texas.

d/ 60% of the northern sources planting was on an oxisol yellower and less acid than Nipe clay.

Table 3.--Variation in number of seedlings planted for seed sources and mother trees.

Seed Source	Mother trees in plantings (no.)	Seedlings planted[a] (no.)	Coefficient of variation[b] (%)
MMA	12	263	137
MMB	16	350	33
MMC	14	367	80
MMD	16	343	34
MME	16	361	10
MGA	16	347	17
MHA	7	254	99
MNA	16	350	14
MNB	16	335	43
MPA	15	349	7
MPB	16	351	12
HMA	14	357	80
HMB	7	156	123
HME	16	337	9
HGA	15	351	19
HSA	16	352	6
HNA	16	351	9
HCA	16	348	20

a/ Initial field planting, i.e., excludes replacements.

b/ Standard deviation of number of seedlings planted from each mother tree, times 100, and divided by the average number of seedlings planted per mother tree.

Table 4.--Characteristics of 5-month-old seedlings of nine *Swietenia* seed sources in a Puerto Rico nursery.

Seed Source	Height (cm)[a]	Simple leaves per tree (no.)[a]	Seedlings with compound leaves (no. out of 5)
MHA	19.5	8.4	0.6
MNA	24.8	11.0	0.4
MNB	24.8	10.7	0.7
MPA	20.0	11.1	1.9
MPB	18.0	9.8	2.2
HGA	21.3	9.8	0.8
HSA	21.4	6.6	5.0
HNA	20.4	6.9	5.0
HCA	20.8	10.8	3.0

a/ Mean of five tallest seedlings from each mother tree.

Table 5.--Survival of *Swietenia* seed sources in Puerto Rico and the Virgin Islands as influenced by moisture regime of the planting location.

Northern collection				Southern collection			
Seed source	All 13 locations	9 wetter locations	4 drier locations	Seed source	All 11 locations	9 wetter locations	2 drier locations
	% survival				% survival		
MMA	65	73	48	MHA	82	89	50
MMB	72	80	53	MNA	80	88	40
MMC	64	71	48	MNB	76	87	26
MMD	72	77	60	MPA	66	72	37
MME	73	77	64	MPB	73	78	52
MGA	75	81	63				
				M mean	75	83	41
M mean	70	76	56				
				HGA	80	85	58
HMA	38	26	64	HSA	47	41	74
HMB	38	28	60	HNA	46	38	80
HME	41	27	74	HCA	72	71	77
H mean	39	27	69	H mean	61	59	72
WIM	35	23	68				

Table 6.--Variation in survival of *Swietenia* species from location to location in Puerto Rico and the Virgin Islands.

		Northern collection			Southern collection	
Moisture regime	Location	*macrophylla*	*humilis*	*mahagoni*	*macrophylla*	*humilis*
		% survival				
Drier	COAM	52	76	84	16	52
	JEAL	18	26	..	..	..
	THOM	84	91	89	..	..
	CAMB	70	71	70	66	92
Wetter	GUAJ	76	34	17	87	84
	T105	85	18	8	87	48
	LMAR	71	29	27	73	77
	RABA	70	41	43	93	82
	EVER	88	79	59	91	90
	GUAV	92	26	26	88	62
	MARI	78	9	14	68	18
	MATR	72	0	4	72	33
	GUIL	56	5	8	87	37

Table 7.--Statistically significant differences in survival among select *Swietenia* seed sources and planting locations.

Variation among seed sources

Northern collection: Seed source	Survival %	Southern collection: Seed source	Survival %
MGA	84 [a]	HGA	93
MMD	82	MPB	89
MME	82	MHA	88
MMB	80	MNA	85
MMA	72	MNB	81
MMC	72	MPA	75

Variation among planting locations

Northern collection: Planting location	Survival %	Southern collection: Planting location	Survival %
GUAV	92	RABA	93
EVER	88	EVER	92
T105	85	GUAJ	88
GUAJ	76	GUAV	88
LMAR	71	T105	88
CAMB	70	LMAR	76
RABA	70	CAMB	70

[a] Values not connected by a line are statistically different at the 5% confidence level.

Table 8.--Shoot borer attack in field plantings in early 1969.

Planting location	Trees attacked (%)	Northern collection: Seed source	Northern collection: Trees attacked (%)[a]	Southern collection: Seed source	Southern collection: Trees attacked (%)[a]
COAM	34	MMA	66	MHA	64
JEAL	0	MMB	68	MNA	64
THOM	0	MMC	63	MNB	73
CAMB	91	MMD	65	MPA	60
GUAJ	0	MME	64	MPB	59
T105	74	MGA	64	M mean	64
LMAR	28	M mean	65		
RABA	2			HGA	65
EVER	95	HMA	56	HSA	52
GUAV	37	HMB	42	HNA	45
MARI	0	HME	46	HCA	64
MATR	0	H mean	48	H mean	56
GUIL	0				
		WIM	0		

[a] At the six locations with most attack.

Table 9.--Annual height growth of five-to-six year old *Swietenia* seed sources in Puerto Rico and the Virgin Islands as influenced by moisture regime of the planting location.

Northern collection				Southern collection			
Seed source	All 13 locations	9 wetter locations	4 drier locations	Seed source	All 11 locations	9 wetter locations	2 drier locations
	meters/year				meters/year		
MMA	0.79	0.82	0.74	MHA	1.00	1.05	0.78
MMB	0.88	0.94	0.77	MNA	1.05	1.13	0.70
MMC	0.87	0.89	0.83	MNB	1.14	1.24	0.66
MMD	0.88	0.89	0.86	MPA	0.82	0.83	0.74
MME	0.84	0.83	0.88	MPB	0.81	0.81	0.82
MGA	0.90	0.93	0.84	M mean	0.96	1.01	0.74
M mean	0.86	0.88	0.82				
				HGA	0.78	0.80	0.68
HMA	0.47	0.34	0.78	HSA	0.36	0.31	0.55
HMB	0.44	0.31	0.75	HNA	0.40	0.36	0.58
HME	0.40	0.23	0.77	HCA	0.62	0.60	0.67
H mean	0.44	0.30	0.76	H mean	0.54	0.52	0.62
WIM	0.45	0.34	0.71				

Table 10.--Annual height growth of *Swietenia* species on Puerto Rico and Virgin Islands planting locations.

Planting location	*Swietenia macrophylla*	*Swietenia humilis*	*Swietenia mahagoni*
	meters/year		
COAM	0.48	0.41	0.44
JEAL	1.04	0.96	....
THOM	0.96	0.88	0.79
CAMB	0.89	0.82	0.58
GUAJ	1.33	0.47	0.18
T105	1.01	0.40	0.22
LMAR	1.41	0.73	0.25
RABA	0.81	0.62	0.35
EVER	0.82	0.52	0.56
GUAV	1.27	0.52	0.56
MARI	0.67	0.13	0.21
MATR	0.53	0.17	0.29
GUIL	0.63	0.28	0.46

Table 11.--Height of the fastest growing five-to-six-years-old seed sources of *Swietenia* on the best sites in Puerto Rico.

	Height growth		DBH growth	
Comparison	Seed source or location	Height (meters)	Seed source or location	DBH (cm)
Northern seed sources[a]	MMB	6.6 [c]	MMB	8.2
	MGA	6.6	MGA	7.4
	MMD	6.4	MMC	7.3
	MMC	6.3	MMD	7.2
	MME	6.1	MMA	6.8
	MMA	5.7	MME	6.6
Southern seed sources[b]	MNB	7.4	MNB	7.1
	MNA	6.9	MNA	6.8
	MHA	6.3	MHA	6.8
	MPB	5.5	HGA	6.7
	HGA	5.4	MPA	5.6
	MPA	5.3	MPB	5.5
Locations over northern sources[a]	LMAR	8.0	GUAV	8.5
	GUAV	7.9	LMAR	8.3
	GUAJ	7.3	EVER	7.6
	T105	5.9	T105	7.0
	EVER	5.2	GUAJ	6.8
	CAMB	5.1	CAMB	6.7
	RABA	4.6	RABA	5.9
Locations over southern sources[b]	LMAR	8.6	LMAR	8.7
	GUAJ	7.8	GUAJ	6.6
	GUAV	6.6	GUAV	6.6
	T105	5.5	CAMB	6.3
	CAMB	5.4	RABA	6.1
	RABA	5.0	T105	5.4
	EVER	4.0	EVER	5.3

a/ Approximately six years after planting.

b/ Approximately five years after planting.

c/ Values not connected by a line are statistically different at the 5% confidence level.

Table 12.--Leaflet numbers and leaf dimensions of *Swietenia* seed sources.

Seed source	Leaflets (no.)	Petiole length(cm)	Rachis length(cm)	Petiolule length(cm)	Leaflet length(cm)	Leaflet width(cm)
MMA	11.3	14	30	0.52	19	6.5
MMB	12.4	20	31	0.62	20	7.3
MMC	11.0	20	29	0.70	19	7.1
MMD	11.4	15	24	0.50	17	5.9
MME	10.8	15	24	0.48	16	6.1
MGA	11.3	19	21	0.56	17	6.1
MHA	10.5	18	26	0.52	19	6.6
MNA	11.1	18	27	0.42	17	5.8
MNB	10.3	16	27	0.52	19	6.5
MPA	9.4	14	22	0.58	15	5.9
MPB	11.3	19	24	0.61	15	6.1
M mean	11.0	17	26	0.55	18	6.3
HMA	9.8	11	16	0.27	10	4.2
HMB	9.3	11	16	0.10	11	4.6
HME	10.4	10	14	0.19	10	4.0
HGA	10.5	20	28	0.80	18	6.8
HNA	9.9	12	17	0.24	11	4.2
HSA	9.4	13	13	0.16	11	4.2
HCA	12.1	11	23	0.29	13	5.0
H mean	10.2	13	18	0.29	12	4.7
WIM	9.7	5	8	0.27	5	2.1
Location[a]						
GUAJ	11.4	12	26	0.46	15	5.8
LMAR	11.2	21	18	0.47	16	5.5
MARI	9.4	13	30	0.42	18	5.8

[a] *S. mahagoni* (WIM) excluded.

Appendix I.--Description of the collection areas.

Seed Source	Dry Season from	Dry Season to	Months (No.)	Altitude (meters)	Topography	Exploitation	Extent of remaining mahogany[d]
MA	Nov.	May	7	25	Flat	Some to much[c]	NN
MB	Jan.	May	5	90	Flat	None evident	M
MC	Feb.	April	3	640	Mountainous[a]	None evident	VH
MD	Dec.	May	6	110	Flat	Some	M
ME	Sept. and May	Jan. June	7	30	Flat	Twice cut to diameter limit	M
GA	Feb.	May	4	120 to 300	Hilly	none evident	H
HA	April	June	3	35	Mountainous[b]	None evident	L
NA	mid Feb.	mid April	2	0 to 30	Flat	None evident	M
NB	March	April	2	15	Flat	Some to much	M
PA	mid Dec.	April	4 1/2	380 to 710	Mountainous[b]	None to evident	M
PB	Jan.	mid April	3 1/2	60	Hilly[b]	None to evident	M[e]
MA	Dec.	May	6	150 to 210	Hilly[b]	None to evident	NN
MB	Nov.	June	8	30 to 90	Mountainous[a][b]	None to evident	NN
HE	April	Sept.	6	180 to 210	Hilly[b]	Much	NN
GA	Dec.	April	5	45	Flat	Some	L
SA	Nov.	April	6	460 to 610	Hilly[b]	Much	NN
NA	Nov.	April	6	150	Hilly	Much	NN
CA	Nov.	May	7	90	Flat	Much	NN

a/ Trees found at bottom of slopes.

b/ Trees found on slopes.

c/ Collection trees found in 0.5 acre area left after logging.

d/ VH= very heavy, H= heavy, M= medium, L= light, NN= next to none.

e/ In the Chucunaque Indian Reservation; NN outside the reservation.

Appendix II.--Description of the mother trees.

Seed source	Height (meters) Mean	Height (meters) Range	Diameter breast height (cm) Mean	Diameter breast height (cm) Range	Height to first branch (m)	Height of buttresses (m)
MMA	21	15 - 23	55	35 - 90	9	0.8
MMB	20	12 - 26	55	20 - 85	8	0.6
MMC	49	35 - 57	180	130 - 260	20	2.1
MMD	22	14 - 30	80	60 - 140	10	0.9
MME	19	15 - 24	70	40 - 145	10	0.8
MGA	30	26 - 39	90	55 - 115	15	1.3
MHA	40	34 - 52	110	75 - 130	19	2.0
MNA	39	34 - 44	75	50 - 130	17	1.2
MNB	30	24 - 34	65	55 - 80	15	1.4
MPA	31	24 - 40	90	65 - 130	17	1.2
MPB	30	24 - 37	130	55 - 200	16	2.6
HMA	12	8 - 16	45	25 - 90	4	0.0
HMB	11	6 - 15	35	15 - 60	3	0.0
HME	9	8 - 14	35	20 - 85	3	0.0
HGA	16	11 - 22	65	25 - 100	8	0.5
HSA	9	8 - 11	20	15 - 30	3	0.0
HNA	10	8 - 14	45	15 - 60	3	0.0
HCA	14	9 - 19	55	25 - 100	4	0.3

Appendix III.--Description of the seed pods and months of maximum seed ripeness.

Seed source	Pods measured (No.)	Length (cm)	Diameter (cm)	Rates of length to diameter	Months of maximum seed ripeness
MMA	64	14.1	9.2	1.55	February
MMB	64	15.5	10.0	1.55	February
MMC	64	14.6	8.6	1.70	February
MMD	64	12.6	8.2	1.55	February
MME	64	12.6	8.5	1.50	February
MGA	64	14.2	8.9	1.60	late Feb., mid March
MHA	8	14.0	7.6	1.85	early February
MNA	62	13.7	7.9	1.75	February
MNB	58	13.0	7.5	1.75	February
MPA	51	14.1	8.2	1.70	December
MPB	58	14.8	8.9	1.65	mid November
HMA	64	11.8	7.9	1.50	late January
HMB	63	14.0	9.0	1.55	February
HME	42	12.6	9.4	1.35	late Dec., Jan.
HGA	0	. . .	. . .	. . .	January
HSA	53	13.3	8.7	1.55	early February
HNA	42	13.4	9.6	1.40	January
HCA	55	12.8	8.6	1.50	mid Jan., early Feb.