10-YEAR STATISTICAL ANALYSES OF TREE IMPROVEMENT IN HAITI

AND

TRIAL MANAGEMENT RECOMMENDATIONS

submitted to

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by

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Introduction

This draft is part of a continuing effort to analyze and to recommend management strategies for tree improvement in Haiti. It is based on a group of orchards, progeny and provenance trials that were established throughout Haiti with USAID funding during the 1988–1991 period. Many of these trials were evaluated at five years and published by SECID/Auburn University. These reports are referenced as they pertain to the management of a particular species. Several species have never been published and this report serves as the first time they are formally analyzed.

The importance and justification of this report is several-fold. First, it summarizes the results of a group of trials that are the only known trials in Haiti specifically designed to quantify genetic differences and to yield improved tree seed. The investment to improve the genetic quality of trees for the purpose of increased productivity, better broad-site adaptability and improved economic value is an asset that is certain to benefit Haitians and the island as a whole. Second, the continuous monitoring of the trials is probably the only wide-scale effort at the current time to maintain data on tree growth in Haiti. During and following the economic embargo in 1991, practically all scientific tree research and development ceased. Though reforestation efforts in Haiti continue today, the general status of such efforts is based on genetic material with little or no track record in Haiti. This poses a risk that tree improvement research attempts to overcome, particularly since genetic mistakes mass-produced on a national scale can be disastrous and long-term. Third, the seed orchard is the focus of such development, since it is from the orchard that genetic gains, and economic potential, can be multiplied a million-fold through distribution to Haitian residents nationwide. Fourth, the trials attempt to mitigate the loss of genetic diversity — one of the most serious problems facing sustainable tree management in Haiti. Genetic erosion is a subtle process that occurs as desirable phenotypes are harvested, but not reproduced, and their habitats are lost or converted to other land uses. Such a process began with the colonization of Hispaniola, but has accelerated with population growth and the fragmentation of natural forest areas. Since deforestation is such a large-scale phenomenon in Haiti, few options exist to maintain the genetic integrity of economically important tree species. These trials offer an option that must be seriously considered by any institution in Haiti that supports efforts to mitigate the environmental and ecological deterioration of the country.

The recent report by the author (Timyan, 1999) outlines the strategic framework to manage these orchards and trials as part of a tree improvement program. It should be reviewed to better orient the reader to the methodologies used to make the trial management recommendations contained in this report. Two notes should be kept in mind regarding the statistical analyses. First, the Tukey Test was selected for means comparison tests. This test is considered more conservative by statisticians than others, such as the Waller-Duncan or Duncan Test, often used by foresters. That is, the Tukey Test is less likely to detect differences among means than the Waller-Duncan Test. It is the opinion of the author that the tree program in Haiti is better served by erring on the conservative side. Second, an effort was made to adjoin the complete provenance or mother tree information with the report, since it is critically important that this source information be maintained as a breeding record to sustain tree improvement in Haiti.

1. Progeny Trials

1.1 *Catalpa longissima* at Crocra, Plaine du Nord

Background. This is one of several progeny trials established in Haiti for *C. longissima*. At this particular site, two trials were established, but one was eliminated due to damages associated with a change in land use decisions by the land owner. The origin of the eight half-sib families tested in this trial is provided in Appendix 1 (Table 5).

The trial was established in May, 1989 as a randomized complete block design with nine replications of six-tree row plots. The trial is planted along the border of the property as a double row of trees planted in triangular fashion. The placement of each family was located randomly within each of the nine blocks.

This particular site is not typical of *C. longissima* habitat which is a well-drained, gravelly flood plain or alluvial soils at the base of ravines. The soil at this site is a poorly drained vertisol characterized by months of standing water alternating with severe cracking of the clayey soil during drought periods.

The five-year results of the trials (Timyan et al., 1997) showed no difference among families in survival, height or stem diameter. Site averages for these parameters were 87%, 2.7 m and 3.4 cm respectively.

Survival. The ten-year survival rate of the site was 71.7%. The ANOVA showed no family effect (Pr = 0.1977) in survival. Table 1.11 summarizes the family means after five and ten years. Figure 1.1 illustrates the survival of the families during the life of the trial.

Table 1.11. Survival means among families after five and ten years at the Crocra progeny trial.

FAMILY	5 YEARS (%)	10 YEARS (%)
105	89 a	74 a
116	79 a	60 a
117	89 a	67 a
120	89 a	83 a
128	91 a	73 a
132	86 a	60 a
136	94 a	80 a
160	81 a	74 a
SITE	**87.0**	**71.7**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.820 (5 yrs.); Pr = 0.1977 (10 yrs.)

Height. The site averaged 6.0 m over a period of ten years. The ANOVA showed no differences among family means (Pr = 0.2133). The family means after five and ten years are summarized in Table 1.12. The range of height growth fell between 5.3 m of family 136 and 6.9 m of family 105. The distribution of ten-year heights among the families is shown in Figure 1.2.

Table 1.12. Height means among families after five and ten years at the Crocra progeny trial.

FAMILY	5 YEARS (m)	10 YEARS (m)
105	2.7 a	6.9 a
116	2.7 a	6.4 a
117	2.6 a	5.9 a
120	2.8 a	5.9 a
128	2.6 a	5.8 a
132	3.0 a	6.8 a
136	2.5 a	5.3 a
160	2.8 a	6.0 a
SITE	**2.7**	**6.0**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.940 (5 yrs.); Pr = 0.2133 (10 yrs.)

Merchantable Volume Index. The MVI combines the merchantable height of the main stem with the square of the stem diameter. The index reflects a form factor that is likely to be passed on genetically as a qualitative trait.

The ANOVA for this parameter did not show a significant family effect (Pr = 0.0595). However, the Tukey Test revealed that the top mean, family 116, was different than the bottom mean, family 136, at the 0.05 probability level. Table 1.13 summarizes the MVI among families in this trial. Figure 1.3 shows the distribution of MVI by family.

Table 1.13. MVI means among families after ten years at the Crocra progeny trial.

FAMILY	10 YEARS ($x\ 10^{-2}\ m^3$)
116	4.1 a
105	3.5 ab
132	2.9 ab
117	2.8 ab
128	2.6 ab
160	2.4 ab
120	2.0 ab
136	1.4 b
SITE	**2.52**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0595.

Trial Management Recommendations. Family differences were not shown for survival or height growth after ten years. While family differences were detected for the merchantable volume index, the differences were not highly significant. For this reason, no families should be eliminated. The trial should be thinned by selecting two trees per family plot, selected on the basis of vigor and form on the vertisol. Moderate amount of genetic gain is to be expected from this selection process.

1.2 *Catalpa longissima* at Laborde, Camp Perrin

Background. This trial contains the progeny of 13 half-sib families of *Catalpa longissima* (Appendix 1, Table 5). This species is perhaps the most valuable wood species in Haiti, considering the annual volume that is harvested, its general utility, and quality. The experimental design is a randomized block design, with each family represented by a row-plot of six trees in each of nine blocks. The variables considered for statistical evaluation at ten years include survival, height and merchantable volume index.

The trial was established in 1989, along with a *Cedrela odorata* provenance trial, and was measured at the same intervals: 0.5, 1, 3, 5, and 10 years. The evaluation of the trial at five years is described in Timyan et al. (1997). While survival and height differences were insignificant among families, significant differences were exhibited for merchantable volume index (MVI) at the 5-year stage. MVI takes into account a form factor attributed at the family level that is a combination of stem length:stem diameter ratios and the height of the first major fork. Since such qualitative traits are more likely to be inherited, the merchantable volume index is more important than either height or stem diameter as a selection criterion of superior families.

Survival. No differences were shown among families at the 5 or 10 year stage (Table 1.21). The extremely high survival rate of the trial, among the highest ever observed for *C. longissima* in Haiti, is similar for all the families after ten years (Figure 1.4). The noticeable drop in survival after ten years may be due to natural thinning because of competition for space as the trees mature.

Table 1.21. Survival means among families after five and ten years at the Laborde progeny trial.

FAMILY	5 YEARS (%)	10 YEARS (%)
103	100 a	93 a
104	98 a	91 a
105	100 a	94 a
110	92 a	91 a
111	98 a	94 a
117	98 a	89 a
118	98 a	93 a
122	100 a	96 a
123	100 a	96 a
124	98 a	93 a
125	100 a	98 a
159	96 a	94 a
169	96 a	93 a

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0047 (5 yrs.); Pr = 0.00005 (10 yrs.)

Height Growth. Height growth of *C. longissima* at Laborde averages under one meter per year. The 10-year analysis of variance shows a significant P value for family means (Pr = 0.0025), indicating that at least one mean differs from another among the thirteen families. These results contrast with the 5-year results that showed no difference among family means.

The scatter plot of the data (Figure 1.5) shows a wide range of heights within each family group, indicating the superior performers that would be selected for improved seed production. Table 1.22 summarizes the 10-year results of height growth and the differences shown by the Tukey Test at the 0.05 probability level.

Table 1.22. Comparison of height means among *C. longissima* families at Laborde after 10 years.

FAMILY	HEIGHT (m)
117	9.7 a
111	9.7 a
104	9.3 a
105	9.2 ab
110	8.6 ab
123	8.6 abc
118	8.4 abc
169	7.8 bc
103	7.7 bc
124	7.6 bc
122	7.4 bc
159	7.2 bc
125	7.2 c
SITE MEAN	**8.33**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0005.

Merchantable Volume Index. Results at five years showed significant differences among and within families for MVI (Figure 1.6). The highest yields were exhibited by 117, 104 and 105, averaging 53, 52 and 50 m^3 ha^{-1}, respectively. While the results at ten years follow approximately the same order, it is noteworthy the rank changes. This points out the necessity of evaluating tree trials over a relatively long period of time — a time depth that is absent from the technical knowledge of tree planters in Haiti. As shown in Table 1.23, the results of 5- and 10-year MVI means show significant differences among the families. Figure 1.7 illustrates both the fact that families ranks change between five and ten years and that the MVI increases several fold during this period. The latter point shows the acceleration of wood volume that is beginning to take place due to the allometric relationship of stem diameter and volume. A doubling of stem diameter is equivalent to approximately a quadrupling of wood volume. Furthermore, the family ranks for MVI are noticeably different from the family ranks for height, thus suggesting the superior form factor of certain families independent of their heights.

Table 1.23. Comparison of family ranks of MVI at five and ten years for *C. longissima* progeny.

FAMILY	5 YEARS ($x 10^{-2}$ m^3)	10 YEARS ($x 10^{-2}$ m^3)
117	3.6 a	8.8 a
104	3.6 ab	7.9 a

FAMILY	5 YEARS ($x 10^{-2} m^3$)	10 YEARS ($x 10^{-2} m^3$)
105	3.1 abc	7.0 ab
111	2.3 abcde	6.3 abc
118	2.7 abcde	4.9 bc
123	2.8 abcd	4.8 bc
110	1.7 cde	4.7 bc
122	2.2 bcde	4.7 bc
103	2.6 abcde	4.4 bc
125	1.8 cde	3.6 bc
124	2.1 bcde	3.5 bc
169	1.3 e	3.1 c
159	1.5 de	3.0 c
SITE	**2.41**	**5.11**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0036 (5 yrs.), Pr < 0.0005 (10 yrs.).

Trial Management Recommendations. The genetic base of this progeny trial is small relative to what is available on the island of Hispaniola. However, it is one of the only opportunities to improve the genetic quality of seed for this species, either on the island or the entire world.

There is no guarantee that the differences shown among families in this trial will be expressed in the offspring through seed. However, the objective of tree improvement is to increase the probability of genetic gain and this is much more likely to occur if superior families and superior individuals within those family are breeding together.

The following recommendations for rogueing and thinning the trial are made in order to transform the progeny trial to an improved seed production area.

1) Eliminate the worst three families from the trial (159, 169, 124).
2) Select 2-3 trees of each remaining family to the desired stand density for the next 5 years. Crowns should not overlap, since flower production and flower set require full exposure to sun for optimal yields.
3) Space the *C. longissima* appropriately with the selection of *C. odorata*. Since entire provenance plots will be eliminated from the latter species, a higher density of *C. longissima* stems per hectare is allowed in these areas of the trial.
4) If two superior *C. longissima* individuals of the same family occur side-by-side, select the individual that is closest to other neighbors of different families. This will maximize the probability of outcrossing with non-related families and increase the likelihood of “hybrid” vigor among distantly related genetic lines.
5) Error on the conservative side and attempt to balance the trial with an equal number of trees of each family, since combining ability of the parent trees is unknown.
6) Prune the lower and older branches along the main stem to channel energy to well-formed branches and to increase the merchantable quality of the remaining trees. The trees that will be culled are an asset that needs to be managed for both timber and seed production.

7) Vegetatively propagate culled individuals of superior families for distribution to farmers that express interest in planting the species or have the greatest likelihood of sharing seed with other farmers interested in the species. These families include 117, 104, 105, and 111.

1.3 *Lysiloma sabicu* at Crocra, Plaine du Nord

Background. This progeny trial was established at the same time as the *Catalpa longissima* in May, 1989. The trial contains seven families and a control bulked seed lot (Appendix 1, Table 11). The design is a randomized complete block with nine replications and six-tree row plots. It is planted along the border of the property as a double row of trees planted in triangular fashion. The placement of each family was located randomly within each of the nine blocks.

Originally, two trials of *L. sabicu* were established at this site with eight families each. However, due to land management problems, one of the trials was abandoned after a year.

Though the vertisol soil conditions are generally considered difficult, due to the high content of shrink-swell clays, *L. sabicu* appears to adapt better than other high-quality wood species such as *C. longissima*. The results of this trial have not been published prior to the analyses in this report.

Survival. The overall survival of the trial after ten years was 56.8%. The range among half-sib families fell between 43.9–81.1%. The bulked seed lot, 2511, serving as a control, achieved the highest survival (81.1%), though no statistical differences were shown by the ANOVA (Pr = 0.1116). The summary of survival at ten years is provided in Table 1.31.

Table 1.31. Ten-year survival rates of *L. sabicu* families at Crocra.

FAMILY	SURVIVAL (%)
504	65
517	48
518	44
519	50
525	61
529	58
537	48
Control (2511)	81
SITE	**56.8**

Height. The mean height of the eight families was 6.2 m after ten years. Family means ranged between 5.4–6.6 m. The trial ANOVA detected no family effect (Pr = 0.2114). A summary of the family means is provided in Table 1.32. Ten-year height distribution among families is shown in Figure 1.8.

Merchantable Volume Index. The overall mean merchantable volume index (MVI) was 1.44×10^{-2} m^3 with a range of 1.0–1.7 among family means. The ANOVA for this parameter did not show a family effect (Pr = 0.4611). The distribution of MVI among families is shown in Figure 1.9.

Table 1.32. Ten-year height means and merchantable volume index of *L. sabicu* families at Crocra.

FAMILY	**HEIGHT (m)**	**MVI ($x\ 10^2\ m^3$)**
504	6.1	1.4
517	6.1	1.7
518	6.6	1.7
519	5.5	1.0
525	6.4	1.7
529	6.2	1.3
537	5.7	1.1
Control (2511)	6.4	1.5
Site	**6.16**	**1.44**

Trial Management Recommendations. The near uniformity of height growth and merchantable volume index among families suggests that all families should be maintained on site to broaden the genetic base for future seed harvests. A modest genetic gain for form and vigor will result from selection at the individual level. Furthermore, progeny from the trial may exhibit increased heterozygosity resulting from the interbreeding of distantly related *L. sabicu* genotypes. This is commonly referred to as "hybrid vigor."

Due to the relatively wide crown diameter of *L. sabicu*, no more than two trees should be left per family plot after thinning. The selected population should be monitored for resistance to pests, diseases, strong winds and other environmental factors.

1.4 *Lysiloma sabicu* at Lapila, Pignon.

Background. L. sabicu is a premium hardwood, esteemed in Haiti for its high-quality and lustrous wood used in furniture. Since the species is often over-harvested for its commercial value, the species is vulnerable to high-grading pressures and approaches commercial extinction in most areas of Haiti. Furthermore, seed yields are light and naturally poor due to the high infestation of the pods by insects, notably beetles. The genetic variation within the species is largely unknown since prior to 1989, no progeny trials were established to study this variation.

The trial at Lapila is one of several progeny trials that were established for this species. The trial is a randomized block design, comprised of 15 half-sib families and the control (Appendix 1, Table 11). The site, typical of the Central Plateau, experiences lengthy droughts on shallow alkaline soils that overlay soft calcareous rock. The control, 2581, is a bulked seed lot representative of the germplasm distributed to farmers by PADF during 1989. How well the half-sib families compare with the control is of interest to support the potential of tree improvement by means of selecting plus trees.

Survival. The overall survival of the trial was 78.6% after ten years. The ANOVA detected no differences in survival rates among families (Pr = 0.1617). These rates ranged from 63.7 – 94.4%, as summarized in Table 1.41.

Table 1.41. Ten-year survival rates of *L. sabicu* families at Lapila.

FAMILY	**10 YEARS (%)**	**FAMILY**	**10 YEARS (%)**
504	76	529	87
505	65	530	94
513	68	532	76
517	82	537	78
518	87	538	89
519	83	539	72
521	82	Control (2581)	79
522	69	**SITE**	**78.6**
525	72		

Height. Ten-year total heights differed significantly among families (Pr = 0.03847). Families 505 (5.5 m) and 530 (5.3 m) were considered different from the 2581 (4.4 m), the control, by the Tukey Test. Table 1.42 summarizes the mean heights among the *L. sabicu* families at the Lapila trial after ten years. The species grew an average of 0.5/year at this site. Height distribution, by family, is shown in Figure 1.10.

Table 1.42. Ten-year height growth of *L. sabicu* families at Lapila.

FAMILY	**10 YEARS (m)**	**FAMILY**	**10 YEARS (m)**
505	5.5 a	519	5.1 ab
530	5.3 a	521	5.0 ab
532	5.3 ab	525	5.0 ab
529	5.2 ab	539	4.9 ab
504	5.2 ab	517	4.9 ab
518	5.2 ab	513	4.6 ab
522	5.1 ab	Control (2581)	4.4 b
538	5.1 ab	**SITE**	**5.07**
537	5.1 ab		

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.
Pr = 0.03847.

Merchantable Volume Index. The typical specimen of *L. sabicu* has a short bole with merchantable heights that average under two meters. Merchantable volume index among families for this trial averaged 0.008 m^3 with the best tree exhibiting 0.06 m^3. The ANOVA detected no difference among the families (Pr = 0.0540), though several families appear more promising than others, as illustrated by Figure 1.11. These families show a much wider distribution of MVI, indicating greater variability that might be captured through selection of superior genotypes. A summary of the mean MVI, by family, is provided in Table 1.43.

Table 1.43. Ten-year merchantable volume index of *L. sabicu* families at Lapila.

FAMILY	10 YR MVI ($x\ 10^{-2}\ m^3$)	FAMILY	10 YR MVI ($x\ 10^{-2}\ m^3$)
504	0.7	529	0.9
505	0.9	530	1.0
513	0.6	532	1.0
517	0.5	537	1.0
518	0.9	538	0.8
519	1.0	539	0.7
521	0.9	Control (2581)	0.6
522	0.7	**SITE**	**0.82**
525	0.8		

Trial Management Recommendations. The trial data does not support a strong family effect on the productivity of *L. sabicu* as indicated by the ANOVA for ten-year height and MVI. However, certain families contain a high proportion of individuals in the upper percentiles of productivity. These families should be considered first in the selection of individuals that remain on site for seed production. It is recommended to maintain all families in the trial and select at the level of the individual for thinning purposes and a moderate genetic gain. Since the site is secure and in excellent position to produce good seed crops, the trees should be selected on the combined factors of form and seed production. The species develops a large canopy relative to its stem diameter and thus should be thinned to approximately 15% of the original density. This would leave one tree per family plot. If two or more excellent trees are available for selection in a family plot, the tree that provides maximum outcrossing with non-related families should be selected.

1.5 *Simarouba berteroana* at Lapila, Pignon

Background. This is a small progeny trial, comprised of four half-sib families and a control propagated at a local nursery in the area. It was established at the same time and on the same site as the *S. glauca* progeny trial analyzed below. The trial is a randomized complete block design, with nine replications of six-tree family plots. The source of the germplasm is provided in Appendix 1 (Table 14).

S. berteroana is similar to its more common relative, *S. glauca*. However, it is much less common in Haiti, though it is harvested for similar purposes. The species is often found in sub-humid areas of the island that extend beyond the natural range of *S. glauca*. As such, it is more drought hardy and likely to perform better than *S. glauca* at a site such as Lapila. The species is endemic to the island of Hispaniola.

Survival. The site averaged 67% survival after ten years. This is significantly higher than the survival of *S. glauca* at the same site (46%) as tested by a standardized *t*-test (Pr = 0.0001). The results confirm the observation that the species is better adapted to the drier conditions found at Lapila. The ANOVA showed a significant family effect (Pr = 0.0341) and the results are summarized in Table 1.51.

Table 1.51. Survival of *S. berteroana* families at Lapila.

FAMILY	TEN-YEAR SURVIVAL (%)
267	91 a
Control	**69 ab**
263	68 ab
262	67 ab
264	43 b
SITE	**67.4**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0341.

Height. The average height growth after ten years was 5.6 m. This slighter greater than the average for *S. glauca* (5.4 m), though the difference is not significant (Pr = 0.334). The ANOVA showed a significant difference among family means (Pr = 0.00002), as summarized in Table 1.52. Height distribution among families is shown in Figure 1.12.

Table 1.52. Height growth of *S. berteroana* families at Lapila.

FAMILY	TEN-YEAR HEIGHT (m)
267	6.6 a
262	5.7 ab
263	5.2 b
Control	**5.0 b**
264	5.0 b
SITE	5.6

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0341.

Form. The response of *S. berteroana* to the droughty site at Lapila is reflected in the proportion of trees that fork below 1.3 m. Approximately 37% of the population was affected. Another 4% of the population had main stems with a major sweep or crooked. About 60% of the population had stems that were considered straight. These traits affected all families equally so that no genotypic differences were apparent.

Trial Management Recommendations. The trial is one of several that were established in Haiti for this endemic species. Since the number of families is so small, all families should be retained and managed together as a seed production area. As in the case of *S. glauca*, this species is dioecious, so approximately half of the population should bear seed if the sexes are equally distributed. Each family plot, including the control, should be thinned to two trees until the sex of the trees can be determined. As such time that the population matures to full fruit bearing age, the plots can be further thinned to one tree per family plot. The families and sexes should be balanced in the trial to produce a bulk seed lot that is representative of the genetic base that is available. Genetic gain in this case will be made as a result of selection at the individual rather than at the family level. Modest gains are to be expected.

1.6 *Simarouba glauca* at Lapila, Pignon (est. 5/89)

Background. This progeny trial was among the first trials established at this site in May, 1989 and is distinguished from a second and larger *S. glauca* progeny trial established in October, 1989 (see 1.7 below). Though *S. glauca* is common in the Lapila area, it is rarely found where soft calcareous rock is close to the surface as in the case at this site. This rock, known locally as *tif* (tuff), is prone to drought and nutrient deficiencies, particularly organic carbon and the minor elements (e.g., iron, manganese).

The design of the progeny trial is a complete randomized block design, with nine replications and six-tree row plots. Seven half-sib families are represented (Appendix 1, Table 14). Since no previous attempt was made to publish the results of the trial, this report is the only formal analysis of the trial since its establishment.

Survival. The trial averaged 86.3% survival after ten years. This is a remarkably high survival rate for a droughty site typical of conditions in the Central Plateau. The fact that the seedlings were raised in polythene bags with a potting mixture comprised with the local soil likely contributed to the differences in survival between this trial and the adjacent *S. glauca* trial. An additional reason is the amount of effective rainfall during the early establishment phase. Establishing a trial during the Spring rains is likely to show superior results than the Fall rains because of the lengthy winter drought period.

The range in survival rates among families was 81–94%. The ANOVA for the trial detected no family effect. Differences among family means are not considered significant. Table 1.61 summarizes the survival rates of the *S. glauca* families.

Table 1.61. Survival of *S. glauca* families at Lapila.

FAMILY	TEN-YEAR SURVIVAL (%)
207	83 a
210	85 a
213	94 a
214	85 a
215	85 a
216	85 a
234	89 a
SITE	**86.3**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.6309.

Height. The average height growth of the seven families was 7.0 m after 10 years. Family means ranged from 6.5–7.6 m. The means tested different (Pr = 0.025) indicating a significant family effect. A summary of the mean height growth is provided in Table 1.62. The distribution of height among families is shown in Figure 1.13.

Table 1.62. Height of *S. glauca* families at Lapila.

FAMILY	TEN-YEAR HEIGHT (m)
207	7.6 a
213	7.3 ab
210	7.2 ab
214	6.8 ab
215	6.7 ab
216	6.5 b
234	6.5 b
SITE	**6.96**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.025.

Merchantable Volume Index. The average MVI, including all families, was 1.88 x 10^{-2} m^3. There was about a two-fold difference between the MVI of the top family, 213, and the worst performing family, 234. This difference was significant (Pr = 0.0144). Table 1.63 summarizes the MVI rankings in descending order of importance. Figure 1.14 shows the distribution of MVI values by family.

Table 1.63. Merchantable volume index of *S. glauca* families after ten years at Lapila.

FAMILY	MVI (x 10^{-2} m^3)
213	2.5 a
210	2.3 ab
207	2.2 abc
215	1.8 abc
214	1.6 bc
216	1.4 c
234	1.3 c
SITE	1.88

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.015.

Trial Management Recommendations. The following recommendations should be implemented in order to achieve an optimal balance of genetic gain and broad adaptability with *S. glauca*.

1) Eliminate from the trial the worst two families in terms of MVI and height growth: 234 and 216.
2) Thin the remaining families to an approximate density of 2 trees per family plot. In some cases, only one tree per family plot will be left due to mortality or poor site conditions.
3) If co-dominants occur, choose the female over the male for seed production. It is likely that the trial can contain a greater number of females and still maintain adequate seed production. The presence of only male trees for a particular family is acceptable provided that conditions are adequate to optimize crossbreeding rates.
4) Investigate the possibility of fertilizing the site, especially for the major nutrients such as NPK. A small amount may boost flower and fruit production considerably given the nutrient imbalances and deficiencies that are associated with tuff soils.

1.7 *Simarouba glauca* at Lapila, Pignon (est. 10/89)

Background. This is the largest progeny trial of *S. glauca* in Haiti. Eighteen half-sib families representing plus trees throughout Haiti were established in a randomized complete block design, with nine replications and six trees per plot. The parent information of the half-sib families is provided in Appendix 1 (Table 14). The trial was established in October, 1989, at the same time as a smaller *Simarouba berteroana* progeny trial. A smaller *S. glauca* progeny trial was also planted at the same site in May, 1989 (see 1.6 above).

S. glauca is a medium-grade lumber species used in furniture and house construction. It is found as a common species on moist sites in the area of the trial. On typical sites, the tree grows rapidly with a straight self-branching bole that is easily sawn into lumber. This ten-year analysis of the progeny trial is the first conducted on the trial since its establishment.

Survival. The site averaged 46% survival over a period of ten years. The low survival rate is reasonable considering the droughty site and variability of rainfall at this site. The ANOVA showed a significant family effect on survival (Pr = 0.0003). Family means ranged from 17–70% as summarized in Table 1.71.

Table 1.71. Survival of *S. glauca* families after ten years at Lapila.

FAMILY	SURVIVAL (%)	FAMILY	SURVIVAL (%)
256	70 a	220	44 abc
247	67 ab	252	38 abc
248	63 abc	210	33 abc
228	62 abc	257	33 abc
217	61 abc	201	30 abc
227	59 abc	253	26 abc
219	57 abc	237	19 c
250	48 abc	211	17 bc
230	46 abc	**SITE**	**46.0**
232	46 abc		

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0003.

Height Growth. One effect that severe droughts has on *S. glauca* is terminal branch die-back and basal sprouting. This is a typical response of a moist forest species to sub-humid conditions, effecting total height growth of the species. It also has a negative effect on form as discussed below.

Height growth averaged 5.4 m at this trial during the ten-year period. This is very slow growth for the species as a result of the difficult growing conditions. Height increment during the five to ten year interval averaged only 1.4 m among families. A summary of the family means is provided in Table 1.72. Though the ANOVA indicated a family effect on height growth (Pr = 0.0129), the Tukey Test showed no differences in the comparison of the means. This is typical of unbalanced designs resulting from the high mortality of several families. The distribution of heights, by family, is shown in Figure 1.15.

Table 1.72. Ten-year height growth of *S. glauca* families at Lapila.

FAMILY	5-YEAR HEIGHT (m)	10-YEAR HEIGHT (m)
232	4.6 a	6.0 a
228	4.2 a	6.0 a
220	4.4 a	5.9 a
248	4.2 a	5.9 a
247	4.1 a	5.9 a
256	4.2 a	5.6 a
252	3.8 a	5.5 a
253	3.3 a	5.3 a
210	3.9 a	5.3 a
227	4.2 a	5.2 a
219	3.9 a	5.1 a
217	3.8 a	5.0 a
250	3.7 a	5.0 a
257	3.4 a	4.9 a
201	3.9 a	4.9 a
211	3.6 a	4.7 a
230	3.6 a	4.6 a
237	3.2 a	4.2 a
SITE	**3.98**	**5.40**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0003.

Form. As noted earlier, the poor form of *S. glauca* on droughty sites is supported by the data that reveal 45% of the trees forking under 1.3 m above ground. An additional 1% of the trees are leaning and 1% of the trees crooked. Only 53% of the trees would be considered normal regarding the form that is typical of the handsome *S. glauca*. The poor form of the trees appears to be equally distributed across families, suggesting that this is largely an environmental effect. As a result, family selection based on form is not justified.

Trial Management Recommendations. The site at Lapila may be considered an "off site" for *S. glauca*. Certain families are surviving better and appear more vigorous than others. Natural selection has favored these families which are disproportionately represented in the trial. The advantage of the trial at Lapila is that droughty sites are often ideal for seed production. Since the seed is likely exported out of the region to other more ideal planting sites, the conversion of the trial to a seed production area is justified.

All families should be maintained on site to ensure the greatest selection intensity. The trial should be culled in two stages. The first stage includes thinning the entire trial to two individuals per family plot. These individuals would be the most vigorous and well-formed individuals in the plot. Since the family plots are randomly distributed, the optimization of cross pollination among families seems assured. However, *S. glauca* is dioecious meaning that female and male flowers occur on separate trees. By selecting two individuals per family, there is a 50:50 chance that one female and one male are selected.

The second stage of selection would be implemented at such time that the species reaches sexual maturity. During the peak flowering season, about February or March, the trees should be identified as either male or female. The number of males and females are then tallied for each family. While it is not certain the optimum number of males required to sufficiently pollinate the females, the best guess would be to manage the trial at an even ratio so that half the trial is female. At such time that space is critical and the trial is thinned to one tree per family plot, selection should favor females for fruit production.

The above strategy will be difficult to accomplish, simply because several families are represented by as few as six individuals. However, the goal is to balance family representation so that the bulked seed originating from the trial is a worthy genetic mix of phenotypes selected on the basis of their vigor and broad adaptability.

2. Provenance/Progeny Trials

2.1 *Grevillea robusta* at Paillant, Miragoane

Background. G. robusta, originating from Australia, is a promising premium quality wood species for montane areas in Haiti above 600 m. While the species has been introduced to Haiti during the past 40 years, no systematic attempt to identify superior provenances or progeny of the species in the country had been implemented prior to 1990.

The trial is one of two trials that were established in Haiti to test genotypes available from the tree improvement program at CSIRO (Center for Scientific Investigation and Research Organization) Forestry in Australia. Three provenances, each represented by ten half-sib families of plus trees, were tested against a control seed lot harvested in the Fermathe area (Appendix 1, Table 10). The Fermathe nursery of Baptist Haiti Mission purchased *G. robusta* seed periodically during the past 30 years and introduced the species in the area through its tree planting program. The introduced seed represents what is commercially available through horticultural suppliers, rather than from professional tree improvement programs. Thus, one of the main objectives of the trial is to verify whether any differences exist between a local source of seed, hereafter referred to as the control, and seed from plus trees in its native range.

The trial design is a nested version of a complete randomized block design, comprised of three provenances, each with ten half-sib families, and a control. Each of the three provenances and the control were randomized within block with the half-sib families randomized within provenance. The half-sib families are replicated four times and established in 7-tree row plots.

Since the trial is large, each block encompasses a large area and block homogeneity should not be assumed. However, the random placement of provenance and progeny somewhat compensates for site heterogeneity. This can be tested by a significant interaction term of the ANOVA.

Survival. Survival at ten years was performed to test differences among provenances and to test differences among half-sib families within provenances. There were no differences detected among provenances compared with the control. In fact, the interaction effect (genotype x environment) contributed a greater share of the trial variance, indicating that block heterogeneity was problematic. Thus, the true genetic effects could not be detected in the trial and the survival rates are considered statistically equal. Table 2.11 summarizes the 10-year survival rates among the three provenances and the control. The survival rate of the entire trial, after ten years, was 61%.

Table 2.11. Ten-year survival rate of *G. robusta* provenances and Haitian control at Paillant.

PROVENANCE	SURVIVAL (%)
15872 (Australia)	64 a
15873 (Australia)	51 a
17185 (Australia)	64 a
Control (*ex* Fermathe, Haiti)	63 a
SITE	**61**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.5492.

Among the half-sib families, only two differences were detected at the 0.0152 probability level for provenance 15873. The survival rate of family 2 (50%) and family 7 (64%) was significantly lower than that of family 6 (89%). All other half-sib families showed insignificant differences in survival within their respective provenance.

Height. Total tree height (m) after ten years was analyzed among the provenances and the control. The analysis of variance showed significant differences among the provenance means. As summarized in Table 2.12, the control grew significantly less than the top two provenances, 15872 and 15873. The latter would appear better adapted than the control to site conditions similar to Paillant.

Table 2.12. Ten-year height growth of *G. robusta* provenances and Haitian control at Paillant.

PROVENANCE	HEIGHT (m)
15872 (Australia)	9.3 a
15873 (Australia)	8.8 a
17185 (Australia)	8.6 ab
Control (*ex* Fermathe, Haiti)	6.9 b
SITE	**8.39**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.01719.

About half of the families comprised a balanced data set, allowing for an analysis of variance to detect differences at the family level. None of the families were shown to differ significantly from the control. However, two families, each representing a difference provenance, showed a significant difference in their heights. Family 15872-1, with a mean height of 10.3 m, exceeded that of family 15873-7, with a mean height of 6.9 m.

Merchantable Volume Index. Analysis of variance did not detect differences among the provenances (Pr = 0.1577), though the Australian sources averaged 60-90% more in merchantable wood volume than the control. Table 2.13 summarizes the results after ten years.

Table 2.13. Ten-year merchantable volume index of *G. robusta* provenances and Haitian control at Paillant.

PROVENANCE	**MVI ($x\ 10^{-2}\ m^3$)**
17185 (Australia)	5.9 a
15872 (Australia)	5.8 a
15873 (Australia)	5.0 a
Control (*ex* Fermathe, Haiti)	3.1 a
SITE	**4.95**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.1577.

An analysis of variance at the family level also detected no differences in MVI. As in the case of height growth, certain families contributed a disproportionate share of the most productive individuals, as shown in the distribution of MVI by family (Figure 2.1).

Trial Management Recommendations. The evidence is weak that there are strong genetic effects shown by the testing of different *G. robusta* provenances at Paillant. This is partially due to the difficulty imposed when establishing large blocks on a site that varies tremendously in soil depth and other factors. These factors can be a source of significant genotype x environment interaction. Because the trial is not strongly conclusive regarding the superiority of provenance or family, the best strategy at this stage would be to select the entire trial at the individual tree level with nearest neighbor comparisons. Individuals differ in merchantable volume index by orders of magnitude. Selecting individuals with the highest MVI, regardless of provenance, should create a gene pool with higher probability of expressing superior quality traits. Additional traits to select for would include pest/disease resistance, natural branch pruning, wind firmness and canopy shape. Narrow and well-proportioned canopies are preferred over disproportionately large canopies for agroforestry systems.

The final selection would reflect the density at which plus trees could develop without competition for light and soil resources that would effect flower and fruit production. While the form of the tree is important for selection, the ultimate goal of optimizing fruit production does not require the ideal form for timber production. However, in order to optimize the value of the stand, it is recommended to maintain good timber form while advancing seed production. If a final density of 100-125 trees per ha were selected, approximately a fourth of the population would be comprised of the healthiest and best formed individuals that represent each provenance and the control. This strategy would maintain the widest genetic diversity available in Haiti (and possibly the island of Hispaniola) while making modest genetic gains on the quality of the species available for tree planting purposes and economic potential.

3. Provenance Trials

3.1 *Acacia auriculiformis* at Lapila, Pignon

Background. This is the only true provenance trial of *Acacia auriculiformis* in Haiti, probably containing the broadest genetic base of the species on the island. The trial includes eight provenances, representing the species' natural range in Australia and Papua New Guinea, and a control plot comprised of five half-sib families selected in Haiti. The parent trees were selected for desirable traits. The provenance information identifying the origin of the germplasm is provided in Appendix 1 (Table 1).

The original design of the trial was a randomized complete block with four replications. However, due to changes in land use plans by the owner of the land, only two replications were maintained. Thus, the conclusions based on the ten-year data should be regarded with some caution. The results of this trial has relevance to the *A. auriculiformis* seedling seed orchard at Sapatè, since identical accessions were established at the two sites.

This report is the first time that the trial has been evaluated. The trial was established prior to the embargo in 1991. Consequent cuts in the research budget of SECID did not allow for the trial to be evaluated prior to this report.

Survival. The average survival rate of the trial was 72% after ten years, the same as the *A. auriculiformis* orchard located at Sapatè, south of Hinche and also in the Central Plateau. The ANOVA showed no difference among provenance survival rates (Table 3.11).

Table 3.11. Ten-year survival rates of *A. auriculiformis* provenances at Lapila.

PROVENANCE	SURVIVAL (%)
Haitian Control	**62 a**
15697	70 a
15985	84 a
16142	76 a
16152	80 a
16160	76 a
16355	78 a
16484	48 a
16607	78 a
SITE	**72**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.2851.

Height Growth. The site average for ten-year height growth was 11.3 m. The ANOVA showed a significant provenance effect ($Pr = 1.055 \times 10^{-7}$) indicating that several means were statistically different. The results of the Tukey Test is summarized in Table 3.12, showing only one provenance (16484) that out preformed the Haitian control. In turn, the Haitian control grew faster than provenance 16152.

Table 3.12. Ten-year height growth of *A. auriculiformis* provenances at Lapila.

PROVENANCE	HEIGHT (m)
16484	13.1 a
16607	12.1 ab
15697	12.0 ab
16142	11.3 abcd
Control	**11.2 bc**
16355	11.2 bcd
15985	11.2 bcd
16160	10.3 cd
16152	9.9 d
SITE	**11.3**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0000001.

The fact that the same top two provenances (16484, 16607) at Lapila are identical with the top two at Sapatè strongly suggests that these provenances are the best adapted to conditions found in the Central Plateau. The third and fifth top performing provenances at the Sapatè orchard, 16107 and 16610, are not present at Lapila. This is noted to argue for the maintenance of a broad genetic base that includes unique provenances not available elsewhere in Haiti. The distribution of height means, by provenance, is provided in Figure 3.1.

The provenances from Australia allow for the selection of phenotypes that are straighter, single-stemmed and possessing an architecture less prone to wind damage. (*A. auriculiformis* has a reputation of being low-forked with heavy main branches that split at the main fork in high winds). The provenances with the fastest height growth are logical candidates for selection based on this important criteria.

Biomass Index. An index that takes into account the varying ratios between stem diameter and tree height was used as an indicator of the differences in wood productivity. (*A. auriculiformis* is generally not considered saw timber and thus merchantable height was not measured for this species). While wood productivity may be considered less important than form, it remains an important trait of a fast-growing species.
The ANOVA showed a significant provenance effect for biomass index (Pr = 1.7487 x 10^{-6}). The top performing provenance, 16484, was significantly different from the bottom two, 16152 and 16160. Table 3.13 summarizes the results of the statistical analyses for biomass index.

Table 3.13. Ten-year biomass index of *A. auriculiformis* provenances at Lapila.

PROVENANCE	BIOMASS INDEX (x 10^{-2} m^3)
16484	22.4 a
15697	16.9 ab
16355	14.9 abc
16142	14.8 abc
16607	14.2 abc

PROVENANCE	BIOMASS INDEX ($x\ 10^{-2}\ m^3$)
Control	**12.7 bc**
15985	12.4 bc
16152	9.2 c
16160	7.6 c
SITE	**13.4**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.000002.

The distribution of biomass index, by provenance, is shown in Figure 3.2. Note the difference in provenance variation. It is this variation that allows for genetic gains to be made when converting the provenance trial to a seed production area.

Form. The provenances with the lowest proportion of stems forking below 1.3 m were 16484 (0 individuals), 15985 (two individual), 15697 (two individuals), and 16142 (one individual). Each individual tree was also scored for stem form on a scale of 0 – 3. The lowest score, 0, indicates a straight stem and the highest score, 3, is for a stem of low value, branching below 1.3 m. The lowest average scores among provenances, indicating superior stem form, were 15697 (0.03), 16142 (0.11), 16484 (0.17) and 16607 (0.32). The worst performing provenances were the control (1.22), 16160 (1.05) and 16152 (1.02).

Trial Management Recommendations. The trial should be rogued of the inferior provenances for a combination of height and biomass index. *The bottom 3 provenances should be eliminated completely, including 16152, 16160 and 15985.* This leaves five Australian/Papua New Guinean provenances and the "Haitian Select" that should be thinned according to the following selection criteria:

1) Select the best formed individuals that have a tendency of a single trunk, high main fork and/or a narrow canopy architecture. This improves its wind resistance and commercial value.
2) Thin to a stand density that is appropriate for full canopy development and flower production during the next five years.
3) If co-dominants occur side-by-side that are both superior trees, cull the one that as the least chance of interbreeding with non-related provenances.
4) Occasionally introduce seed of the best formed and adapted provenances from CSIRO seed orchards to maintain genetic diversity and long-term performance.

3.2 *Azadirachta indica* at Roche Blanche, Croix-des-Bouquets

Background. This is the oldest trial in Haiti for this species, designed to test differences among imported seed lots of the species. The origin of these seed lots is summarized in Appendix 1 (Table 2). The original objective of the trials was to test differences in azadirachtin content of the seed kernel, since this ingredient is the primary basis for the insecticidal qualities of the seed. However, due to budgetary constraints, the appropriate analyses were never conducted properly and differences among seed lots remain unknown.

The trial was established in October, 1991 and assessed for differences in growth performance at five years (Timyan et al., 1997). While no differences were shown for survival nor stem diameter at three or five years, there was a difference exhibited at three years for height (No. 7 (Niger) vs. No. 14 (Burkina Faso)). However, height means at five years showed no difference in height growth, suggesting the uniformity of the genetic base represented in the trial. Whether this is evidence of the species' narrow genetic base or an inherent feature of the species is uncertain.

Survival. The analysis of variance for survival showed no differences among seed lot means at the 0.05 probability level. Table 3.21 summarizes the survival means for the *A. indica* seed lots at five and ten years. The survival curves of the seed lots since their establishment in 1989 is shown in Figure 3.3. In general, the survival rates are stable once the two-year stage is passed with an overall high rate of survival for the species.

Table 3.21. Survival means of *A. indica* at Roche Blanche after five and ten years.

PROVENANCE	5 YEARS (%)	10 YEARS (%)
2 (Puerto Rico)	80 a	80 a
3 (Dom. Rep.)	95 a	84 a
4 (Senegal)	100 a	100 a
5 (Togo)	88 a	88 a
6 (Niger)	96 a	96 a
7 (Niger)	100 a	100 a
8 (Burkina Faso)	90 a	76 a
9 (Burkina Faso)	75 a	60 a
10 (Burkina Faso)	85 a	72 a
12 (Burkina Faso)	100 a	84 a
13 (Burkina Faso)	95 a	92 a
14 (Burkina Faso)	90 a	80 a
15 (Burkina Faso)	100 a	96 a
17 (Control Haiti)	95 a	92 a
SITE	**92.4**	**86.4**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.2061 (5 yrs.); Pr = 0.0891 (10 yrs.)

Height Growth. The analysis of variance for height showed no difference among seed lot means (Pr > 0.25). The scatter plot comparing the height distribution of the seed lots (Figure 3.4) illustrates the uniformity of the *A. indica* seed lots. Height, as an indicator of adaptability and vigor, does not provide an adequate selection criterion to rogue the trial. All seed lots appear to be equally adapted to the site conditions at Roche Blanche.

Stem Diameter Growth. The square of stem diameter at breast height (DBH), measured in cm, was used as an indicator of wood volume. Analysis of variance does not show a significant effect of seed lot (Pr > 0.05). As in the case for height, there is insufficient evidence that seed lots are different. They should be considered equally when thinning the trial for development of superior individuals.

Trial Management Recommendations. This is probably the only known trial of its kind on the island — perhaps the most diverse genetic base of *A. indica* on Hispaniola. The uniqueness of the trial and the species' economic potential increases its importance, particularly on behalf of the farmers seeking alternative methods of insect control.

Based on the statistical analyses for survival, height and stem diameter squared, no significant differences were shown to distinguish the seed lots. In order to preserve the genetic diversity of the species for seed production and propagation, it is recommended to thin the trial at the level of the individual tree to stem densities appropriate for optimal flower and seed production.

The trial was originally designed to maximize the production of fruit for its azadirachtin yield. This is a function of both the concentration of azadirachtin and total fruit yield. If an opportunity exists to finally test the seed lots for both these variables, then USAID should take the lead on this for its value to farmers throughout Haiti. Based on the results, the trial would then be rogued of the inferior sources of azadirachtin in order to improve the genetic base of aza production.

3.3 *Cedrela odorata* at Bérault, Torbec

Background. This trial contains the same eight provenances that are tested in the Laborde trial (below), all from Central America (Appendix 1, Table 6). Statistical analyses and recommendations of the trial to the 5-year stage are provided in Béliard et al. (1997). Differences were shown among provenances for survival, stem diameter and merchantable volume index, but not for total height.

The original design of the trial was a complete randomized block design with three replications. However, due to problems of trial management, two of the three blocks gradually deteriorated over the course of the ten years, mostly due to uncontrolled grazing and periodic use of the land for crops. These problems were exacerbated by the site's position near a ravine that experienced severe disturbance, including flooding and the deposit of boulders and silt.

Only Block 1 is analyzed for variance and comparison of means among provenances. Despite the weakness of the trial for analysis of variance (i.e., cannot separate provenance and environmental factors), several plus trees of the most promising provenances are available for seed harvest and propagation by branch cuttings. Due to missing data, conclusions are to be interpreted with caution.

Survival. Table 3.31 summarizes the 10-year survival rates of the provenances in Block 1. Since only eighteen trees were established, the ranks of the provenances should be considered with caution, especially since not all mortality can be attributed to natural causes. Nevertheless, the most vigorous and best adapted provenances can be expected to have higher survival rates despite management problems. Rank among provenances reflects a similar pattern as the Laborde trial. The notable exception is the low survival of 36/78. The graphical presentation of the survival rates is shown in Figure 3.5.

Table 3.31. Survival of *C. odorata* at Bérault after ten years. Means are based on a single plot of 18 trees.

PROVENANCE	SURVIVAL (%)
6888 (Honduras)	83
23/77 (Belize)	78
14/75 (Nicaragua)	78
52/79 (Honduras)	61
2532 (Costa Rica)	33
42/79 (Guatemala)	22
25/80 (Colombia)	22
36/78 (Nicaragua)	17
SITE	**49.3**

Height. The results show a significant difference among provenances for total height. One of the provenances, 2580, is represented by only one individual considered adequate for measurement. (The other two individuals of the same provenance were damaged by human activity during some time of the trial). The results of the 10-year trial is summarized in Table 3.32. Figure 3.6 illustrates the distribution of heights by provenance.

Table 3.32. Ten-year height comparisons among *C. odorata* provenances at Bérault.

PROVENANCE	HEIGHT (m)
6888 (Honduras)	17.2 a
52/79 (Honduras)	17.0 a
23/77 (Belize)	15.7 ab
14/75 (Nicaragua)	13.4 bc
25/80 (Colombia)*	13.4 bc
2532 (Costa Rica)	11.9 c
42/79 (Guatemala)	10.4 cd
36/78 (Nicaragua)	5.4 d
SITE	**13.0**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 1.679×10^{-11}. * One individual only.

Merchantable Volume Index (MVI). At the 5-year stage, differences were shown among provenances. Despite two- to five-fold increases of MVI at Bérault, as compared to Laborde, the rankings of the provenances remain similar. The exception is the poor performance of 36/78 at Bérault, which also survived poorly.

No differences were detected among provenances at the 10-year stage. Table 3.33 compares the 5- and 10-year MVI means, showing a 2-fold increase in merchantable wood volume with a doubling of time. The distribution of the MVI among provenances is illustrated in Figure 3.7.

Table 3.33. Merchantable volume index of *C. odorata* provenances at Bérault after five and ten years.

PROVENANCE	5 YEARS (x 10^{-2} m^3)	10 YEARS (x 10^{-2} m^3)
6888 (Honduras)	20.7 a	41.0 a
52/79 (Honduras)	16.2 ab	33.4 a
23/77 (Belize)	15.3 ab	33.2 a
14/75 (Nicaragua)	11.5 ab	20.9 a
42/79 (Guatemala)	9.7 ab	12.7 a
2532 (Costa Rica)	7.9 ab	10.5 a
25/80 (Colombia)*	2.0 ab	6.3 a
36/78 (Nicaragua)	0.7 b	1.5 a
SITE MEAN	14.4	28.5

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0105 (5 yrs.), Pr = 0.1555 (10 yrs.).

The Bérault site is typical of habitat conditions that favor *C. odorata.* The largest tree in the trial, representing an Honduran provenance, measures 23 m tall with a stem diameter of 45 cm. Merchantable height is over 9 m with a merchantable volume index of 1.9 m^2. Such growth cannot be expected on a uniform basis, but this example illustrates the potential when a genotype is optimally matched with site conditions.

Trial Management Recommendations. The trial was thinned, but not rogued of inferior provenances, in September, 1999. The final density changed from the original 1667 trees per ha to 158 trees per hectare, leaving approximately 9% of the trees. This density appears sufficient to permit adequate crown development to optimize flower and fruit production.

The map for the plus tree is incorrect according to the numbering order in the data files. This is a common mistake and should be corrected for the archives. In general, the selection at the individual level was completed satisfactorily. A combination of form and stem girth was the main criterion. *However, the poorest performing provenances should be eliminated from the site, since it is at this level that the greatest genetic gains are made.* In this case, it would be the following the bottom four provenances in terms of MVI: 36/78, 25/80, 2532 and 42/79.

Perhaps the greatest concern at this stage is the speculative performance of the progeny that may arise from the provenance trial as a source of seed. (There are generally no problems if branch cuttings are used for improved tree production). Outcrossing levels and combining abilities of such a broad genetic base are largely unknown and may exhibit variable results if trees are grown from seed. Thus, at some stage, the variability of the progeny from the trial should be tested to confirm the degree of heterozygosity in the seed. Reliability and broad adaptability are subtle criteria that are the goals of many tree improvement programs.

The plus trees of all provenances should be evaluated for their wood quality, especially if the wood is sawn for lumber. Such properties as density, grain straightness, aroma, color, sanding ability and warping should be compared with local sources of *C. odorata* that are on the market. There is a chance that an exceptionally high score for these properties may compensate for the volume of the poorer provenances. Alternatively, wind firmness and disease or pest resistance may be a factor as well in provenance selection. Ideally, the provenances that best combine wood quality, volume production, wind firmness, and pest/disease resistance are the candidates that should be selected.

3.4 *Cedrela odorata* at Laborde, Camp Perrin

Background. This trial contains eight provenances of *Cedrela odorata* (Appendix 1, Table 6), highly esteemed throughout the Americas for its fragrant and easily worked timber. The experimental design consists of a randomized block design, with each provenance represented by a row-plot of ten trees in each of four blocks. The variables considered for statistical evaluation at ten years include survival, height and an index of merchantable volume. The first two are considered important for the evaluation of adaptability and vigor; the latter is considered important to asses the economic potential of the species in Haiti.

The trial was established in 1989 and measured at 0.5, 1, 3, 5, and 10 years. The evaluation of the trial at five years is described in Béliard et al. (1996). The statistical analyses, evaluation and recommendations that follow are based on the 10-year performance data, though comparisons with the 5-year data are useful to visualize any differences in development that might exist as a function of provenance.

Survival. A summary of the 5- and 10-year survival data is shown in Table 3.41. Overall, the survival of the species is remarkable for this particular site, indicating an excellent match of site conditions for a species that is generally considered difficult to cultivate. It should be noted that all the provenances originate from Central America, though the species is also native to Haiti. Also noteworthy is that the provenances fell roughly into two forms that could be distinguished by the appearance of their bark and the color of their leaves. The smooth-barked and lighter green-leafed form (e.g., 5279, 6888) is distinguished from the furrow-barked and reddish-leafed form (2532, 2580) that resembles local *C. odorata.* In general, the smooth-barked form exhibits higher survival as a result of its greater vigor and productivity. One of these forms, 6888, is a commercially available seed lot from Honduras, and was distributed throughout Haiti via PADF during the same time that the trial was established.

Table 3.41. Survival rates at five and ten years for *C. odorata* provenances.

PROVENANCE	5 YEARS (%)	10 YEARS (%)
6888 (Honduras)	93 a	93 ab
52/79 (Honduras)	100 a	88 ab
23/77 (Belize)	95 a	85 ab
36/78 (Nicaragua)	93 ab	68 ab
14/75 (Nicaragua)	95 ab	63 ab
42/79 (Guatemala)	90 ab	63 ab
25/80 (Colombia)	80 ab	30 bc
2532 (Costa Rica)	63 b	18 c

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0047 (5 yrs.); Pr = 0.00005 (10 yrs.)

Survival rates declined for all provenances during the 5 and 10 year interval. However, rates vary by provenance and declined more rapidly for the two worst performing provenances. The survival results after ten years are important, since trials of such age are practically non-existent in Haiti (or elsewhere in the Caribbean) for most of the economically important tree species. These are better visualized by Figure 3.8.

The low survival rates for 25/80 and 2332 may appear not acceptable, though they may be reasonable for more typical conditions under which the species is planted by farmers. However, such low rates are acceptable only if these provenances proved to be of exceptional quality in form or other desirable trait. Since there are many other provenances to choose from for both superior survival and growth, it is not necessary to continue with these particular genetic lines.

Height Growth. Height growth is perhaps the simplest measure that indicates the vigor and adaptability of a species to a particular site. Total height is measured and is distinguished from merchantable height, which is the height of the merchantable portion of the stem used for either poles or timber. Only heights of trees undamaged by livestock or human activity are used for statistical analyses in order to assess the natural response of the provenance to its environmental conditions.

The 10-year analysis of variance generated an insignificant P value for provenance means (Pr = 0.23). The scatter plot of the data supports this conclusion, as shown in Figure 3.9.

Though the analysis of variance shows no significant difference among tree height, further analysis of merchantable height is necessary to examine qualitative differences among the provenances. These differences would be economically more important than tree height in order to base a selection strategy for genetic improvement.

Merchantable Volume Index. An index was developed based on the equation: MVI = $(Dbh)^2*(MH*100)$, where MVI = Merchantable Volume Index (x 10^{-4} m^3), Dbh = stem diameter (cm) at 1.3 m above ground and MH = merchantable height (m).

The 10-year analysis of variance, taking into account all trees, did not show significant differences among provenances for the merchantable volume index (Pr = 0.07). That is, the variability within provenances is too large to detect differences between provenances. Another aspect of the trial also weakens the conclusions ? it is unbalanced due to mortality and the elimination of three plots. However, as shown by Figure 3.10, the largest volumes derive from provenances (6888, 5279, 3678, 2377, and 1475), supporting a provenance effect. An analysis of variance using the plot means as replicates generates a significant F statistic (Pr = 0.039). The worst performing provenances (2532, 2580, 4279) would be eliminated from the trial, leaving the best formed individuals of the five remaining provenances. Figure 3.11 compares the five and ten year merchantable volume indices of the provenances in this trial. The 95% error bars are shown for comparative purposes.

Trial Management Recommendations. Theoretically, provenance trials such as this one have a much broader genetic base than progeny trials. It is typical for provenances that originate from a wide geographic base to show large differences in performance. The selection of *C. odorata* germplasm at Laborde should proceed at this ten-year stage of its life along the following steps:

1) Eliminate the worst performing provenances (2532, 2580, 4279) within the trial to preclude the possibility of multiplying poorly adapted germplasm outside the trial.
2) Select the top 1-3 individuals within each plot of the best performing provenances in order to provide sufficient space to develop and to flower. If two superior individuals are adjacent to each other, remove one of the co-dominants in order to provide space for proper development of the other. Final density at maturity should approximate 100-140 trees/hectare.
3) Thin the superior provenances during the dormant time of year for *C. odorata* in order to exploit the opportunity of multiplying, by branch cuttings, any superior tree that requires removal.
4) Determine the wood quality of the culled trees, by provenance, and compare with local *C. odorata* to note distinguishing features that might effect market value or woodworking qualities as a premium wood.
5) Monitor flowering and fruiting cycles of the provenances, in order to verify the differences among provenances and the pollination biology of these Central American sources. Note any disease, pests, wind or other damages that may attack the trees and affect the provenances differentially.

3.5 *Cedrela odorata* at Labordette, Petite Goâve

Background. The provenance trial is located at a mid-elevation farm site at 450 m. It contains seven provenances from Central America (Appendix 1, Table 6). The trial design was established at the time the soil was prepared for annual crops of corn and beans. The trial was intercropped during several seasons and this had an adverse effect on the trial. Mortality and damages associated with human activity seriously compromises the statistical value of the trial, though select specimens of the most promising provenances are available for multiplication. Nevertheless, the better adapted provenances are the same as those in other trials thereby confirming the broad adaptability of these provenances for reforestation purposes.

The trial design is a randomized complete block design with four replications of 18-tree plots representing each provenance. Only undamaged trees were considered for analyses.

Survival. The overall survival of the trial after ten years is 27%. This is considered a low survival rate as compared to sites with greater land use control, such as Laborde. However, given the typical nature of annual garden land in Haiti over a period of a decade, this rate is within the range that can be expected.

The provenances ranged widely in their survival rates. The highest rates were observed for the same provenances that achieved the highest survival rates at other sites: 6888, 2377 and 5279. Conversely, the lowest rates (25/80, 2532) are also the poorest survivors at other sites where these provenances have been tested in Haiti.

The ANOVA for the trial detected significant differences among provenance means (Pr = 0.0029). Provenance 6888 was significantly different at the 0.05 level with 25/80 and 2532, as summarized in Table 3.51.

Table 3.51. Survival means of *C. odorata* at Labordette after ten years.

PROVENANCE	SURVIVAL (%)
6888 (Honduras)	53 a
23/77 (Belize)	46 ab
52/79 (Honduras)	35 ab
36/78 (Nicaragua)	22 ab
42/79 (Guatemala)	17 ab
25/80 (Colombia)	8 b
2532 (Costa Rica)	6 b
SITE	**26.7**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Height. The average height of the trial was 12.1 meters after ten years. The fact that two of the provenances were represented by such few individuals caused problems in the analysis of variance. Provenance 2532 had two individuals and provenance 2580 had three individuals that were included in the analyses. Thus, the ANOVA did not detect differences among the provenances for height (Pr = 0.8786). A summary of the mean heights, by provenance, is provided in Table 3.52.

Table 3.52. Height means of *C. odorata* at Labordette after ten years.

PROVENANCE	HEIGHT (m)
42/79 (Guatemala)	13.0 a
23/77 (Belize)	12.6 a
6888 (Honduras)	12.4 a
36/78 (Nicaragua)	12.1 a
52/79 (Honduras)	12.0 a
2532 (Costa Rica)	12.0 a
25/80 (Colombia)	11.3 a
SITE	**12.1**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Merchantable Volume Index. The average merchantable volume index was 15.2 x 10^{-2} m^3. The range in the index among provenances was much greater than for height means. However, the ANOVA failed to detect a difference among means (Pr = 0.3667). The low indices for 2532 and 2580 confirm poor results of these provenances at other trial sites in Haiti. A summary of the MVI among provenances is provided in Table 3.53.

Table 3.53. Merchantable volume indices of *C. odorata* provenances at Labordette after ten years.

PROVENANCE	MVI (x 10^{-2} m^3)
42/79 (Guatemala)	20.9 a
36/78 (Nicaragua)	17.7 a
6888 (Honduras)	16.4 a
23/77 (Belize)	15.4 a
52/79 (Honduras)	12.0 a
2532 (Costa Rica)	8.2 a
25/80 (Colombia)	8.1 a
SITE	**15.2**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Trial Management Recommendations. The trial should be rogued of its poorest performing provenances (e.g., 2532, 2580) despite the fact that statistical evidence is weak due to the unbalanced nature of the trial. Evidence of poor performance from the other *Cedrela odorata* trials at Laborde and Bérault are sufficient to determine the winners and losers of this particular set of provenances. After the poorest provenances are rogued, each remaining provenance should be selected for its superior trees. These should be thinned so that sufficient space is available for their optimal development as sources of seed or cuttings. The top 10-20% of the total number of stems available for selection should remain following selective thinning.

Since the owner of the trial is a commercial tree seed broker for many projects throughout Haiti, it is critical to intervene in this trial so that inferior seed is not distributed for sale. Also, there may be financial pressures to harvest the best formed trees. The price of seed harvested from the best trees should reflect the opportunity cost of forgoing harvest during an adequate period of time (e.g. 5 or 10 years). The owner should be encouraged to prepare cuttings from the select trees and expand his seed production area with vegetative clones. These clones may produce seed earlier than the current trees that were propagated from seed.

3.6 *Cordia alliodora* at Pémel, Camp Perrin

Background. This is one of several provenance trials established for this species in Haiti. *C. alliodora* is native to Haiti, but uncommon and occurring in restricted areas of the country as a relic of the native forests. It is rarely cultivated in numbers as other timber species, though the species has a reputation of wood quality that compares with the highly esteemed *Catalpa longissima*. At the time of trial establishment, only provenances from Oxford Forestry Institute (Oxford, UK) collection and a commercial collection (COHDEFOR, Honduras) were available. This trial contains four provenances, placed in a randomized complete block design with four replications. The provenance information is provided in Appendix 1 (Table 7).

A summary of trial results at five years is provided in Béliard et al. (1996). At the five-year stage, no significant differences were shown among provenances for survival, total height or stem diameter (at 1.3 m). Trial survival at this stage averaged 64.8%, height growth averaged 8.1 m and stem diameter averaged 9.1 cm.

Survival. Survival of the species continued to decline to average 43.5% after ten years. This is an underestimate of the true value due to selective harvesting of several trees during the 5 – 10 year interval by the land owner. Stumps that had rotted during this time appeared to have been tallied for mortality when in fact the trees were harvested and simply not present during trial measurements. In most cases, the harvested stems were the smaller size classes used for roundwood construction. These would have been selected for thinning as prescribed by conventional forestry methods.

Table 3.61 summarizes the 1-, 2-, 3-, 5- and 10-year survival means for each provenance. The noticeable drop in survival between five and ten years is confounded with selective harvesting by the land owner as noted above. The ANOVA indicated no differences among means (Pr = 0.7869). Figure 3.12 illustrates the survivorship of the provenances over a 10-year period.

Table 3.61. Survival rates of *Cordia alliodora* provenances at Pemel.

PROVENANCE	1	2	3 (%)	5	10
4017	60	60	60	59	49
4108	78	76	74	68	44
4140	73	72	71	69	43
7488	69	67	67	63	38
SITE	**70.2**	**68.6**	**67.9**	**63.3**	**43.5**

Height. Height increased 50% during the interval between five and ten years. The site average, 12.0 m, indicates that the growth rate is decreasing, as illustrated in Figure 3.13. Figure 3.14 shows the height distribution, by provenance, after ten years. The ANOVA for the trial detected differences in height mean among provenances (Pr = 0.0136). The mean height of 4108 (12.8 m) is significantly different from the mean height of 4107 (11.4), as supported by the Tukey Test summarized in Table 3.62.

Table 3.62. Ten-year height means of *C. alliodora* provenances at Pemel.

PROVENANCE	10-YEAR HEIGHT (m)
4108	12.8 a
7488	12.0 ab
4140	11.9 ab
4107	11.4 b
SITE	**12.0**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0136.

Merchantable Volume Index. The statistical differences that were shown in height were not evident with MVI. Despite 4108 also exhibiting the highest MVI, the mean was not considered significantly different from the other provenance means (Pr = 0.3887). The distribution of MVI by provenance is illustrated in Figure 3.15. The greater within provenance variation masks any genetic effect that might be a result of geographic origin. A summary of the MVI at the ten-year stage is provided in Table 3.63

Table 3.63. Ten-year merchantable volume index of *C. alliodora* provenances at Pemel.

PROVENANCE	MVI ($x\ 10^{-2}\ m^3$)
4107	13.4 a
4108	17.6 a
4140	14.8 a
7488	15.1 a
SITE	**15.2**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.3887.

Trial Management Recommendations. *Cordia alliodora* is an extremely well-formed species with rather large within provenance variation in terms of its merchantable volume index. Such a large variation indicates that superior specimens are likely to be found regardless of provenance. Height was the only criteria evaluated that showed a provenance effect. Other criteria, such as canopy volume and leaf area index, were not evaluated, those these have shown to be different among provenances. Provenance 7488 has distinct characteristics compared with the other more slender provenances, developing a larger canopy area with a much higher leaf area. It is likely more vigorous on a larger number of sites, though the ratio of merchantable stem volume:canopy volume is probably less. These factors should be addressed when thinning the site, since such differences in form and adaptability are important considerations in agroforestry.

At this stage of the trial, it is best to maintain all provenances and select by individual tree on the basis of form, canopy health and overall tree architecture that contributes to an improved breeding population. Simply culling out the poorest individuals or those that occupy a co-dominant position in the canopy should achieve the most important objective of exposing the canopy to full radiation for flower and fruit production. The random allocation of provenances within the blocks appears sufficient to provide adequate outcrossing rates. This will yield bulk seed that is representative of the best trees in the trial. If at such time a particular provenance is more desirable, it would be better to isolate this provenance by eliminating the other three genotypes.

3.7 *Cordia alliodora* at Bérault, Torbec

Background. This is one of three *C. alliodora* provenance trials that was established in 1989. It is comprised of five provenances from Central America: four provenances from the CATIE collection and one commercial seed lot from COHDEFOR (Honduras). Though the trial was established as a randomized block design with four replications, one replication was discarded from statistical analyses due to damages associated with uncontrolled grazing and cropping activities. The provenance information is provided in Appendix 1 (Table 7).

An evaluation of the provenances at five years is given in Béliard et al. (1996). Significant differences in survival, height growth and merchantable volume index occurred among provenances at the five year stage. The commercial seed lot, 7488, was the highest survivor (92%) and different from the bottom three provenances: 1877 (68%), 4140 (67%), and 4108 (31%). Provenances 4140 and 7488 grew significantly faster than the other three provenances: 10.2 and 10.5 m, respectively compared to 7.9, 7.9, and 8.4 m. These provenances also were the winners in terms of merchantable volume index and significantly different from 4107, but not 1877 and 4108. No differences were shown in stem diameter among the provenances.

Survival. Factors associated with human-caused damages confound the natural causes of mortality. As a result, survival means may underestimate the true values. The ANOVA for ten-year survival detected differences among provenance means (Pr =0.0350). The low survival rate of provenance 4108 (24%) is a result of a zero value for one of the replications and low survival rates (39%, 33%) for the other replications. Table 3.71 summarizes the ten-year survival at the Bérault trial. Figure 3.16 illustrates the survival trends by provenance.

Table 3.71. Ten-year survival rates of *C. alliodora* at Bérault.

PROVENANCE	**1**	**2**	**3**	**5**	**10**
			(YEARS)		
1877	68	68	68	68	59 ab
4017	83	83	83	78	59 ab
4108	41	33	33	31	24 b
4140	67	67	67	67	46 ab
7488	92	92	92	92	78 a
SITE	**70.2**	**68.8**	**68.8**	**67.2**	**53.3**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0350.

Height. The rankings in height growth changed among the mid-ranked provenances compared with the five year results. The tallest provenance, 7488, at five years remained the tallest provenance at ten years (14.3 m). The shortest provenance, 1877, at five years remained the shortest provenance at ten years (12.2). The ANOVA at ten years detected a significant provenance effect (Pr = 0.0005). A summary of height growth is provided in Table 3.72. Figure 3.17 illustrates the trends in height growth by provenance. Figure 3.18 shows the distribution of total heights by provenance.

Table 3.72. Ten-year height growth of *C. alliodora* at Bérault.

PROVENANCE	**HEIGHT (m)**
7488	14.7 a
4107	14.0 a
4108	14.0 ab
4140	13.6 ab
1877	12.2 b
SITE	**13.7**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0005.

Merchantable Volume Index. Despite a 60% difference between the top provenance (4108) and the bottom provenance (4107), no significant differences were shown among the means (Pr = 0.1815). The summary of the MVI at five and ten years is provided in Table 3.73. The distribution of MVIs by provenance is shown in Figure 3.19.

Table 3.73. Merchantable volume index of *C. alliodora* at Bérault.

PROVENANCE	5-YR MVI ($x\ 10^{-2}\ m^3$)	10-YR MVI ($x\ 10^{-2}\ m^3$)
4108	8.6 ab	23.3 a
7488	10.6 a	22.1 a
4140	10.7 a	16.6 a
1877	6.7 ab	15.6 a
4107	4.5 b	14.8 a
SITE	**8.2**	**18.1**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0738 (5 yr); Pr = 0.1815 (10 yr).

Trial Management Recommendations. Recommendations to rogue the trial based on the above results are complex. One aspect that should be considered is the demand for seed and a selection process that is coordinated with the Pemel trial.

At both trials, the winners tend to be provenances 7488 and 4108. Two options are available which should be considered. One option is to maintain all provenances at the Pemel trial and keep only provenances 7488 and 4108 at the Bérault trial. In both cases, the selected provenances would be thinned to the desired density for optimal flower and fruit production. The less desirable option would be to maintain all provenances at both sites and select only at the individual level. The latter is less likely to achieve the genetic gains that results by elimination at the provenance level.

The drawback to provenance 7488 is its non-merchantable biomass production, high leaf area and prolific flowering. These characteristics may not be suitable as a shade tree for coffee and other perennial crops. Nothing is known at this stage regarding differences in wood quality or the commercial stem volume:total biomass ratios among provenances. This should be an obvious area of research in order to select the genotypes that require a minimum of space at maturity with the maximum value of wood.

At such time that it is possible to evaluate the flowering of the provenances, this should be studied to estimate the likelihood of provenances being interbred. Certain hybrids may be less desirable than others, particularly if shown to be less uniform regarding desirable traits.

3.8 *Enterolobium cyclocarpum* at Lapila, Pignon

Background. This species is a well-known multiple-purpose tree used principally for its shade, fodder value and wood quality throughout Central America. The trial at Lapila is one of two provenance trials established for this species in 1989. Three provenances from Costa Rica and Honduras (Appendix 1, Table 8) were selected for testing, using a complete randomized block design with four replications and 18-tree plots. Site conditions are similar to those described for the other trials at Lapila with a detailed description given in Bélaird et al (1996) for this species.

The five-year results showed no difference in survival rates among provenances, but a significant difference in height and wood biomass production. The Costa Rican provenance, 792, achieved a 50% height advantage and produced three times more wood than the Nicaraguan provenance, 1371. Both parameters were significant at the 0.05 level. The commercial accession from Honduras fell between the other two provenances and exhibited no difference among any parameters.

Survival. The overall survival of the trial was 46%, a drop of 10% from the five-year stage. No differences were shown among provenance survival rates (Pr = 0.4843). Table 3.81 summarizes the ten-year survival rates of the trial.

Table 3.81. Survival means of *E. cyclocarpum* at Lapila after ten years.

PROVENANCE	SURVIVAL (%)
792 (Costa Rica)	56.3
1371 (Nicaragua)	40.6
11387 (Honduras)	40.6
SITE	**45.8**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.

Height. The overall height of the trial was 5.1 m after ten years. The ANOVA showed a significant provenance effect (Pr = 0.0202). The Tukey Test revealed differences between the top provenance, 792, and the slowest growing provenance, 1371 (Table 3.82). This reflects the same ranking that occurred at the five-year stage.

Table 3.82. Heights of *E. cyclocarpum* provenances at Lapila after ten years.

PROVENANCE	HEIGHT (m)
792 (Costa Rica)	5.5 a
11387 (Honduras)	4.8 ab
1371 (Nicaragua)	4.7 b
SITE	**5.1**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.

Biomass Index. The trial averaged 67.4 cm^2 per tree, using the square of the stem diameter as an indicator of biomass production. The ANOVA showed significant differences among provenance means (Pr = 0.0456). A summary of the Tukey Test is provided in Table 3.83 revealing the advantage of the Costa Rican provenance 792 over the Nicaraguan provenance 1371.

Table 3.83. Biomass indices of *E. cyclocarpum* provenances at Lapila after ten years.

PROVENANCE	INDEX (cm^2)
792 (Costa Rica)	82.1 a
11387 (Honduras)	70.7 ab
1371 (Nicaragua)	43.4 b
SITE	**67.4**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.

Trial Management Recommendations. There is strong statistical evidence that the Nicaraguan provenance, 1371, is inferior to the other two provenances in the trial. It was recommended at the five-year stage to eliminate 1371 from the trial in order to improve seed production potential for this species. This should be done immediately to avoid the possible contamination of adjacent provenances and the distribution of this provenance through seed harvests.

Though two provenances would not be considered a sufficient genetic base for country-wide distribution of the species, it is yet uncertain how broad a genetic base these two provenances represent. This can only be reconciled through the continued introduction of a larger genetic base and the concomitant testing of these introductions.

3.9 *Senna siamea* at Lapila, Pignon

Background. This is a smaller version of the trial at Roche Blanche, containing seven accessions. The trial was established in 1989 at the same time as several other provenance and progeny trials. Information providing the origin of the accessions is summarized in Appendix 1 (Table 13a). Site conditions are similar as for the other trials reported for Lapila with more detailed information provided in Timyan et al. (1996).

Results after five years showed no difference in accession means for survival (site average: 52%) or height growth (site average: 4.5 m). Differences were noted for estimated wood yield with a Haitian accession (1501) showing a significant advantage over an imported accession from Costa Rica (2507).

Survival. The overall survival of the trial after ten years was 48.1%. The ANOVA showed no differences among accessions (Pr = 0.5231). A summary of the survival means is provided in Table 3.91.

Table 3.91. Survival means of *S. siamea* at Lapila after ten years.

PROVENANCE	SURVIVAL (%)
554 (*ex* Rwanda)	33.3
1365 (*ex* Nicaragua)	60.4
1501 (*ex* Haiti)	43.8
1511 (*ex* Haiti)	57.3

PROVENANCE	SURVIVAL (%)
1581 (*ex* Haiti)	39.6
2507 (*ex* Costa Rica)	51.0
4039 (*ex* Costa Rica)	51.0
SITE	**48.1**

Height. The average height of *S. siamea* was 8.9 m after ten years. The ANOVA detected highly significant differences among accessions (Pr = 0.00000009) led by two Haitian accessions. Results of the Tukey Test are summarized in Table 3.92.

Table 3.92. Height means of *S. siamea* at Lapila after ten years.

PROVENANCE	HEIGHT (m)
1581 (*ex* Haiti)	7.1 a
1501 (*ex* Haiti)	6.9 a
554 (*ex* Rwanda)	6.8 a
4039 (*ex* Costa Rica)	6.4 ab
1511 (*ex* Haiti)	6.0 abc
2507 (*ex* Costa Rica)	5.4 bc
1365 (*ex* Nicaragua)	4.9 c
SITE	**6.1**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Wood Yield. The average wood yield per tree was 15.4 kg. Despite over a two-fold difference between the top and bottom accessions, the ANOVA detected no significant difference among accessions (Pr = 0.8215). A summary of the accession means is provided in Table 3.93.

Table 3.93. Wood yield of *S. siamea* at Lapila after ten years.

PROVENANCE	HEIGHT (m)
1581 (*ex* Haiti)	15.3 a
1501 (*ex* Haiti)	21.1 a
554 (*ex* Rwanda)	15.1 a
4039 (*ex* Costa Rica)	13.1 a
1511 (*ex* Haiti)	11.4 a
2507 (*ex* Costa Rica)	9.7 a
1365 (*ex* Nicaragua)	21.3 a
SITE	**15.4**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Trial Management Recommendations. Though highly significant differences occur among accessions for height growth, these differences do not translate to differences in wood yield. No basis was given for differences in wood value that is a function of stem form. Given the important interaction between environment and genotype, it is possible that certain accessions express themselves better on a harsh site such as Lapila as compared to a more fertile site such as Roche Blanche. As such, Lapila is an important site to select for vigor under rather difficult site conditions. All accessions should be preserved with selection at the individual tree only. Trees should be selected based on a combination of form, vigor and resistance to pests and diseases. The final density should be based on the optimal space required for full exposure of tree canopy to light. Fertilizer should be considered to improve flower and fruit production.

3.10 *Senna siamea* at Roche Blanche, Croix-des-Bouquets

Background. This is the largest provenance trial of *S. siamea* in Haiti, containing ten accessions. What is being considered as "provenances" are actually seed lots (hereafter termed "accessions") imported from other countries where the popular species is introduced. The goal of testing a wider genetic base of an introduced species is both to increase the genetic vigor of the species and to improve adaptability, as indicated by an increase in survival and wood value.

The design of the trial is a randomized complete block design, with three replications and 24-tree plots per provenance. Information providing the origin of the accessions is summarized in Appendix 1 (Table 13a). Detailed information of the site conditions at this trial are given in Timyan et al. (1996). This report also summarizes the five-year results. At five years, the trial averaged 75% survival, with differences shown among accessions. It was concluded that survival differences were due to seedling quality at the time of trial establishment rather than genotype differences. Height averaged 11 m with no significant differences detected among accessions. Differences were shown among accessions for wood production, with a local bulked seed lot (1501) exhibiting the highest average wood yield per tree (74 kg/tree).

Survival. The ten-year survival rate of the trial was 60.3%, showing a significant accession effect (Pr = 0.0084). However, the Tukey Test failed to show these differences among accessions at the 0.05 level. A summary of the survival rates for the accessions in this trial is provided in Table 3.101.

Table 3.101. Survival means of *S. siamea* at Roche Blanche after ten years.

PROVENANCE	SURVIVAL (%)
554 (*ex* Rwanda)	77.8 a
1206 (*ex* Nicaragua)	69.4 a
1214 (*ex* Tanzania)	65.3 a
1365 (*ex* Nicaragua)	76.4 a
1501 (*ex* Haiti)	44.4 a
1511 (*ex* Haiti)	47.2 a
1564 (*ex* Nicaragua)	56.9 a
1581 (*ex* Haiti)	41.7 a
2507 (*ex* Costa Rica)	73.6 a
4039 (*ex* Costa Rica)	50.0 a
SITE	**60.3**

Means followed by the same letter are not considered different by the Tukey Test , a = 0.05.

Height. The average height measured at ten years was 10.6 m. Remarkably, this is less than the site average at five years (11.0 m). It is uncertain whether this is due to complete height stagnation, periodic die-back due to severe drought and winds or selective thinning. The ANOVA for the trial detected a highly significant effect of accession on height growth (Pr = 0.000003). The Tukey Test showed significant differences among height means (Table 3.102).

Table 3.102. Height means of *S. siamea* at Roche Blanche after ten years.

PROVENANCE	HEIGHT (m)
2507 (*ex* Costa Rica)	11.8 a
1564 (*ex* Nicaragua)	11.6 a
1365 (*ex* Nicaragua)	11.4 a
1501 (*ex* Haiti)	11.3 ab
1511 (*ex* Haiti)	11.1 ab
1214 (*ex* Tanzania)	10.0 ab
1206 (*ex* Nicaragua)	9.8 ab
554 (*ex* Rwanda)	9.7 b
1581 (*ex* Haiti)	9.7 b
4039 (*ex* Costa Rica)	9.7 b
SITE	**10.6**

Means followed by the same letter are not con-sidered different by the Tukey Test , a = 0.05.

Wood Yield. The equation reported in Timyan (1996) to estimate wood yield was used to compare accessions. The overall mean was 82 kg wood per tree, nearly double the average wood yield determined at five years (45 kg). This is due to both the elimination of the smaller diameter trees through thinning and the incremental growth of the select trees over time.

The ANOVA did not show a significant difference among accession means (Pr = 0.5208) despite a four-fold difference between the top and bottom means. Table 3.103 summarizes the mean yield per tree among the accessions.

Table 3.103. Estimated wood yield of *S. siamea* at Roche Blanche after ten years.

PROVENANCE	WOOD YIELD (kg)
1365 (*ex* Nicaragua)	178.5 a
1501 (*ex* Haiti)	138.0 a
1564 (*ex* Nicaragua)	95.8 a
2507 (*ex* Costa Rica)	78.1 a
1206 (*ex* Nicaragua)	69.2 a
1511 (*ex* Haiti)	60.1 a
1581 (*ex* Haiti)	51.3 a
554 (*ex* Rwanda)	43.3 a
1214 (*ex* Tanzania)	42.1 a
4039 (*ex* Costa Rica)	41.6 a
SITE	**82.0**

Means followed by the same letter are not con-sidered different by the Tukey Test , a = 0.05.

Trial Management Recommendations. The statistical evidence that true differences occur among accession means is not great enough to rogue the trial. The best approach is to preserve all accessions in order to maximize genetic vigor of this *S. siamea* population. All individuals within a given accession should be scored for a combination of form, girth and vigor (i.e., resistance to diseases and pests) and selected based on the highest scores. Optimal density for fruit production rather than stem form should be calculated to determine the number of individuals that require thinning. Monitoring for disease resistance, particularly leaf spots and cankers, should continue to verify an accession effect.

4. Seedling Seed Orchards

4.1 *Acacia auriculiformis* at Sapatè, Hinche

Background. This is one of several *A. auriculiformis* seed orchards established in Haiti in 1991. The importance of the orchard is that has a source of seed, it contains the broadest genetic base known in Haiti and perhaps the island of Hispaniola. Regarding introduced species, such as *A. auriculiformis*, selected for their relatively fast growth, drought hardiness and wood production, land races of improved genotypes can be generated quickly. As typical of most introduced tree species in Haiti, the genetic base of the species has largely been introduced to Haiti without control of genetic quality.

The design of the orchard is to maximize the probability of outcrossing among provenances and half-sib families selected for their superior traits. Each tree in the orchard represents a difference provenance or family and is surrounded by neighbors of different genotypes. The orchard contains ten provenances, selected by CSIRO (Australia) throughout the species' native range, and five half-sib families of plus trees in Haiti (Appendix 1, Table 1). The Haitian select is considered the "control" in the following statistical analyses in order to compare the differences in survival, height and a total wood index among provenances. The latter index is used, rather than merchantable volume index, since the species is not considered a premium-grade hardwood and is generally used only for fuelwood and small roundwood construction.

Survival. The 10-year survival of the orchard averaged 72%, ranging from 47–100%. Table 4.11 summarizes the survival rates of the fifteen genotypes represented in the orchard. Statistical analysis showed that survival rates were not significantly different between the Haitian families and the Australian/Papua New Guinean provenances.

Table 4.11. Survival rates of *A. auriculiformis* provenances after ten years at Sapatè orchard.

PROVENANCE	SURVIVAL (%)	PROVENANCE	SURVIVAL (%)
541	60	16142	100
542	67	16152	57
548	60	16160	80
552	47	16355	65
553	87	16484	80
15697	73	16607	87
15985	73	16610	87
16107	62	**SITE**	**72**

Height Growth. Height growth, as an indicator of vigor and adaptability to the site conditions of the Plateau Central, was analyzed for 10-year results. Any differences would favor one genotype over another with the goal of selecting the most promising genotypes and improving the orchard as a source of seed in Haiti.

The analysis of variance showed insignificant differences among height means (Pr = 0.1571). A comparison of the ten-year heights for the 15 genotypes, with 95% confidence intervals, is shown in Figure 4.1. Though the differences appear large enough to detect differences, the data show that heights vary considerably within genotype and that all genotypes are represented by individuals that would be selected for their superior traits (Figure 4.2). However, certain genotypes are likely to produce a greater proportion of the final selection, since selective criterion not only includes height growth, but form, wind firmness and resistance to pests and diseases. The species is particularly susceptible to wind damage. Therefore, wind firmness and canopy form would be important selective criteria besides total height.

Biomass Index. Total biomass is related to the square of the stem diameter multiplied by total height. This biomass index provides a means to compare the *A. auriculiformis* provenances based on their potential wood yield. Since the index integrates both stem diameter and height, it provides a more meaningful measure of field performance that determines the productivity value of a given provenance.

No significant differences were observed among the provenances for the biomass index (Pr = 0.3604). As in the case of height, large differences occurred within provenance, obscuring any differences among provenances (Figure 4.3). There were also no differences exhibited between the Haitian and Australian genotypes, as confirmed by a t-Test (Pr = 0.1906).

Trial Management Recommendations. The genetic base of this orchard is broad, since ten of the accessions are provenance-wide collections. Five of the accessions are the progeny of plus tree selections made in Haiti. The large variability that exists in each provenance for height and biomass index suggests that the entire orchard should be represented by the best-formed individuals of each genotype. Several genotypes will contribute a greater proportion of the final density since they are more likely to be represented more trees of better form and girth. These genotypes include one Haitian accession (553) and several of the CSIRO selections (15985, 16142, 16152, and 16610).

Since the species grows rapidly and reproduces at an early age, the density of the thinning at this stage should be sufficient to expose the entire canopy to full sun. Individuals severely damaged by the wind should be removed from the orchard. The ideal phenotype selected for the orchard should have a healthy canopy that is in proportion to the stem girth to lessen its susceptibility to wind damage. Form and branch thickness would be important criteria for selection since these are critical factors of its wind firmness and utility as an agroforestry species. These criteria in addition to height and stem girth should be considered together in the final selection for improved seed.

4.2 *Acacia auriculiformis* at Terrier Rouge

Background. This is a small orchard comprised of the progeny of five plus trees selected in Haiti (Appendix 1, Table 1). It was established at the same time as the other trials at Terrier Rouge. Each family is represented by single-tree plots randomly placed with plots of the other families. Each family is represented by twenty trees in the orchard.

Site conditions are similar as described for the other trials. This report represents the first formal analysis of the species at this site.

Survival. The overall survival of the orchard after ten years was 44%. The range in survival (20%–65%) is most likely a result of the differences in seedling quality among families at the time of orchard establishment rather than a genetic difference. A summary of family survival rates is provided in Table 4.21.

Table 4.21. Survival of *A. auriculiformis* at Terrier Rouge after ten years.

FAMILY	SURVIVAL (%)
541	60
544	65
545	50
546	25
552	20
SITE	**44**

Height. The mean height of the orchard, after ten years, was 8.0 m. Mean heights ranged from 7.5 m (family 544) to 8.7 m (family 546). Family means are not significantly different (Pr = 0.2612). A summary of family heights is provided in Table 4.22.

Table 4.22. Height of *A. auriculiformis* at Terrier Rouge after ten years.

FAMILY	HEIGHT (m)
541	7.6
544	7.5
545	8.6
546	8.7
552	7.9
SITE	**8.0**

Biomass Index. The square of the stem diameter is selected as an index for wood biomass. The overall mean index was 71.4 cm^2. The ANOVA detected no difference among family means (Pr = 0.9307). A summary of the family means is provided in Table 4.23.

Table 4.23. Biomass index of *A. auriculiformis* at Terrier Rouge after ten years.

FAMILY	BIOMASS INDEX (cm^2)
541	79.7
544	63.5
545	72.8
546	61.7
552	72.6
SITE	**71.4**

Trial Management Recommendations. There is no evidence that significant differences occur among families in terms of survival, height growth or wood biomass production. The trial should retain all families and the orchard should be improved by several silvicultural steps:

- All trees of a given family should be compared to cull inferior individuals from the orchard.
- Sufficient space should be available to the remaining trees to optimize flower and fruit production over a period of five years (2001–2006).
- The select trees should be pruned carefully to avoid high wind damage to the heavy crown.
- Fertilizer should be considered to boost fruit production.
- Resistance to pests or diseases and overall vigor should be recorded by family to detect genetic differences and monitor interactions between the orchard and environmental factors..

4.3 *Calophyllum brasiliense* at Marmont, Hinche

Background. This is one of two orchards comprised of half-sib family collections made in this area of the Central Plateau and the southern peninsula of Haiti. *C. brasiliense* is esteemed as high-value wood for round wood, with many uses associated with its high tensile strength and resistance to decay. The fruit is widely dispersed by bats and natural regeneration of the species is commonly observed in the deforested landscape of Haiti. Though the species is better adapted to the moist, riparian zones of the Central Plateau, this upland site was selected for its security and the management capabilities of the local NGO in the area.

The design of the orchard optimizes cross pollination by completely randomizing single trees representing each family. Five families are represented in this orchard, each family originally established with twelve trees. Though the space allocated to the orchard is small, it is expected that the orchard will produce sufficient seed to meet demand since the species is relatively prolific. The origin of the *C. brasiliense* families is provided in Appendix 1 (Table 3).

Survival. The overall survival of the orchard was 30% after ten years. One year following the establishment of the orchard, the dead individuals of each family were replaced by sibling seedlings. At the current time, 45% of the orchard remains with each family represented by 3–9 trees. The survival, based on the original number of trees planted per family, and the current number of trees per family in the orchard, are summarized in Table 4.31.

Table 4.31. Survival of *C. brasiliense* families at Marmont orchard. Numbers in parentheses indicate actual number of individuals per family, including 9-year old replants.

FAMILY	TEN-YEAR SURVIVAL (%)
902	25 (5)
915	17 (3)
918	33 (6)
919	27 (4)
920	38 (9)
SITE	**30.0**

Height. The average height of *C. brasiliense* was 4.7 m (SD = 1.9 m). The replants, at an age of nine years, averaged 3.5 m (SD = 1.7 m). Due to the variation among heights within each age group, no significant difference exists between them. The ANOVA was not conducted due to an insufficient sample size of original trees representing each family.

The relative slow growth of the species may indicate off-site conditions for *C. brasiliense*. Certainly, the species has been subjected to terminal stem die-back as a result of prolonged droughts in the Central Plateau. Table 4.32 summarizes the height growth of the species for both the original population (10 years) as well as the replants that are a year younger.

Table 4.32. Height growth *C. brasiliense* families at Marmont orchard. Numbers in parentheses indicate the mean heights of the 9-year old replants.

FAMILY	TEN-YEAR HEIGHT (m)
902	6.7 (3.4)
915	4.3 (6.6)
918	3.9 (3.3)
919	5.4 (2.8)
920	4.2 (3.1)
SITE	**4.7 (3.5)**

Trial Management Recommendations. There is no evidence that there are genetic difference in survival and height growth among *C. brasiliense* families. The orchard was not designed to test such differences, but to produce seed of a broader genetic base than usually harvested for this species.

The orchard trees are progeny selected from superior phenotypes, increasing the likelihood of desirable traits being expressed through seed harvested from the orchard. Since survival is low, the selection intensity for this orchard is low. The best management option is to maintain all families and select at the level of the individual tree in an attempt to balance the number of individuals per family. The culled individuals would be selected based on their position in the orchard in relation to the other families and their form compared with members within the family.

4.4 *Calophyllum brasiliense* at Paillant, Miragoâne

Background. This is the second *C. brasiliense* seed orchard in Haiti. In contrast to the deep clayey loam of the Marmont site, Paillant is a rocky site (red bauxitic soils overlaying calcareous rock) at a higher elevation (650 m). The site receives a higher amount of rainfall than Marmont though the skeletal soils lack moisture holding capacities.

The Paillant orchard was established two years later than the Marmont orchard along with several other orchards, provenance trials and an arboretum. The orchard contains four half-sib families, with only one that also occurs at the Marmont orchard. The origin of the *C. brasiliense* families is provided in Appendix 1 (Table 3).

Survival. The overall survival of *C. brasiliense* was 88% after ten years. The families ranged in survival rate between 72–96%. The relatively high survival rates reflects the moister site at Paillant.

Table 4.41. Survival of *C. brasiliense* families at Paillant orchard.

FAMILY	N	TEN-YEAR SURVIVAL (%)
901	24	96
904	24	96
920	18	72
923	22	88
SITE	**88**	**88**

Height. The orchard averaged 3.4 m after ten years. The ANOVA for the orchard showed highly significant differences among families for height growth (Pr = 0.00002). Family 923 is the clear winner in height growth over the other three families, as summarized in Table 4.42.

Table 4.42. Height growth of *C. brasiliense* families at Paillant orchard.

FAMILY	N	TEN-YEAR HEIGHT (m)
923	22	4.3 a
920	18	3.4 b
904	24	3.1 b
901	24	2.7 b
SITE	**88**	**3.4**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.00002.

Assuming that approximately eight trees would be selected in each family for seed production, an analysis was conducted of the eight tallest trees in each family. (*These may not necessarily be the actual trees selected due to their form or position within the orchard that would optimize cross pollination rates*). The ANOVA showed a significant family effect (Pr = 0.00017) as summarized in Table 4.43.

Table 4.43. Height growth of the eight tallest members of *C. brasiliense* families at Paillant orchard.

FAMILY	N	TEN-YEAR HEIGHT (m)
923	8	5.0 a
920	8	4.4 ab
904	8	4.1 bc
901	8	3.3 c
SITE	**32**	**4.2**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.00017.

Trial Management Recommendations. Though significant differences are shown in height growth, even among the dominant trees, this is not considered sufficient to warrant the elimination of the poorer performing families due to the small number of families represented in the orchard. However, the trial should be thinned immediately at the individual tree level to provide ample light and soil nutrient resources to the remaining trees.

Since each family is represented by a fairly large number of individuals, the selection intensity is much greater than at the Marmont orchard. At least half of the trees should be culled from the orchard, depending on the desired density at which reproductive maturity occurs. As noted above, the trees that are selected for seed production should optimize the possibility of cross pollination and form considerations. Resistance to high winds, pests and diseases are additional factors to consider in the selection of individuals that remain in the orchard. Fertilizer should be considered for greater orchard productivity.

4.5 *Catalpa longissima* at Roche Blanche, Croix-des-Bouquets

Background. This is the largest *C. longissima* seed orchard in Haiti. It is also true that it is the largest known orchard in the entire native range of the species. The orchard was established in 1988, originally with 18 half-sib families that were being tested elsewhere in Haiti as progeny trials. In 1989, the orchard was expanded to include an additional 36 half-sib families and three bulk seed lots collected from throughout the country. The origin of the families and bulked seed lots is provided in Appendix 1 (Table 5).

The original portion of the orchard was monitored throughout a ten year period. However, the expanded part of the orchard was monitored only up to three years. The reason for not monitoring this portion of the orchard thereafter is unclear, except that possibly the trees did not fare as well in terms of both survival and growth and thus were not considered as important to measure.

Survival. The overall survival of the original 18 families was 87% after ten years. Survival was generally uniform, with no family falling below 70% survival. Several families achieved 100% survival after ten years. The three-year survival rate of the expanded portion of the trial was 84%. Survival among families ranged from 56–100%. A summary of the survival rates is provided in Table 4.51.

Table 4.51. Survival rates of original and expanded portions of *C. longissima* orchard at Roche Blanche. Age of the original portion is ten years; age of the expanded portion was three years when measurements terminated.

ORIGINAL		EXPANDED			
FAMILY NO.	**SURVIVAL (%)**	**FAMILY NO.**	**SURVIVAL (%)**	**FAMILY NO.**	**SURVIVAL (%)**
103	80	102	88	146	75
104	100	107	100	148	88
105	100	109	78	149	75
106	90	112	88	150	88
107	90	114	100	151	100
108	90	115	83	155	89
110	80	116	89	158	71
111	80	119	100	160	89
114	80	122	88	161	89
117	100	127	63	163	100
118	70	128	100	174	89
120	80	129	88	177	86
121	80	131	88	178	86
123	90	132	100	181	88
124	80	134	100	185	75
125	100	136	100	188	100
159	70	137	100	1271	50
169	100	138	56	2101	80
SITE	**87**	140	71	2213	89
		143	100	**SITE**	**84**

Height. The ten-year height growth of the original portion of the orchard averaged 8.9 m. There was no family effect (Pr = 0.2197), though the family means ranged between 7.6–10.3 m. The expanded portion of the trial averaged 1.2 m after three years with the range in family means remarkably uniform. The slow growth of the latter portion of the orchard suggests why this portion was abandoned for measurement. Table 4.52 summarizes the height growth of the *C. longissima* orchard at Roche Blanche.

Table 4.52. Height of original and expanded portions of *C. longissima* orchard at Roche Blanche. Age of the original portion is ten years; age of the expanded portion was three years when measurements terminated.

ORIGINAL		EXPANDED			
FAMILY NO.	HEIGHT (m)	FAMILY NO.	HEIGHT (m)	FAMILY NO.	HEIGHT (m)
103	9.2	102	1.4	146	1.2
104	8.7	107	1.3	148	1.2
105	9.7	109	1.3	149	1.1
106	8.8	112	1.1	150	1.1
107	8.9	114	1.4	151	1.1
108	8.3	115	1.1	155	1.4
110	8.2	116	1.2	158	1.4
111	8.9	119	1.1	160	1.3
114	9.4	122	1.2	161	1.5
117	9.5	127	0.8	163	1.1
118	8.2	128	1.3	174	1.2
120	8.4	129	1.2	177	1.0
121	10.3	131	1.2	178	1.1
123	9.0	132	1.0	181	1.1
124	9.0	134	1.1	185	1.3
125	7.6	136	1.5	188	1.2
159	8.5	137	na	1271	1.4
169	8.7	138	1.6	2101	1.4
SITE	**8.86**	140	1.3	2213	1.2
		143	1.2	**SITE**	**1.22**

Merchantable Volume Index. The MVI of the original orchard families showed a significant family effect (Pr = 0.0398), though the Tukey Test did not detect differences among family means due to the unbalanced design. The MVI of the expanded orchard was not calculated since the trees were not developed sufficiently at three years. Table 4.53 summarizes the MVI values of the original portion of the orchard.

Table 4.53. Merchantable volume index of orchard families after ten years at Roche Blanche.

FAMILY NO.	MVI (x 10^{-2} m^3)	FAMILY NO.	MVI (x 10^{-2} m^3)
103	15.8 a	118	8.2 a
104	7.2 a	120	9.8 a
105	17.3 a	121	14.3 a
106	6.8 a	123	9.2 a
107	11.4 a	124	11.3 a
108	8.1 a	125	5.4 a
110	5.6 a	159	4.6 a
111	12.5 a	169	12.9 a
114	10.8 a	**SITE**	**10.1**
117	9.6 a		

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0398.

Trial Management Recommendations. The large genetic base, relatively fertile site conditions and long-term institutional stability of Double Harvest make this a valuable seed orchard. No evidence supports that the families represented in orchard are different in adaptability at this site. Therefore, the trial should be silviculturally managed in a manner consistent with the optimal production of fruit. Thinning individuals at the family level should proceed as necessary by comparing all individuals within the same family and selecting the best combination of form, vigor and crown balance. Position within orchard is less important since the families have equal chance of occurring next to non-related families. If on the basis of progeny trials certain families emerge as being genetically superior, these families can be tagged and harvested for their seed separately from the bulked seed. Fertilizing and care of the slower growing expanded portion of the orchard should proceed immediately in order to maintain a broad genetic base of one of the most important timber species in Haiti.

4.6 *Eucalyptus camaldulensis* and *E. tereticornis* at Marmont, Hinche

Background. This is a small orchard comprised of the progeny of advanced generations of selection in Haiti. Progeny of three *E. camaldulensis* trees and one *E. tereticornis* tree, selected for superior form and fast growth, are represented in the orchard. The parent trees were themseleves a result of advanced selected during the 1980s by Double Harvest (Appendix 1, Table 9). The orchard was established along with other orchards and an arboretum in 1990. Each family was originally represented by 14 trees randomly allocated in a design to maximize cross pollination among families.

The site is typical of the Central Plateau with deep clayey loam formerly covered with the invasive *madam michel* grass or a mix of hardwoods dominated by *Swietenia mahagoni* and legumes. The lengthy droughts that periodically hit the region favor *Eucalyptus* spp. and their high water/nutrient efficiencies when compared with most other tree species.

Survival. The orchard averaged a survival rate of 82% after ten years. The three families of *E. camaldulensis* had survival rates of 100% (52), 93% (58), and 93% (66). The *E. tereticornis* family exhibited a survival rate of 43%.

Height. Average height of the orchard was 10.3 m after ten years. The ANOVA showed a significant family effect (Pr = 0.00078). The Tukey Test showed the best family, 52 (❹ = 12.2m) was significantly different from the other three families: 58 (❹ = 9.6 m), 66 (❹ = 9.8 m) and 76 (❹ = 8.0 m).

Merchantable Volume Index. The average MVI for the orchard was 9.2 x 10^{-2} m^3. As in the case of height, the ANOVA showed a significant family effect (Pr = 0.00073). The Tukey Test showed the best family, 52 (❹ = 17.1 x 10^{-2} m^3) was significantly different from the other three families: 58 (❹ = 5.7 x 10^{-2} m^3), 66 (❹ = 5.8 x 10^{-2} m^3) and 76 (❹ = 5.0 x 10^{-2} m^3).

Trial Management Recommendations. It is tempting to discard the superiority of family 52 in order to maintain a broader genetic base of *E. camaldulensis* for seed production. But given the introduced nature of the species and the rapidity to make genetic improvement by a narrow selection, the best option would be to eliminate the three families that are inferior in both height and wood volume production. Family 52 would then be selected for the dominant trees of its genotype for seed production. *E. camaldulensis* is sufficiently variable, even with a single family line, to be of little consequence in the field where pests and diseases have yet to make an economic impact. The species is non-invasive and generally harvested through coppice rotations before subsequent planting from seedlings is necessary.

4.7 *Eucalyptus camaldulensis* and *E. tereticornis* at Terrier Rouge

Background. This small orchard is comprised of same four families as represented at the Marmont orchard (Appendix 1, Table 9). An additional *E. camaldulensis* control was tested, but all the trees died within the first six months of the trial and are not included in the analyses below. The design of the trial is complete randomization of single-tree plots.

The site is a semi-arid site in northeast Haiti. The soil is unique with quartz gravel, resembling a lateritic soil that is uncommon in Haiti. The rainfall season is also peculiar in that rains fall later into the winter than in other regions of Haiti. As such, the trials at this site are unique and potentially important for the selection of genotypes suitable for reforestation in this area of Haiti.

Survival. Overall survival of the orchard was 43% after ten years. Most of the mortality occurred during the first six months following orchard establishment. A lengthy drought during this period was responsible for the poor survival results.

The best performing family, *E. camaldulensis* 52, achieved the highest survival rate of 72%. This was followed by 44% (*E. tereticornis* 76), 33% (*E. camaldulensis* 58) and 22% (*E. camaldulensis* 66).

Height. The orchard averaged 11.6 m in total height growth after ten years. The ANOVA detected a significant family effect (Pr = 0.0072). The results of the Tukey Test show a significant difference between the top family, *E. camaldulensis* 52 (12.4 m) and the bottom family, *E. tereticornis* 76 (9.9 m). The means of the middle two families (*E. camaldulensis* 58 - 11.7 m and *E. camaldulensis* 66 - 10.9 m) are no different from the top and bottom families.

Merchantable Volume Index. The orchard averaged 18.1 x 10^{-2} m^3. As in case of height, the ANOVA detected a family effect (Pr = 0.0147). Results of the Tukey Test showed the top family, 52 (25.1 x 10^{-2} m^3) as different from the bottom family, 76 (7.7 x 10^{-2} m^3). The means of the two middle families (No. 58 – 12.1 x 10^{-2} m^3 and No. 66 – 16.5 x 10^{-2} m^3) are no different from the top and bottom families.

Trial Management Recommendations. This orchard confirms the dominance of family 52 that is also superior at the Marmont orchard. While it has been recommended to eliminate all families *except* family 52 at Marmont, it is recommended to eliminate only *E. tereticornis* 76 at the Terrier Rouge orchard. The principle reason for this is that family 66 shows a respectable MVI relative to its mean height and family 58 has a mean height that is slightly below family 52, but not considered different.

The results of rogueing will leave three family lines of *E. camaldulensis*. The individuals of each family should than be compared with each other for thinning purposes. Since families 58 and 66 have fewer individuals than family 52, fewer individuals should be thinned in order to attempt to balance the representation of each family. However, the optimal density for fruit production should determine the number of individuals represented per family.

4.8 *Senna siamea* at Marmont, Hinche

Background. This orchard is comprised of progeny from 13 plus trees selected throughout Haiti for form and vigor (Appendix 1, Table 13b). *S. siamea* is an introduced species to Haiti and likely of narrow genetic base, though periodic introductions over a 50-year period is believed to have moderately broadened the gene pool.

The design of the orchard is randomized location of single-tree family plots. The number of replications ranged from 5–17 per family. Site conditions are similar to those described for the other trials at Marmont.

Survival. A survival rate of 61% was achieved for the orchard during the ten-year period. Rates ranged from 17–86%, as summarized in Table 4.81.

Table 4.81. Survival rates of *S. siamea* families after ten years at Marmont orchard.

FAMILY	SURVIVAL (%)	FAMILY	SURVIVAL (%)
573	50	580	44
574	67	581	86
575	80	582	56
576	40	583	56
577	75	588	50
578	71	589	33
579	17	**SITE**	**72**

Height. The average height of the orchard was 7.3 m after ten years. The ANOVA for the trial did not detect family differences (Pr = 0.3419). A summary of the family means is provided in Table 4.82.

Table 4.82. Height of *S. siamea* families after ten years at Marmont orchard.

FAMILY	HEIGHT (m)	FAMILY	HEIGHT (m)
573	8.7	580	8.1
574	6.9	581	7.9
575	7.1	582	8.3
576	8.1	583	6.5
577	7.7	588	7.0
578	6.4	589	7.7
579	6.9	**SITE**	**7.30**

Biomass Index. The square of the stem diameter at breast height (1.3 m above ground) was used as an index for biomass. The ANOVA for this parameter showed no family effect (Pr = 0.3982), as in the case for height.

Trial Management Recommendations. There is no statistical evidence that family effects are influencing growth parameters. Due to the design of the orchard, survival means cannot be tested for differences. The trial should maintain all families to maximize the genetic base. Individuals within the same family should be compared and selected based on their form and other desirable traits in agroforestry. The orchard should be thinned of individuals that are inferior within their family in order to provide space to neighboring dominant and co-dominant trees. An attempt should be made to balance family representation and to improve fruit production through fertilization and pruning.

4.9 *Senna siamea* at Terrier Rouge

Background. This orchard is comprised of the progeny of four plus trees selected for form and vigor (Appendix 1, Table 13b). The orchard design consists of randomly located single-tree plots with 20 replications.

Site conditions are similar to those described for the *Eucalyptus camaldulensis* orchard (see 4.7). The results of this trial were not published when provenance trials of *S. siamea* established in other areas of Haiti were evaluated at the five-year stage (Timyan et al., 1996).

Survival. The average survival rate of the orchard was 75% after ten years. Family means were 75% (580), 95% (582), 75% (583) and 55% (588).

Height. Total height averaged 8.3 m. The ANOVA for the trial showed no difference among family means (Pr = 0.7314). Family means were 8.6 m (580), 8.2 m (582), 8.2 m (583) and 8.2 m (588).

Biomass Index. Stem diameter squared was used as an index for wood biomass. The ANOVA did not show any difference among the family means for this parameter.

Trial Management Recommendations. There is no evidence that family effects play a role in the differences shown in growth. The trial was not designed to test differences among families for survival.

All families should remain in the orchard. All the trees of each family should be compared together in order to select the superior trees based on form and other desirable criteria (e.g., vigor, wind resistance, pest and disease resistance). Inferior trees and co-dominants should be thinned from the orchard to allow the superior trees to develop as rapidly as possible. Ample space should be given the final selection so that seed production is optimized for the next five years.

4.10 *Simarouba glauca* and *S. berteroana* at Roche Blanche, Croix-des-Bouquets

Background. These two closely-related species were established on adjacent sites at Roche Blanche. *S. glauca* is the more commonly utilized species and considered economically more important than *S. berteroana*. Though the two species overlap in their distribution, *S. glauca* is found in the humid or wet forests, whereas *S. berteroana* is generally found in sub-humid areas experiencing greater drought. The availability of seed for both species is critical due to the relatively short fruiting season, low storage capacity of the seed and the variability of site conditions that favor one species over another.

The Roche Blanche contains two orchards: one representing 20 half-sib families of *S. glauca* and one representing four half-sib families of *S. berteroana*. A summary of the plus tree parents is provided in Appendix 1 (Table 14). The fact that *S. berteroana* contains so few families reflects the uncommon nature of the species combined with the standards by which the plus trees were selected. Each family in the orchard is represented by ten individuals randomly located to maximize the probability of outcrossing among neighbors of non-related families. It should be noted that both species are dioecious (male-flowered and female-flowered trees are separate). Combining abilities and the effect of sexuality on genetic gain is uncertain.

Survival. *S. glauca* averaged 55% survival after ten years and *S. berteroana* averaged 60% survival. These differences are not significant (Pr = 0.7033).

Two *S. glauca* families are represented by a single individual and an additional two families are represented by two individuals. Thus, there is a possibility that the orchard lacks female trees (and seed potential) for these families. Table 4.101 summarizes the effects of survival on the proportion of the orchard represented by each family. Replanting within six months of orchard establishment was not included to calculate survival though it is reflected in the current family representation. Considering canopy dominance and thinning, the final family representation will lie somewhere between an equitable distribution (5%) and the percentages shown in Table 4.101.

Table 4.101. Survival and representation of *S. glauca / S. berteroana* families at Roche Blanche, Haiti.

FAMILY	TEN-YEAR SURVIVAL (%)	PERCENTAGE OF ORCHARD
	Simarouba glauca	
204	70	6.4
210	30	2.4
211	10	0.8
213	50	4.8
216	50	4.0
217	10	0.8
219	60	5.6
220	60	6.4
227	80	6.4
228	60	6.4
230	80	6.4

FAMILY	TEN-YEAR SURVIVAL (%)	PERCENTAGE OF ORCHARD
232	20	1.6
237	10	1.6
247	50	6.4
248	90	7.9
250	80	6.4
252	70	6.4
253	60	6.4
256	90	7.1
257	60	6.4
ORCHARD	**55**	**100**
	Simarouba berteroana	
263	50	25.0
264	70	32.1
266	30	10.7
267	90	32.1
ORCHARD	**60**	**100**

Height. Ten-year height growth was analyzed for the 20 *S. glauca* families. Though the ANOVA detected differences among height means (Pr = 0.0490), the Tukey Test indicated that these differences were not significant. The primary cause of these statistical results is the unbalanced nature of the trial, resulting in a higher critical difference value for means comparison.

The same analyses were conducted for the *S. berteroana* families. The ANOVA showed insignificant results (Pr = 0.8164) and the Tukey Test was not conducted. The height means for the families of both species is summarized in Table 4.102.

A difference was shown between the mean height of *S. glauca* (8.9 m) and the mean height of *S. berteroana* (9.6 m) at a probability level of 0.0133.

Table 4.102. Height and merchantable volume index of *S. glauca* / *S. berteroana* families at Roche Blanche, Haiti after ten years.

FAMILY	TEN-YEAR HEIGHT (m)	TEN-YEAR MVI (x 10^{-2} m^3)
	Simarouba glauca	
204	8.5	7.0
210	7.6	2.4
211	10.1	8.6
213	8.4	4.6
216	8.8	5.6
217	9.5	6.7
219	8.3	5.2
220	9.4	11.4
227	9.1	7.6
228	9.0	7.8
230	8.5	7.9
232	8.9	12.2
237	9.5	5.0
247	9.6	9.3
248	9.9	11.4

FAMILY	TEN-YEAR HEIGHT (m)	TEN-YEAR MVI (x 10^{-2} m^3)
250	8.3	4.2
252	8.6	8.2
253	9.4	9.4
256	8.7	6.2
257	10.1	13.5
ORCHARD	**8.9**	**7.7**
	Simarouba berteroana	
263	9.0	8.8
264	9.7	7.4
266	9.7	9.3
267	9.7	8.0
ORCHARD	**9.6**	**8.1**

Merchantable Volume Index. MVI exhibited considerably more variance than height for *S. glauca*. Though the ANOVA detected a significant family effect (Pr = 0.0269), the Tukey Test did not show a difference at a = 0.05. The ANOVA showed no differences in MVI among the *S. berteroana* families (Pr = 0.9640). The distribution of MVI among *S. glauca* and *S. berteroana* families is shown in Figure 4.4. Assuming MVI is the best indicator of form, the scatter plot does not suggest a family effect.

The difference between the mean MVI of *S. glauca* (7.2 x 10^{-2} m^3) and *S. berteroana* (8.1 x 10^{-2} m^3) was not significant (Pr = 0.7559).

Trial Management Recommendations. This is probably the largest genetic base of *S. glauca* at one site in Haiti. Regarding the large variations shown among *S. glauca* families for MVI, the following steps should be implemented to upgrade the orchard.

1) DO NOT ROGUE (eliminate at the family level). Select at the individual level and attempt to balance the number of individuals representing each family in the orchard. Since five families are represented by three or less individuals, all the trees of these families should be conserved and pruned.
2) Cull (remove) the poorest phenotypes to provide the space necessary to develop the canopies for flower production. While it is preferable to cull male-flowered individuals, co-dominate female-flowered genotypes may have to be removed in order to optimize fruit production.
3) Maintain family representation, select superior phenotypes, and maximize the probability of outcrossing among neighboring families.

4.11 *Swietenia mahagoni, S. macrophylla*, and *S. mahagoni* x *S. macrophylla* hybrid orchard at Marmont, Hinche

Background. The mahogany orchard at Marmont was established in 1990 along with several other orchards and an arboretum. The site is typical of the Central Plateau with deep clayey soils and a mixed grassland/forest dominated by the native West Indian mahogany, *S. mahagoni*. Results of the orchard after five years are reported in Timyan et al. (1997). The hybrid exhibited the highest survival rates, followed by *S. mahagoni* and *S. macrophylla*. The latter species, requiring moist forest conditions, suffered the greatest rate of mortality. Though no differences were detected in height growth between the species, there was a difference in height growth among the *S. macrophylla* families. Height growth of the hybrid was no different than either the parent trees after five years.

The orchard is designed to produce mahogany hybrid seed, reputed for its drought tolerance, faster growth and trunk form that is superior to the native *S. mahagoni*. Though artificial pollination of the two parent species is possible, the two parent species hybridize naturally with hybrid seed harvested from *S. macrophylla* mother trees. Approximately a third of each species is represented in the orchard, with individual genotypes completely randomized as single tree plots.

The parent species represent plus trees selected throughout Haiti of *S. mahagoni* and the introduced *S. macrophylla*. The hybrid seed originated from the United States Forest Service plantations at Ponce, Puerto Rico, harvested from *S. macrophylla* mother trees naturally outcrossed with native *S. mahagoni*. Provenance information is provided in Appendix 1 (Table 15).

Survival. The ten-year survival of the species and families is summarized in Table 4.111. Comparing overall survival with the five-year results shows a slight decline of 3 %, with all the decline in survival attributed to the *S. macrophylla* families (11%).

Table 4.111. Five- and ten-year survival rates of *Swietenia* accessions at the Marmont orchard.

FAMILY	FIVE-YEAR SURVIVAL (%)	TEN-YEAR SURVIVAL (%)
	Swietenia mahagoni	
463	38.5	38.5
467	30.8	30.8
	S. macrophylla x *S. mahagoni* hybrid	
479	66.7	66.7
	Swietenia macrophylla	
482	66.7	0.0
483	33.3	33.3
486	0.0	0.0
487	0.0	0.0
489	66.7	66.7
493	50.0	50.0
494	50.0	25.0
497	50.0	50.0
ORCHARD	**45.1**	**42.3**

Height. The analysis of variance showed no significant differences in mean height among the three species (Pr = 0.6927). Due to mortality and damages to the trees, statistical analysis at the family level was not possible.

The overall mean of 4.3 m after ten years is only 0.9 m taller than the overall mean of 3.4 m after five years, indicating that die-back associated with severe drought had taken its toll on the orchard trees. The hybrid and *S. macrophylla* trees were particularly affected, with 45% and 40% of the trees showing a reduction in height during the 5–10 year period. In contrast, 11% of the *S. mahagoni* trees showed a reduction in total height. Table 4.112 summarizes the five- and ten-year heights of the orchard families.

Table 4.112. Five- and ten-year heights of *Swietenia* accessions at the Marmont orchard.

FAMILY	FIVE-YEAR HEIGHT (m)	TEN-YEAR HEIGHT (m)
	Swietenia mahagoni	
463	2.9	3.8
467	3.1	5.5
	S. macrophylla x *S. mahagoni* hybrid	
479	3.7	4.1
	Swietenia macrophylla	
482	NA	NA
483	NA	NA
486	NA	NA
487	NA	NA
489	2.3	6.9
493	4.2	4.2
494	4.1	3.7
497	2.5	4.0
ORCHARD	**3.4**	**4.3**

Stem Diameter. Stem diameters were squared for statistical analyses, since this parameter is a better indicator of wood volume. No significant differences were shown either at the species or family levels (Pr_{FAM} = 0.1089; Pr_{SP} = 0.7599) at the ten-year stage. Though reductions occurred in stem diameter among several trees (due to drought-induced die-back), the number of trees was less than in the case of total height. Table 4.113 summarizes the five- and ten-year stem diameter means among the orchard accessions.

Table 4.113. Five- and ten-year stem diameters of *Swietenia* accessions at the Marmont orchard.

FAMILY	FIVE-YEAR DIAMETER (cm)	TEN-YEAR DIAMETER (cm)
	Swietenia mahagoni	
463	2.8	4.8
467	2.6	8.4
	S. macrophylla x *S. mahagoni* hybrid	
479	3.8	5.5
	Swietenia macrophylla	
482	NA	NA
483	NA	NA
486	NA	NA
487	NA	NA
489	1.5	12.0
493	4.6	5.0
494	4.3	4.0
497	1.9	5.8
ORCHARD	**3.3**	**6.0**

Trial Management Recommendations. The orchard contains 43 trees with the potential of producing seed at the time that mahogany becomes reproductive. These trees are divided among the species as follows: 19 (*S. mahagoni*), 13 (*S. macrophylla* x *S. mahagoni* hybrid) and 11 (*S. macrophylla*). Since there is little evidence that genetic differences among accessions are significant, all accessions should remain in the orchard to maintain genetic diversity. Several factors should be considered when thinning the trial for optimal seed production.

- Age of species at flower production;
- Balance of species during flower production;
- Phenology of species, by family;
- Relationship of neighboring trees.

Ideally, the age of flower production will be approximately similar for the two parent species and the hybrid. Since the site is favoring *S. mahagoni* over the other two species, the best strategy would be to thin the poorest developed individuals of the native mahogany in order to balance the representation of the orchard. In the event that neither the hybrid nor the *S. macrophylla* appears well adapted to this Central Plateau site, the orchard should be converted to a pure *S. mahagoni* orchard. Wild trees of the same species occurring on site should be eliminated in order to prevent contamination by wind- and insect-pollination. This should be conducted regardless if the orchard remains as a hybrid seed production orchard or a pure *S. mahagoni* orchard.

5.0 Species/Provenance Trial

5.1 *Casuarina cristata* and *C. equisetifolia* at Lapila, Pignon

Background. This is a small trial that compares two sub-species of *C. equisetifolia* with *C. cristata.* The source of the germplasm is provided in Appendix 1 (Table 4). *C. equisetifolia* is perhaps the most common *Casuarina* in Haiti. Both species were introduced to Haiti for medium-grade wood uses, particularly poles and charcoal.

The site is located in the upper Central Plateau. Conditions are similar as described elsewhere in this report for Lapila. The design of the trial is a randomized block design, with four replications and 24-tree (8 x 3) plots of each species.

The trial was evaluated at five years and published in Béliard et al. (1996). Results showed that *C. equisetifolia incana* was significantly inferior to *C. cristata* in survival (65% vs. 89%) and stem diameter (3.3 cm vs. 5.0 cm). However, height means showed no statistiscal difference among the three species due to the high variability within species. While *C. equisetifolia equisetifolia* ranked the highest in height, *C. cristata* ranked the highest in stem diameters, indicating different form factors. Neither these differences were significant at the 0.05 probability level.

Survival. The overall survival rate of the trial was 68.8%, a loss of 10% since the 5-year stage. The ANOVA showed a significant species effect (Pr = 0.01846). The Tukey Test detected differences between the top survivor, *C. cristata* 1476 (81.3%), and poorest survivor, *C. equisetifolia incana* (52.3%) at the 0.05 probability level.

Height. The average height of the trial was 9.5 m after ten years. The ANOVA showed significant species effect (Pr =0.00002). The Tukey Test confirmed that *C. cristata* (10.3 m) and *C. equisetifolia equisetifolia* (9.5 m) were different from *C. equisetifolia incana* (8.2 m).

Merchantable Volume Index. The ANOVA of the MVI values also showed a significant species effect (Pr = 0.0001). However, only *C. cristata* (7.2×10^{-2} m^3) was different from *C. equisetifolia incana* (3.9×10^{-2} m^3). *C. equisetifolia equisetifolia* (5.5×10^{-2} m^3) was no different from the other two species.

Trial Management Recommendations. One of the recommendations cited in Bélaird et al. (1996) was to eliminate *C. equisetifolia incana* from the trial to avoid possible hybridization with *C. equisetifolia equisetifolia*. This was never implemented and *should be done at this time.* Ten year results support the conclusions that *C. equisetifolia incana* is inferior to the other *Casuarina* species available in Haiti. It is possible that *C. cristata* also naturally hybridizes with *C. equisetifolia*. Seed should not be collected from this trial until the identity of the parents can be confirmed.

The trial may not require thinning, though inferior and weak trees should be culled to keep the neighboring trees healthy. Long-term observations, particularly resistance to severe drought, high winds and pests/diseases, should continue. A nearby stand of *C. equisetifolia*, planted prior to this trial, exhibited die-back of uncertain causes after many years of superb growth.

5.2 *Leucaena leucocephala* at Lapila, Pignon

Background. This is one of two trials in Haiti testing *Leucaena leucocephala* subsp. *glabrata* varieties developed at the University of Hawaii. They are based on genetic improvement of the subspecies for a combination of fast growth and resistance to pests/diseases. The species is the most common one used to establish living hedgerows for soil conservation and soil fertility in Haiti.

The design of the trial is randomized block design, with four replications and 24 trees (8 x 3) per varietal plot. Site conditions are similar to the descriptions for the other trials at Lapila.

Survival. The overall survival of the trial was 76%. No differences occurred among varieties for survival at ten years (Pr = 0.4471). The highest surviving variety was 397 (87%), followed by 584 (78%), 636 (72%) and 605 (68%).

Height. Mean height growth for the trial was 7.2 m after ten years. No differences occurred among the varietal means for height (Pr = 0.2555). The tallest variety, 605 (7.4) was followed by 397 (7.3 m), 584 (7.1 m) and 636 (7.0 m).

Biomass Index. The square of stem diameter is used here as an indicator of biomass production. This differed significantly among varieties as summarized in Table 5.21. Variety 605 produced the greatest mean biomass index, 67.8 x 10^{-2} m^3 per tree, while 584 produced the least mean biomass index, 46.7 x 10^{-2} m^3 per tree.

Table 5.21. Biomass index of *Leucaena* varieties at Lapila.

VARIETY	BIOMASS INDEX (x 10^{-2} m^3)
605	67.8 a
636	57.4 ab
397	47.7 b
584	46.7 b
SITE	**54.0**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.023.

Trial Management Recommendations. Much research has been conducted to improve the productivity and pest resistance of *Leucaena*. This trial represents the culmination of over a decade of research by geneticist Dr. James Brewbaker at the University of Hawaii. The identity of the varieties may be important if a pest, such as a psyllid, becomes epidemic due to the relative homogeneity of the *Leucaena leucocephala glabrata* gene pool in Haiti.

No varieties should be eliminated from the trial. Since *L. leucocephala glabrata* genotypes are largely selfed, there should be little problem to continue collecting seed from the trial and to label it according to its respective variety. Since the varieties are very difficult to distinguish, the parent trees selected for seed production should be clearly labeled with aluminum tags to avoid confusion.

All varietal plots should be culled of inferior trees based on the selection of desirable traits. This may be a combination of form, wood yield, wind and pest resistance.

5.3 *Pinus* spp. at Viard, Kenscoff

Background. This is the only trial in Haiti that compares the performance of the *Pinus occidentalis* control with two provenances collected in the Dominican Republic. The species is endemic to the island of Hispaniola. The trial also compares the native pine with a wide range of commercially important pine species. The source of the *Pinus* accessions is provided in Appendix 1 (Table 12).

The trial was established in 1989 on the private property of Victor Wynne. Natural stands of *P. occidentalis* occur near the trial which is at an elevation of 1,400 m.

Five-year results of the trial were published in Timyan et al. (1996). There were no statistical differences among species and provenances in terms of survival at five years. The overall site survival rate was 80% with provenances ranging from 63–90%. Eleven provenances grew faster than the *P. occidentalis* control, led by four accessions acquired from the pine breeding program of the Zimbabwe Forestry Commission. These were *P. oocarpa* 15319, *P. taeda* 15169, *P. patula* 15275 and *P. khasya* 15212. An additional commercial seed lot, *P. taeda* 496, also ranked among the top five in terms of height growth. Eight provenances yielded a significantly higher merchantable volume index than the *P. occidentalis* control. The top five included *P. patula* 15275, *P. oocarpa* 15319, *P. tecunumanii* 7/77, *P. khasya* 15212 and *P. taeda* 496. There was a 3-fold difference in merchantable volume between the control and the best performing provenance, *P. patula* 15275.

The conclusions of the five year results were to eliminate the inferior provenances based on form and vigor: *P. caribaea caribaea, P. caribaea hondurensis, P. radiata, P. oocarpa* 497, *P. occidentalis* (Cuba), *P. khasya* 538, *P. caribaea bahamensis* 3/80 and 69(7296) and *P. occidentalis* 4/78 and 38/77. This was not accomplished due to the social conflicts between squatters and the land owner. It was reasoned that any culling of the trial would result in uncontrolled cutting of the remaining trees. Nonetheless, illegal harvesting and use of the land has continued despite efforts by the land owner to maintain control and minimize damages to the trees.

Survival. The overall survival of 59% at ten years shows an average annual mortality rate of 4% since trial establishment. The top three surviving provenances (*P. caribaea bahamensis* 3/80, *P. taeda* 496 and *P. taeda* 562) showed significant differences with *P. radiata.* The top provenances averaged 81% compared to the poor survival of *P. radiata* at 12.5%. The *P. occidentalis* control showed no difference in survival compared to the other species and provenances in the trials. Table 5.31 summarizes the survival means among provenances in this trial.

Table 5.31. Survival means of *Pinus* provenances and species after ten years at Viard.

Provenance	**Survival (%)**	**Provenance**	**Survival (%)**
P. car. bah 3/80	82 a	*P. khasya* 538	54 ab
P. taeda 496	82 a	*P. elliottii* 15441	53 ab
P. taeda 562	81 a	*P. car. hon.* 36/83	51 ab
P. oocarpa 15319	76 ab	***P. occidentalis* Control**	**51 ab**
P. taeda 1003	75 ab	*P. khasya* 15212	51 ab
P. car. bah. 69(7296)	75 ab	*P. occidentalis* 38/77	50 ab
P. car. hon. 17/85	74 ab	*P. car. hon.* 563	48 ab
P. car. bah. 1/79	69 ab	*P. tecunumanii* 7/77	46 ab
P. car. hon. 19/85	69 ab	*P. occidentalis* 4/78	44 ab
P. car. bah. 537	69 ab	*P. tecunumanii* 24/85	43 ab
P. car. hon. 20/85	67 ab	*P. car. car.* 15/83	42 ab
P. car. car. 9/76	65 ab	*P. oocarpa* 497	39 ab
P. patula 15275	65 ab	*P. elliottii* 561	25 ab
P. occidentalis 66(7293)	63 ab	*P. radiata* 1008	13 b
P. taeda 15169	61 ab	**SITE**	**59.0**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.01416

Height. The overall mean height of the trial was 8.77 m, with provenance means ranging between 5.1 m (*P. caribaea caribaea* 15/83) to 12.0 m (*P. oocarpa* 15319). The mean heights of the species and provenances are shown in Table 5.32.

Changes in rank between the five- and ten-year stages do not appear significant in terms of their statistical differences. The top and bottom ranked provenances at the five-year stage were the same at ten years. The control jumped in height rank from 12th to 8th, though no differences were shown among provenance means between the top ranks and the control. Much of the change in means is a result of the weaker individuals in the plot eventually dying, though the illegal harvesting of dominant trees may also affect the rank. It cannot be assumed that the provenances are being affected equally, since the better performing provenances would generally be targeted for selective harvests. Height distribution among provenances is shown in Figure 5.1.

Table 5.32. Mean height growth of *Pinus* species and provenances after ten years at Viard. Number in parentheses indicates height rank at five years.

Provenance	Height (m)	Provenance	Height (m)
P. oocarpa 15319 (1)	12.0 a	*P. elliottii* 15441(9)	8.8 abc
P. khasya 15212 (5)	11.1 ab	*P. car. hon.* 20/85 (16)	8.8 abc
P. khasya 538 (8)	11.0 ab	*P. taeda* 562 (13)	8.8 abc
P. tecunumanii 7/77 (6)	10.6 ab	*P. car. bah.* 1/79 (18)	8.5 abc
P. taeda 496 (3)	10.6 ab	*P. car. hon.* 36/83 (22)	8.4 abc
P. car. bah. 537 (10)	10.0 abc	*P. oocarpa* 497 (24)	7.7 abc
P. taeda 15169 (2)	10.0 abc	*P. radiata* 1008 (15)	7.4 abc
***P. occidentalis* Control (12)**	**9.9 abc**	*P. occidentalis* 66-7293 (19)	7.2 abc
P. patula 15275 (4)	9.7 abc	*P. occidentalis* 4/78 (26)	7.0 abc
P. car. bah 3/80 (11)	9.3 abc	*P. car. car.* 9/76 (25)	6.6 bc
P. taeda 1003 (7)	9.2 abc	*P. car. hon.* 19/85 (23)	6.6 bc
P. car. bah. 69-7296 (14)	9.2 abc	*P. elliottii* 561 (27)	5.8 bc
P. car. hon. 17/85 (20)	9.1 abc	*P. car. hon.* 563 (28)	5.8 bc
P. occidentalis 38/77 (21)	9.0 abc	*P. car. car.* 15/83 (29)	5.1 c
P. tecunumanii 24/85 (17)	9.0 abc	**SITE**	**8.77**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.00008.

Merchantable Volume Index. This section has been analyzed by two different methods. The first method calculates MVI based on all trees occurring in the plot, regardless of their status as dominant trees. The second method follows the method used in the 7-year data analyses in which the top six trees per plot were selected. This is equivalent to a density of 450 trees per hectare, suggested at the time as the desired density for thinning the trial. Such a selection biases the data in favor of the better performing provenances since inferior trees are eliminated from the analyses. However, such a selection would be recommended since selection would generally be in favor of the trees yielding the greatest volume of merchantable wood.

Table 5.33 summarizes the mean MVI values based on all trees. Significant changes in rank, such as *P. patula* 15275 that fell from 1st to 17th, are puzzling and warrant further investigation to determine the cause. Several trees of *P. patula* 15275 that were dominant at seven years are missing at ten years. These should be confirmed as being felled rather than having died of natural causes prior to further decisions regarding this provenance.

Table 5.33. Mean merchantable volume index (MVI) of *Pinus* provenances based on all trees in plot. Numbers in parentheses indicate the 7-year rank based on the mean MVI of the dominant trees.

Provenance	**MVI (x 10^{-2} m^3)**	**Provenance**	**MVI (x 10^{-2} m^3)**
P. oocarpa 15319 (2)	26.1 a	***P. occidentalis* Control (17)**	**11.3 abc**
P. khasya 15212 (4)	24.2 ab	*P. patula* 15275 (1)	11.1 abc
P. taeda 496 (5)	19.9 abc	*P. taeda* 562 (14)	10.4 abc
P. tecunumanii 7/77 (3)	19.3 abc	*P. elliottii* 15441 (19)	9.0 abc
P. car. bah 3/80 (6)	19.0 abc	*P. occidentalis* 38/77 (24)	8.1 abc
P. car. hon. 17/85 (8)	16.9 abc	*P. oocarpa* 497 (21)	7.7 abc
P. khasya 538 (10)	16.8 abc	*P. car. car.* 9/76 (22)	7.2 abc
P. car. bah. 69-7296 (9)	15.5 abc	*P. car. hon.* 19/85 (20)	6.2 bc
P. car. hon. 20/85 (7)	15.1 abc	*P. occidentalis* 66-7293 (26)	4.9 bc
P. taeda 1003 (11)	15.0 abc	*P. car. hon.* 563 (25)	4.4 abc
P. tecunumanii 24/85 (12)	13.9 abc	*P. radiata* 1008 (23)	4.3 abc
P. car. hon. 36/83 (18)	13.3 abc	*P. occidentalis* 4/78 (28)	3.4 c
P. car. bah. 537 (13)	13.1 abc	*P. car. car.* 15/83(29)	2.9 c
P. taeda 15169 (15)	12.1 abc	*P. elliottii* 561 (27)	2.6 bc
P. car. bah. 1/79 (16)	11.6 abc	**SITE**	**12.24**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.0003.

The analysis of avergae dominant MVI is summarized in Table 5.34. Generally, the rank changes are not significantly different from those shown in Table 5.33. The most notable changes since seven years was the loss in rank of *P. patula* 15275 and *P. tecunumanii* 24/85 and the gain in rank of *P. caribaea bahamensis* 3/80 and *P. taeda* 1003. These should be investigated as to the possible causes for this shift. A comparison of MVI values is shown in Figure 5.2.

Table 5.34. Mean merchantable volume index (MVI) of *Pinus* provenances based on dominant trees per plot. Numbers in parentheses indicate the 7-year rank based on the mean MVI of the dominant trees.

Provenance	**MVI (x 10^{-2} m^3)**	**Provenance**	**MVI (x 10^{-2} m^3)**
P. oocarpa 15319 (2)	39.7 a	*P. taeda* 15169 (15)	17.4 abcd
P. car. bah 3/80 (6)	39.2 ab d	***P. occidentalis* Control (17)**	**16.7 abcd**
P. taeda 496 (5)	35.7 abc	*P. tecunumanii* 24/85 (12)	16.3 abcd
P. khasya 15212 (4)	33.8 abcd	*P. elliottii* 15441 (19)	13.3 abcd
P. car. hon. 17/85 (8)	27.8 abcd	*P. occidentalis* 38/77 (24)	12.6 abcd
P. tecunumanii 7/77 (3)	27.0 abcd	*P. car. hon.* 19/85 (20)	12.3 abcd
P. taeda 1003 (11)	26.2 abcd	*P. car. car.* 9/76 (22)	12.0 abcd
P. car. hon. 20/85 (7)	26.0 abcd	*P. oocarpa* 497 (21)	10.6 abcd
P. car. bah. 69-7296 (9)	24.8 abcd	*P. occidentalis* 66-7293 (26)	8.0 cd
P. car. bah. 537 (13)	23.6 abcd	*P. car. hon.* 563 (25)	7.0 abcd
P. khasya 538 (10)	23.0 abcd	*P. car. car.* 15/83(29)	6.0 bcd
P. car. bah. 1/79 (16)	20.3 abcd	*P. occidentalis* 4/78 (28)	5.0 d
P. car. hon. 36/83 (18)	20.0 abcd	*P. radiata* 1008 (23)	4.3 cd
P. taeda 562 (14)	18.4 abcd	*P. elliottii* 561 (27)	3.2 cd
P. patula 15275 (1)	17.5 abcd	**SITE**	**19.59**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05. Pr = 0.00008.

Trial Management Recommendations. The trial is not being managed adequately to express the wood value potential of the species and provenances at the individual tree level. The culling and thinning that was recommended based on the analysis at five and seven years was never implemented. This is an unfortunate circumstance of social factors that are inhibiting preferred silvicultural interventions. As the trial now stands, it is more a botanical exhibit of different *Pinus* species and provenances forced into a model of "agroforestry" that may not be compatible to an optimal production of wood value.

Nevertheless, the trial has considerable scientific and technical value. It is the only pine trial in Haiti that has been monitored for ten years and includes a sufficiently broad genetic base to examine adaptability. The same species and provenances that were recommended for elimination at seven years should be discarded as candidates for reforestation: *P. radiata, P. caribaea caribaea,* the *P. occidentalis* from Cuba (66-7293) and the poorest performing provenances of *P. elliotii, P. caribaea hondurensis, P. oocarpa* and *P. tecunumanii*. The best option would be to eliminate all species that fall below the mean dominant MVI of the control, *P. occidentalis* 6666, as shown in Table 5.34. This would leave 17 species and provenances for long-term evaluation.

The different species and provenances should be marked with aluminum nails and tags in order to preserve their genotypic value. No seed should be collected from the trial due to the possibility of hybridization. If seed of selected provenances are required for reforestation purposes, then these should be procured from the original sources. Seed from tree improvement programs, such as the Zimbabwe Forestry Commission, are recommended instead of purchasing seed from commercial seed brokers. The latter are untested in Haiti, often lack pedigree information and of questionable genetic quality.

The farmers that are using the land for agricultural purposes should be engaged by the land owner to preserve the best specimens of each provenance and species to monitor their resistance to natural factors such as hurricanes, pests and diseases. This will require incentives that are the responsibility of the landowner.

5.4 *Swietenia humilis* and *S. macrophylla* at Bérault, Torbec

Background. This species trial is comparing two provenances each of two introduced mahogany species. While *S. macrophylla* or big-leaf mahogany has been widely planted throughout Haiti since the 1940s, *S. humilis* was first introduced to Haiti as a result of two trials, including this trial in 1988.

The absence of the native *S. mahagoni* in the trial is due to the site conditions being wetter than those typically found where the species occurs in Haiti. Site parameters are similar to those of the *Cordia alliodora* and *Cedrela odorata* trials also analyzed in this report. The trial is in the floodplain of a ravine that is periodically flooded during the rainy season. Boulders and gravel are strewn atop alluvial silty loam that is well-drained and remains moist for a large part of the growing season.

The design of the trial is a randomized complete block design, originally with three replications of 18-tree species plots. Only two replications were analyzed in this trial since the third replication of each species was eliminated as a result of high mortality on extremely rocky terrain exacerbated by periodic invasion of livestock destroying what seedlings remained. Each species is represented by two provenances native to Costa Rica (Appendix 1, Table 16).

The five-year results reported in Timyan et al. (1996) showed no difference in survival, height or merchantable volume index among provenances or species. The only difference was between the mean stem diameter of *S. humilis* 2470 (11.6 cm) and *S. macrophylla* 2469 (9.0 cm). Apparently this difference was not great enough for a difference to be detected among merchantable volumes.

Survival. The overall survival of the trial is 56%. *S. humilis* achieved a higher survival rate (65%) than *S. macrophylla* (48%), though these differences are not considered significant (Pr = 0.4339). The ANOVA did not detect differences among the provenance means (Pr = 0.8751). A summary of survival after ten years is provided in Table 5.41.

Table 5.41. Survival of *S. humilis* and *S. macrophylla* at Bérault after ten years.

SPECIES	SURVIVAL (%)
S. humilis 734	72
S. humilis 2470	58
S. macrophylla 1982	50
S. macrophylla 2469	45
SITE	**56.1**

Height. The average total height was 10.7 m. The ANOVA showed significant differences among provenance means (Pr = 0.0260). The top performer was *S. humilis* 2470 and the worst performer was *S. humilis* 734. Both *S. macrophylla* provenances grew at an average rate that fell between the two *S. humilis* provenances. The summary of the Tukey Test results is provided in Table 5.42.

Table 5.42. Height of *S. humilis* and *S. macrophylla* at Bérault after ten years.

SPECIES	HEIGHT (m)
S. humilis 2470	11.6 a
S. macrophylla 1982	11.2 ab
S. macrophylla 2469	10.4 ab
S. humilis 734	9.7 b
SITE	**10.7**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.

Merchantable Volume Index. The average MVI for the trial was 9.8×10^{-2} m^3. The ANOVA for the trial detected no difference among provenance means for MVI (Pr = 0.2478). The summary of the provenance means is provided in Table 5.43.

Table 5.43. Merchantable volume index of *S. humilis* and *S. macrophylla* at Bérault after ten years.

SPECIES	MVI (x 10^{-2} m^3)
S. humilis 2470	10.8 a
S. macrophylla 1982	11.8 a
S. macrophylla 2469	8.6 a
S. humilis 734	8.1 a
SITE	**9.8**

Means followed by the same letter are not considered different by the Tukey Test, a = 0.05.

Trial Management Recommendations. The lack of significant differences among provenance means for MVI indicates that there are select trees available for seed production of each provenance. Both provenances of each species should be preserved in the trial, with the inferior individuals culled to create space for the optimal development of the select trees. Flowering between species should be monitored in order to evaluate the possibility of hybridization, especially if the goal is to produce seed true to species and provenance. The alternative would be to order seed from the CATIE tree improvement program in Costa Rica once it has been determined which species and provenance is best adapted to site conditions similar to Bérault. Long-term observations should include resistance to high winds and various borers, especially the mahogany shoot borer (*Hypsipyla grandella*).

References

Béliard, C. A., L. Verret, J. C. Timyan and Y. Elie. 1996. Essai comparatif d'espèces de *Casuarina* spp. à Lapila (Pignon), Haiti : résultats après cinq ans de croissance. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

_________. 1996. Résultats de croissance de provenances de *Cedrela odorata* après cinq ans en Haiti. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

_________. 1996. Essais de provenances de *Corida alliodora* en Haïti : résultats après cinq ans de croissance. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

_________. 1996. Résultats de croissance de provenances de *Enterolobium cyclocarpum* après cinq ans en Haiti. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

Timyan, J. C. 1999. Management Plan for Improved Tree Seed Production from Orchards and Progeny/Provenance Trials in Haiti. Pan American Development Foundation, Port-au-Prince.

Timyan, J. C., L. Verret, Y. Elie, and C. A. Béliard. 1996. Five year results of the *Pinus* trial near Kenscoff, Haiti. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

Timyan, J. C., L. Verret, C. A. Béliard, and Y. Elie. 1996. Five year results of *Senna siamea* trials in Haiti. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

Timyan, J. C., Y. Elie, C. A. Béliard, and L. Verret. 1997. Haitian Oak (*Catalpa longissima* (Jacq.) Dum. Cours.) Seed Orchards and Progeny Trials in Haiti : 1988–1996. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

Timyan, J. C., L. Verret, C. A. Béliard, and Y. Elie. 1997. Five year results of a neem (*Azadirachta indica*) Trial at Roche Blanche, Haiti. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

Timyan, J. C., L. Verret, Y. Elie, and C. A. Béliard. 1997. Mahogany (*Swietenia*) Trials in Haiti: 1989–1996. SECID/Auburn University Productive Land Use Project, USAID, Port-au-Prince.

APPENDIX 1. SOURCE INFORMATION OF THE PROVENANCES AND FAMILIES CITED IN THIS STUDY.

Table 1. Origin of *Acacia auriculiformis* accessions at Lapila, Sapatè and Terrier Rouge. **CS** = CSIRO (Australia). Numbers in parentheses indicate number of mother trees represented by each accession.

FAMILY/ PROV. NO.	LOCALITY	ALT (m)	LATITUDE	LONGITUDE
541 (1)	*ex* Thomonde	300	19° 00' N	71° 57' W
542 (1)	*ex* Thomonde	290	19° 01' N	71° 58' W
548 (1)	*ex* Casse, Lascahobas	230		
552(1)	*ex* Thomonde	290	19° 00' N	71° 57' W
553(1)	*ex* Casse, Lascahobas	235		
CS 15697 (9)	S. of Coen Cape, York, QLD, Australia			
CS 15985 (10)	Mount Molloy R., Fleck, QLD, Australia			
CS 16107 (15)	Old Tonda Village, Papua New Guinea			
CS 16142 (7)	Coen River, QLD, Australia			
CS 16152 (10)	E. Alligator River, NT, Australia			
CS 16160 (10)	S. Alligator River, NT, Australia			
CS 16355 (15)	Bensbach, W. Province, Papua New Guinea			
CS 16484 (6)	Morehead River, QLD, Australia			
CS 16607 (25)	Mibini Swamp, W. Province, PNG			
CS 16610 (12)	Mai Kussa River, W. Province, PNG			

Table 2. Origin of *Azadirachta indica* accessions at Roche Blanche.

LOT NO.	COUNTRY	LOT NO.	COUNTRY
2	*ex* Puerto Rico	9	*ex* Burkina Faso
3	*ex* Dom. Republic	10	*ex* Burkina Faso
4	*ex* Senegal	12	*ex* Burkina Faso
5	*ex* Togo	13	*ex* Burkina Faso
6	*ex* Niger	14	*ex* Burkina Faso
7	*ex* Niger	15	*ex* Burkina Faso
8	*ex* Burkina Faso	17	*ex* Haiti

Table 3. Mother tree information of *Calophyllum brasiliense* families at Marmont and Paillant.

FAMILY NO.	LOCALITY	ALT (m)	LATITUDE	LONGITUDE
901	Felisiann, Lascahobas	240	18° 55' N	71° 51' W
904	Thomonde	245	19° 00' N	71° 57' W
915	Lompré, Trouin	485	18° 21' N	72° 41' W
918	Jillanime, Fond d'Icaques	95	18° 32' N	73° 96' W
919	Morne-à-Brilé, Jacmel	575	18° 18' N	72° 39' W
920	Felisiann, Lascahobas	230	18° 55' N	71° 51' W
923	Bas Macia, Petite Goâve	65		

Table 4. Origin of *Casuarina cristata* and *C. equisetifolia* at Lapila. **C** = CATIE, **O** = Oxford Forestry Institute.

NO.	SPECIES	ORIGIN	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
C 1476	*C. cristata*	Eidsvold, Queensland, Australie	330	25° 20'S	150° 31'E	1579
O 70/85	*C. equisetifolia equisetifolia*	Wangetti Beach, Queensland, Australie (10)	2	16° 41'S	145° 00'E	1559
O 71/85	*C. equisetifolia incana*	Emu Park, Queensland, Australie (10)	3	23° 13'S	84° 12'W	1909

Table 5. Mother tree information of *Catalpa longissima* families at Crocra, Laborde and Roche Blanche.

FAMILY NO.	LOCATION	ALT. (m)	LATITUDE	LONGITUDE
102	Km 70, Jacmel	360	18° 18' N	72° 34' W
103	Diclo, Km 50, Léogâne	440	18° 23' N	72° 30' W
104	Diclo, Km 50, Léogâne	440	18° 23' N	72° 30' W
105	L'Acul, Km 42, Léogâne	25	18° 26' N	72° 40' W
106	L'Acul, Km 42, Léogâne	25	18° 26' N	72° 40' W
107	L'Acul, Km 42, Léogâne	25	18° 26' N	72° 40' W
108	Bas Tapion, Grand-Goâve	10	18° 25' N	72° 46' W
109	Fontabi, Petit-Goâve	10	18° 25' N	72° 46' W
110	Dlo Rele, Grand-Goâve	180	18° 25' N	72° 47' W
111	Ti Paradis, Grand-Goâve	15	18° 25' N	72° 45' W
112	Gesom, Petit-Goâve	800	18° 18' N	72° 42' W
114	Vinier, Arcahaie	25	18° 45' N	72° 28' W
115	Guillaume, Arcahaie	16	18° 47' N	72° 31' W
116	Band du Nord, Cap Haïtien	60	19° 47' N	72° 12' W
117	Vinier, Arcahaie	100	18° 46' N	72° 28' W
118	Vaudreuil, Cap-Haïtien	30	19° 42' N	72° 15' W
119	Modieu, Limbé	110	19° 41' N	72° 24' W
120	Thomonde, Hinche	300	19° 00' N	71° 57' W
121	Deklero, Quartier Morin	25	19° 41' N	72° 10' W
122	Deklero, Quartier Morin	25	19° 41' N	72° 10' W
123	Labordette, Petit-Goâve	450	18° 23' N	73° 12' W
124	Charlier, Pte Riv. De Nippes	10	18° 29' N	73° 11' W
125	Charlier, Pte Riv. De Nippes	10	18° 29' N	73° 11' W
127	Anons, Jérémie	100	18° 33' N	74° 06' W
128	Band du Nord, Cap Haïtien	90	19° 47' N	72° 12' W
129	Gamel, Cap-Haïtien	50	19° 46' N	72° 25' W
131	Bake, Mirebalais	200	18° 47' N	72° 02' W
132	Manzè Mari, Jacmel	240	18° 15' N	72° 44' W
134	Thomonde	280	19° 00' N	71° 57' W
136	Savane Calebasse, Lascahobas	205	18° 56' N	71° 55' W
137	Limbé	40	19° 42' N	72° 24' W
138	Limbé	40	19° 42' N	72° 24' W
140	Savane Longue, Ouanaminthe	90	19° 31' N	71° 45' W
143	Fauché, Port Margot	55	19° 44' N	72° 25' W
146	L'Acul, Léogane	5	18° 26' N	72° 40' W
148	Ca Charlier, Charlier	15	18° 29' N	73° 12' W
149	Félisian, Lascahobas	200	8° 55' N	71° 51' W
150	Fontabi, Petit Goâve	40	18° 25' N	72° 58' W
151	Fontabi, Petit Goâve	40	18° 25' N	72° 58' W
155	Ravine Pac, Petit Goâve	165	18° 16' N	72° 57' W
158	Kalompre, Trouin	540	18° 21' N	72° 41' W
159	Thomonde	280	19° 00' N	71° 57' W
160.	Dampuce, Grand-Goâve	65	18° 24' N	72° 42' W
161	Félisian, Lascahobas	190	18° 55' N	71° 55' W
163	2ème Plaine, Petit-Goâve	55	18° 24' N	71° 01' W
169	Labordette, Petit-Goâve	450	18° 23' N	73° 12' W

FAMILY NO.	LOCATION	ALT. (m)	LATITUDE	LONGITUDE
174	Jean Rabel	65	19° 51' N	73° 12' W
177	Valoi, Jean Rabel	240	19° 51' N	73° 10' W
178	Fonds Begle, Bombardopolis	465	18° 50' N	73° 35' W
181	Labordette, Petit Goâve	400	18° 23' N	73° 12' W
185	Savane Longue, Ouanaminthe	90	19° 31' N	71° 45' W
188	Coplo, Ouanaminthe25.0	75	19° 30' N	71° 46' W
2101	Baie de Henne, NO	10		
2213	Limbé	25		

Table 6. *Cedrela odorata* at Laborde, Labordette and Bérault. Numbers in parentheses indicate the number of mother trees represented by the trial accession. **C** = CATIE, **CO** = COHDEFOR, **O** = Oxford Forestry Institute.

PROV. NO.	PROVENANCE	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
C 2532	Guapiles, Costa Rica	23.3	249	10° 13'N	83° 46'W	4100
O 14/75	Esteli, Nicaragua (1)	–	800	12° 58'N	85° 58'W	1394
O 23/77	San Ignacio, Belize (100)	25.7	225	17° 10'N	89° 05'W	726
O 25/80	Apartado, Colombia (7)	27.3	75	7° 50'N	76° 40'W	2266
O 36/78	San Marcos,Nicaragua (19)	–	520	11° 54'N	86° 12'W	1514
O 42/79	Chitalon, Guatemala (27)	25.0	320	14° 33'N	91° 30'W	2906
O 52/79	Chamelecon, Honduras (27)	26.0	80	15° 22'N	88° 7'W	1268
CO 6888	Cofradia, Honduras	21.9	1100	14°09'N	87°12'W	832

Table 7. Origin of *Cordia alliodora* at Pemel and Bérault. **O** = Oxford Forestry Institute (UK), **C** = CATIE (Costa Rica), **CO =** COHDEFOR (Honduras).

NO. PROV	PROVENANCE	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
O 1877	Esparza, Costa Rica	22.4	190	09°55'N	84°35'W	2310
C 4107	San Carlos, Costa Rica	20.8	185	10°20'N	84°20'W	3275
C 4108	Talamanca, Costa Rica	24.9	90	09°33'N	82°43'W	2110
C 4117	Turrialba, Costa Rica	22.2	660	09°51'N	83°37'W	2675
C 4140	Upala, Costa Rica	24.9	70	10°50'N	85°01'W	2590
CO B7488	Cofradia, Honduras	21.9	1100	14°09'N	87°12'W	832

Table 8. Origin of *Enterolobium cyclocarpum* accessions at Lapila. **C** = CATIE, **CO** = COHDEFOR.

PROV. NO.	PROVENANCE	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
C 792	Bagaces, Costa Rica	28.5	500	10° 32'N	85° 15'W	1579
C 1371	Leon, Nicaragua	27.0	100	12° 30'N	87° 00'W	1559
CO 11387	Commercial control from Honduras by PADF	—	—	—	—	—

Table 9. Mother tree information of *Eucalyptus camaldulensis* and *E. tereticornis* families at Marmont and Terrier Rouge.

FAMILY NO.	SPECIES	LOCALITY	ALT (m)	LATITUDE	LONGITUDE
52	*E. camaldulensis*	*ex* Cazeau, Port-au-Prince	25		
58	*E. camaldulensis*	*ex* Cazeau, Port-au-Prince	25		
66	*E. camaldulensis*	*ex* Cazeau, Port-au-Prince	25		
76	*E. tereticornis*	*ex* Cazeau, Port-au-Prince	25		

Table 10. Origin of *Grevillea robusta* accessions at Paillant. Numbers in parentheses indicate the number of mother trees represented by each provenance. **CS** = CSIRO (Australia).

PROV. NO.	PROVENANCE	ALT (m)	LAT.	LONG.	RAINFALL (mm)
CS 15872 (10)	Linville, QLD, Australia				
CS 15873	Emu Vale, QLD, Australia				
CS 17185	12.6 km from Woodenbong, QLD, Australia				
Control	*ex* Fermathe, Haiti	1000			

Table 11. Mother tree information of *Lysiloma sabicu* families at Crocra and Lapila.

FAMILY NO.	LOCALITY	ALT (m)	LATITUDE	LONGITUDE
504	Mont Bois, Limbé	10	19° 44' N	72° 18' W
505	Nan Jacques, Jérérmie	248		
513	Kalompré, Trouin	550	18° 21' N	72° 40' W
517	La Prise, Camp Perrin	220		
518	Kalompré, Trouin	590	18° 21' N	72° 40' W
519	Terre Rouge, Petite Goâve	400	18° 24' N	73° 12' W
521	Terre Rouge, Petite Goâve	390	18° 24' N	73° 12' W
522	Geson, Trouin	440	18° 20' N	72° 40' W
525	Lompré, Trouin	560	18° 21' N	72° 40' W
529	Lilet, Morne-à-Brilé	450	18° 18' N	72° 42' W
530	Mme Dimanche, Morne-à-Brilé	465	18° 18' N	72° 42' W
532	Geson, Trouin	450	18° 20' N	72° 40' W
537	Morne-à-Brilé, Jacmel	575	18° 18' N	72° 42' W
538	Morne-à-Brilé, Jacmel	485	18° 18' N	72° 42' W
539	Morne Rouge, Jacmel	575	18° 18' N	72° 42' W
2511	Morne Bois Pin, Limbé			
2581	Duranton, Jeremie			

Table 12. Origin of *Pinus* species and provenance accessions at Viard. **O =** Oxford Forestry Institute, **Z** = Zimbabwe Forestry Commission.

SPECIES	PROV. NO.	ORIGIN	TEMP (°C)	ALT (m)	LAT	LONG	RAIN (mm)
P. caribaea	**O** 1/79	Little Abaco, Bahamas	24.8	10	26°52'N	77°37' W	1,229
P. caribaea	**O** 3/80	*ex* Byfield, Australia	Orchard seed				
P. caribaea	537	Bahamas Island, Bahamas	Commercial seed				
P. caribaea	**O** 69(7296)	Andros Island, Bahamas	24.4	3	24°30'N	78°20'W	1,664
P. caribaea caribaea	**O** 9/76	Consolacion del Norte, Cuba	24.7	75	22°48'N	82°57'W	1,792
P. caribaea caribaea	**O** 51/83	Marbajitas, Cuba	24.7	75	22°48'N	82°57'W	1,792

SPECIES	PROV. NO.	ORIGIN	TEMP (^{0}C)	ALT (m)	LAT	LONG	RAIN (mm)
P. caribaea	563	*ex* SEED EXPORT, MS, USA	Commercial seed				
P. caribaea	**O** 17/85	Mountain Pine Ridge, Belize	23.9	400	17°00'N	88°55'W	1,558
P. caribaea	**O** 19/85	La Mosquitia, Honduras	–	80	15°00'N	84°00'W	–
P. caribaea	**O** 20/85	Trojes, Honduras	23.0	720	14°03'N	85°58'W	1,649
P. caribaea	**O** 36/83	*ex* Byfield, Australia	Orchard seed				
P. elliotii	561	Harrison, MS, USA	Commercial seed				
P. elliotii	**Z** 15441	*ex* ZIMBABWE FORESTRY	Orchard seed				
P. khasya	538	Penhalonga, Zimbabwe	Commercial seed				
P. khasya	**Z** 15212	*ex* ZIMBABWE FORESTRY	Orchard seed				
P. occidentalis	**O** 4/78	Bayoma, Cuba	Source information not available.				
P. occidentalis	**O** 38/77	Jumunco, Rep. Dominicaine					
P. occidentalis	**O** 66(7293)	HondoValley, Rep.					
P. occidentalis	6666	Seguin, Haïti	13.6	1680	18° 19'N	72° 14'W	1735
P. oocarpa	497	*ex* SETROPA, Holland	Commercial seed				
P. oocarpa	**Z** 15319	*ex* ZIMBABWE FOR. COMM.	Orchard seed				
P. patula	**Z** 15275	*ex* ZIMBABWE FOR. COMM.	Orchard seed				
P. radiata	1008	*ex* LAWYER'S NURS., ND,	Commercial seed				
P. taeda	496	*ex* SETROPA, Holland	Commercial seed				
P. taeda	562	Lincoln, MS, USA	Commercial seed				
P. taeda	1003	*ex* LAWYER'S NURS., ND,	Commercial seed				
P. taeda	**Z** 15169	*ex* ZIMBABWE FOR. COMM.	Orchard seed				
P. tecunumanii	**O** 7/77	San Raphael del Norte,	–	1,20	13°14'N	86°08'W	1,362
P. tecunumanii	**O** 24/85	Mountain Pine Ridge, Belize	23.9	700	17°00'N	88°55'W	1,558

Table 13a. Origin of *Senna siamea* accessions at Lapila and Roche Blanche provenance trials. **C** = CATIE**, I =** IRG, **R =** ISAR (Rwanda). Number of trees harvested for a given seed lot, if known, is provided in parentheses.

NO.	SOURCE	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
R 554	*ex* Cyangugu, Rwanda (20)	—	900	2° 15'S	29° 00'E	1100
C 1206	*ex* Managua, Nicaragua	—	100	12° 08'N	86° 15'W	—
C 1214	*ex* Dodoma, Tanzania	—	—	06° 00'S	36° 00'E	—
C 1365	*ex* Leon, Nicaragua	27.4	110	12° 26'N	86° 55'W	1559
C 1564	*ex* Leon, Nicaragua	27.0	100	12° 30'N	87° 00'W	1559
C 2507	*ex* Guanacaste, Costa Rica	27.0	310	10° 05'N	85° 25'W	2230
C 4039	*ex* Guanacaste, Costa Rica	27.0	325	10° 05'N	85° 25'W	2230
I 1501	*ex* Cap-Haitien, Haiti	25.1	75	7° 50'N	76° 40'W	2266
I 1511	*ex* Petit-Goave, Haiti	25.5	520	11° 54'N	86° 12'W	1514

NO.	SOURCE	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
I 1581	*ex* Grand-Anse, Haiti	26.0	320	14° 33'N	91° 30'W	2906

Table 13b. Mother tree information of *Senna siamea* families at Marmont and Terrier Rouge.

FAMILY NO.	LOCALITY	ALT (m)	LATITUDE	LONGITUDE
573	*ex* Kolora, Lascahobas	250		
574	*ex* Nan Charlotte, Petite Goâve	25		
575	*ex* Guinaued, Jean Rabel	245		
576	*ex* Lacraie, Bombardopolis	460		
577	*ex* Pignon	290		
578	*ex* Bayeux	25		
579	*ex* Flexis, Bombardopolis	470		
580	*ex* St. Helene, Jeremie	45		
581	*ex* Couine, Hinche	300		
582	*ex* Couine, Hinche	300		
583	*ex* Paredon, Lascahobas	230		
588	*ex* Riborte, Bombardopolis	430		
589	*ex* Couine, Hinche	300		

Table 14. Origin of *Simarouba* spp. at Lapila and Roche Blanche.

NO.	SPECIES	ORIGIN	ALT.	LATITUDE	LONGITUDE
201	*Simarouba glauca*	Moussignac, Miragoâne	160	18° 23' N	73° 05' W
204	*Simarouba glauca*	Chomaj, Bainet	260	18° 10' N	72° 48' W
210	*Simarouba glauca*	Modieu, Limbé	25	19° 42' N	72° 25' W
211	*Simarouba glauca*	Modieu, Limbé	25	19° 42' N	72° 25' W
213	*Simarouba glauca*	Labordette, Petite Goâve	450	18° 23' N	73° 12' W
216	*Simarouba glauca*	Alabri, Miragoâne	460	18° 22' N	73° 01' W
217	*Simarouba glauca*	Nanzo, Jérémie	300	18° 32' N	74° 06' W
219	*Simarouba glauca*	Ledan, Jérémie	50		
220	*Simarouba glauca*	Moussignac, Miragoâne	130	18° 23' N	73° 05' W
227	*Simarouba glauca*	Band du Nord, Cap Haitien	50		
228	*Simarouba glauca*	Felisiann, Lascahobas	220	18° 55' N	71° 55' W
230	*Simarouba glauca*	Lodorat, Lascahobas	190	18° 51' N	71° 53' W
232	*Simarouba glauca*	Modieu, Limbé	40	19° 42' N	72° 25' W
237	*Simarouba glauca*	Volonté, Port Margot	45	19° 46' N	72° 26' W
247	*Simarouba glauca*	Lospwet, Belladere	260	19° 52' N	71° 54' W
248	*Simarouba glauca*	Band du Nord, Cap Haitien	45		
250	*Simarouba glauca*	Lompré, Petite Goâve	500		
252	*Simarouba glauca*	Malet, Jacmel	450	18° 18' N	72° 40' W
253	*Simarouba glauca*	Malet, Jacmel	450	18° 18' N	72° 42' W
256	*Simarouba glauca*	Baké, Mirebalais	145	18° 48' N	72° 02' W
257	*Simarouba glauca*	Chabanne, Petite Goâve	25	18° 25' N	72° 54' W
Control	*S. berteroana*	Lapila nursery	--		
263	*S. berteroana*	Marmont, Hinche	290	19° 05' N	72° 00' W
264	*S. berteroana*	Marose, Petite Goâve	50	18° 45' N	72° 57' W

NO.	SPECIES	ORIGIN	ALT.	LATITUDE	LONGITUDE
266	*S. berteroana*	Musac, Jacmel	575	18° 16' N	72° 37' W
267	*S. berteroana*	Musac, Jacmel	455	18° 16' N	72° 37' W

Table 15. Origin of *Swietenia* spp. at Marmont. **FS** = United States Forest Service, Rio Piedras, Puerto Rico.

NO.	SPECIES	ORIGIN	TEMP.	ALT.	LATITUDE	LONGITUDE	RAINFALL
463	*S. mahagoni*	Savanne Laraine, Lascahobas, Haiti	25.7	350	18° 58' N	71° 57' W	1750
467	*S. mahagoni*	Savanne Laraine, Lascahobas, Haiti	25.7	250	18° 58' N	71° 57' W	1700
FS 479	Hybrid	Ponce, Puerto Rico	26.2	35	17° 59' N	66° 40' W	927
482	*S. macrophylla ex*	Fond-des-Nègres, Haiti	26.5	275	18° 21' N	73° 13' W	1600
483	*S. macrophylla ex*	Fond-des-Nègres, Haiti	26.5	275	18° 21' N	73° 13' W	1600
486	*S. macrophylla ex*	Labordette, Petit Goâve, Haiti	24.3	400	18° 22' N	72° 58' W	1450
487	*S. macrophylla ex*	Modieu, Limbé, Haiti	25.8	35	19° 41' N	72° 25' W	2057
489	*S. macrophylla ex*	Testas, Jérémie, Haiti	27.0	5	18° 37' N	74° 06' W	1684
493	*S. macrophylla ex*	Limbé, Haiti	25.8	20	19° 42' N	72° 24' W	2057
494	*S. macrophylla ex*	Dirici, Limbé, Haiti	25.8	45	19° 42' N	72° 23' W	2057
497	*S. macrophylla ex*	Testas, Jérémie, Haiti	27.0	5	18° 37' N	74° 06' W	1684

Table 16. Origin of *Swietenia macrophylla* and *S. humilis* at Bérault species trial. **C** = CATIE.

PROV NO.	SPECIES	ORIGIN	TEMP (°C)	ALT (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
C 734	*S. humilis*	Ciruelas, Costa Rica	28.5	100	10° 30' N	84° 50' W	1579
C 2470	*S. humilis*	Bagaces, Guanacaste, Costa Rica	28.5	500	10° 32' N	85° 15' W	1579
C 1982	*S. macrophylla*	Turrialba, Catargo, Costa Rica	22.3	602	9° 51' N	83° 37' W	2690
C 2469	*S. macrophylla*	Chapernal, Punta Arenas, Costa Rica	24.0	1200	9° 51' N	84° 14' W	2250

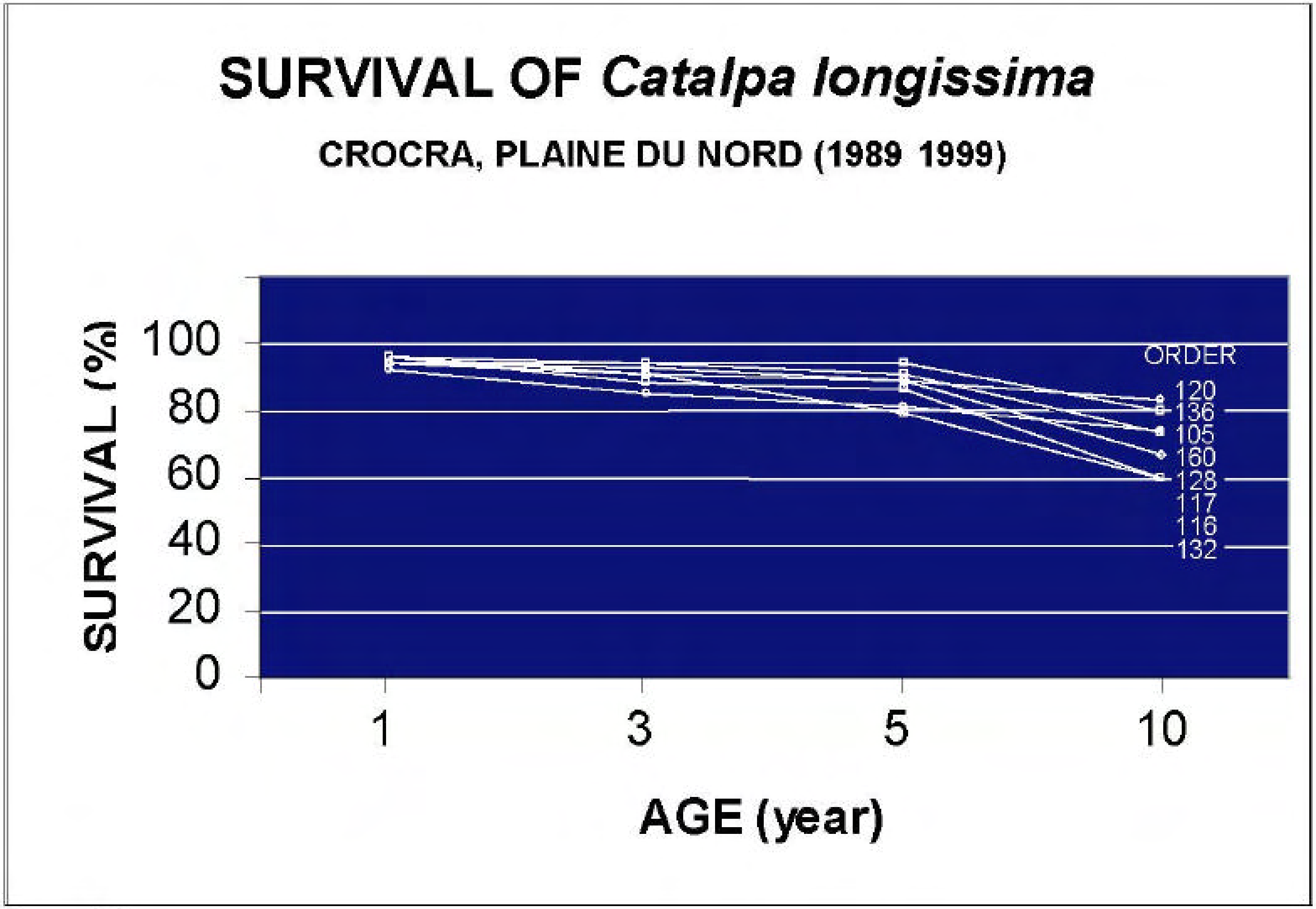
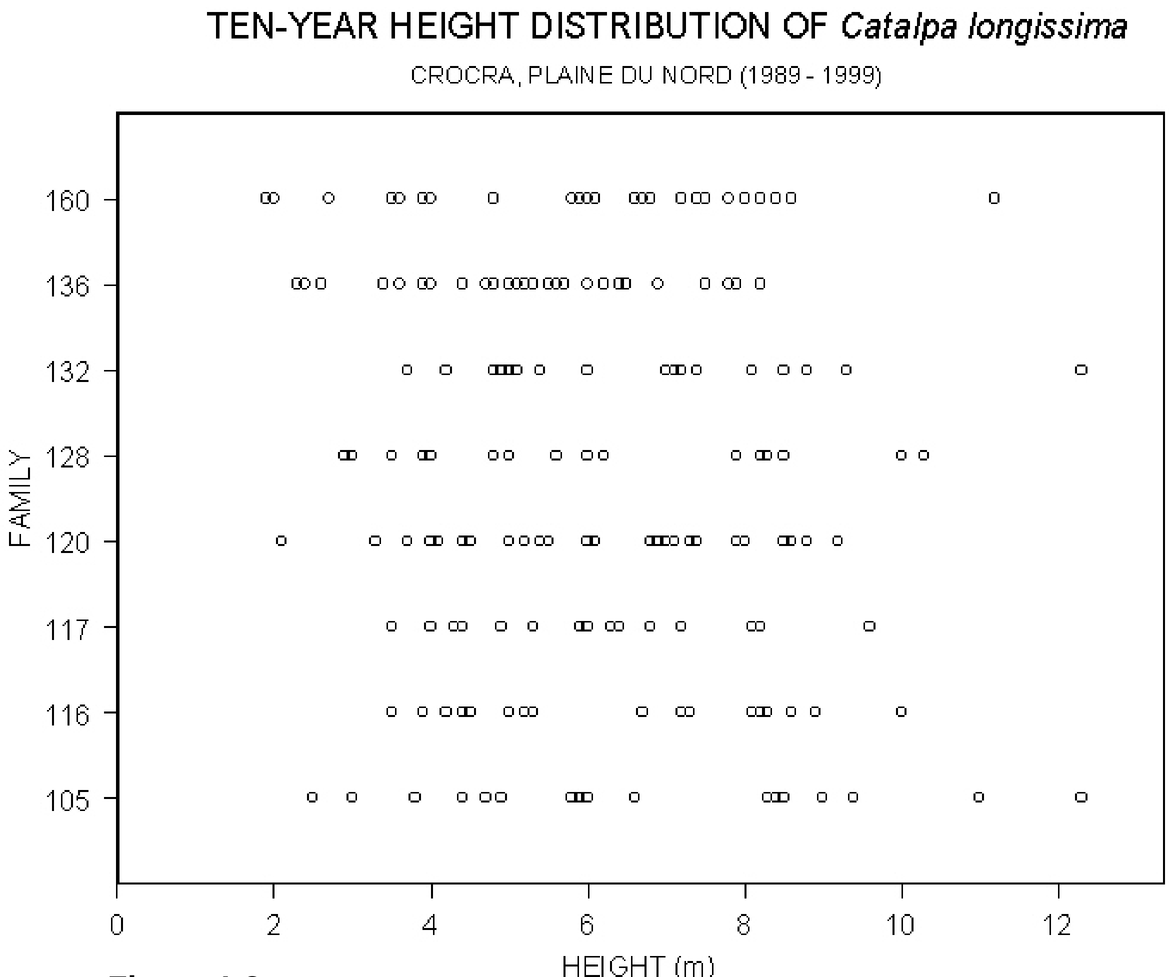

SURVIVAL OF Catalpa longissima
CROCRA, PLAINE DU NORD (1989 1999)
SURVIVAL (%)
100
80
60
40
20
0
1
3
5
10
AGE (year)
ORDER
120
136
105
160
128
117
116
132

Figure 1.1



TEN-YEAR HEIGHT DISTRIBUTION OF *Catalpa longissima*
CROCRA, PLAINE DU NORD (1989 - 1999)
FAMILY
160
136
132
128
120
117
116
105
0
2
4
6
8
10
12
HEIGHT (m)

Figure 1.2

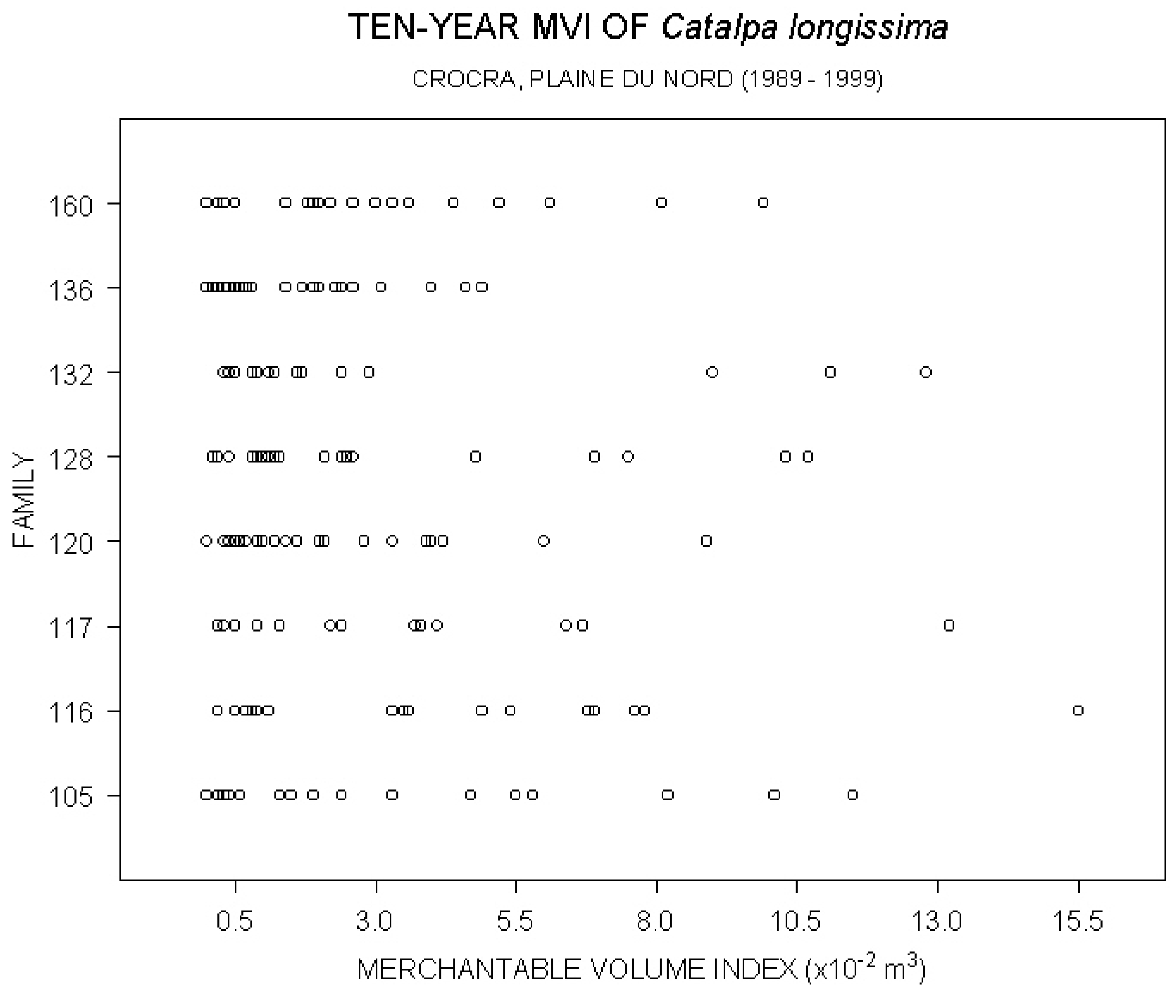

TEN-YEAR MVI OF *Catalpa longissima*
CROCRA, PLAINE DU NORD (1989 - 1999)
FAMILY
160
136
132
128
120
117
116
105
0.5
3.0
5.5
8.0
10.5
13.0
15.5
MERCHANTABLE VOLUME INDEX ($x10^{-2}$ m^3)

Figure 1.3

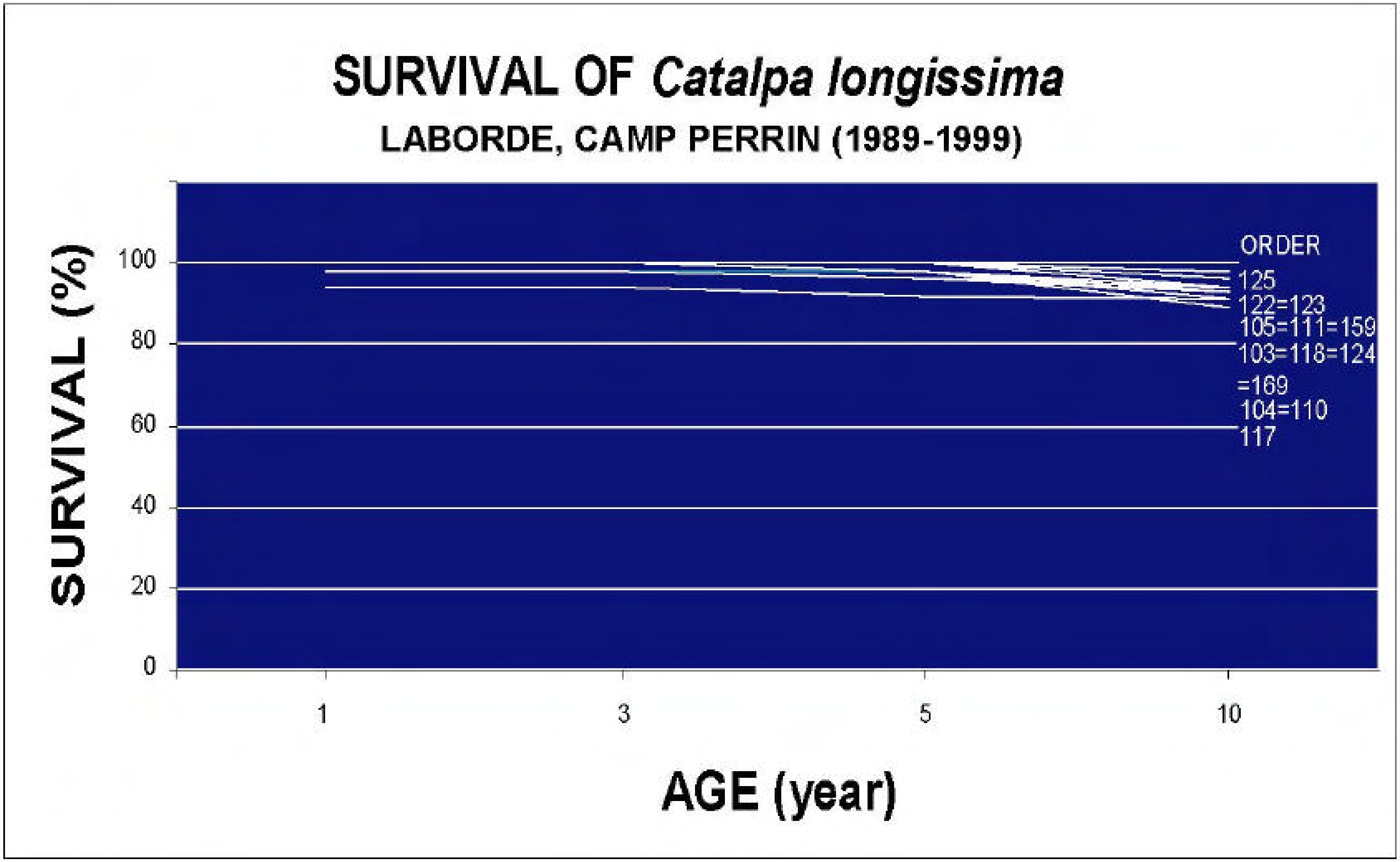

SURVIVAL OF *Catalpa longissima*
LABORDE, CAMP PERRIN (1989-1999)
SURVIVAL (%)
100
80
60
40
20
0
1
3
5
10
AGE (year)
ORDER
125
122=123
105=111=159
103=118=124
=169
104=110
117

Figure 1.4

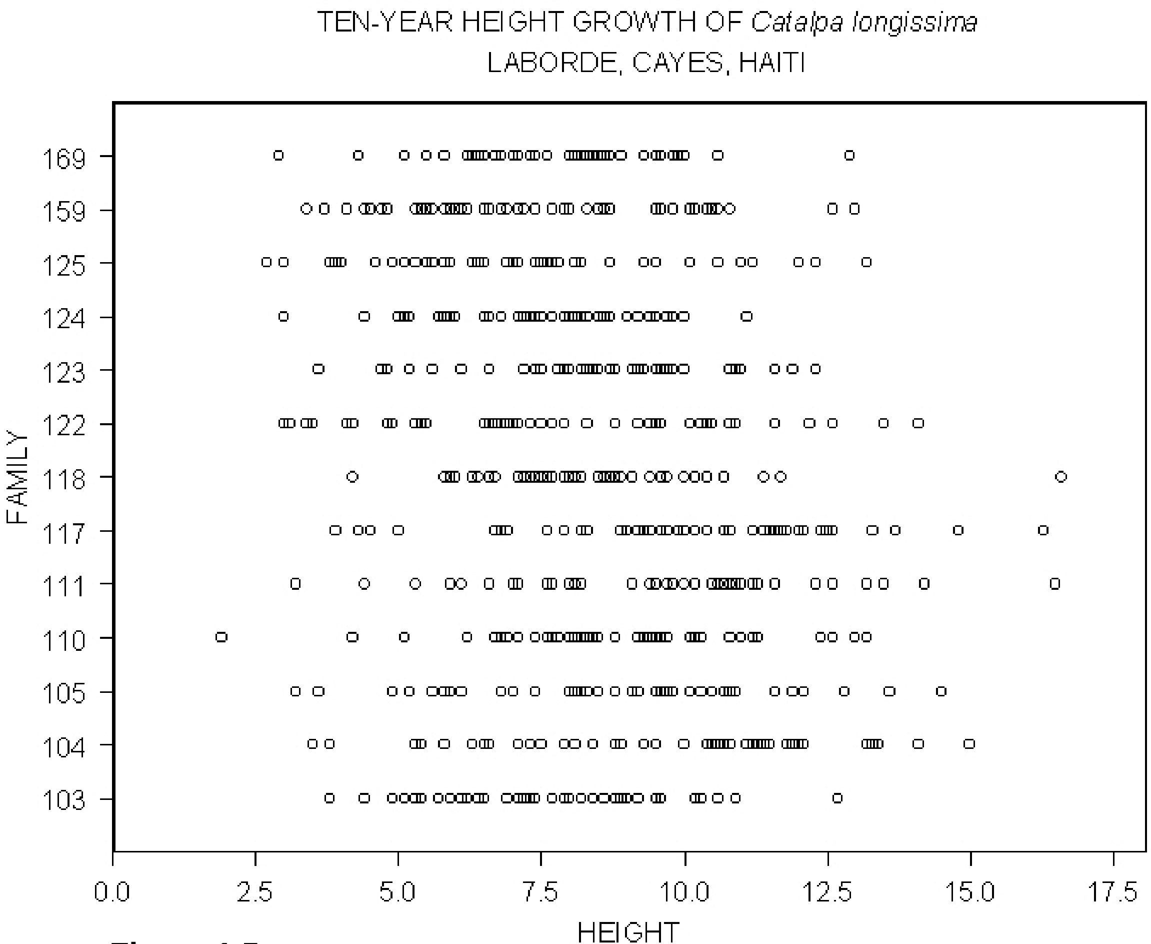

TEN-YEAR HEIGHT GROWTH OF *Catalpa longissima*
LABORDE, CAYES, HAITI
FAMILY
169
159
125
124
123
122
118
117
111
110
105
104
103
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
HEIGHT

Figure 1.5

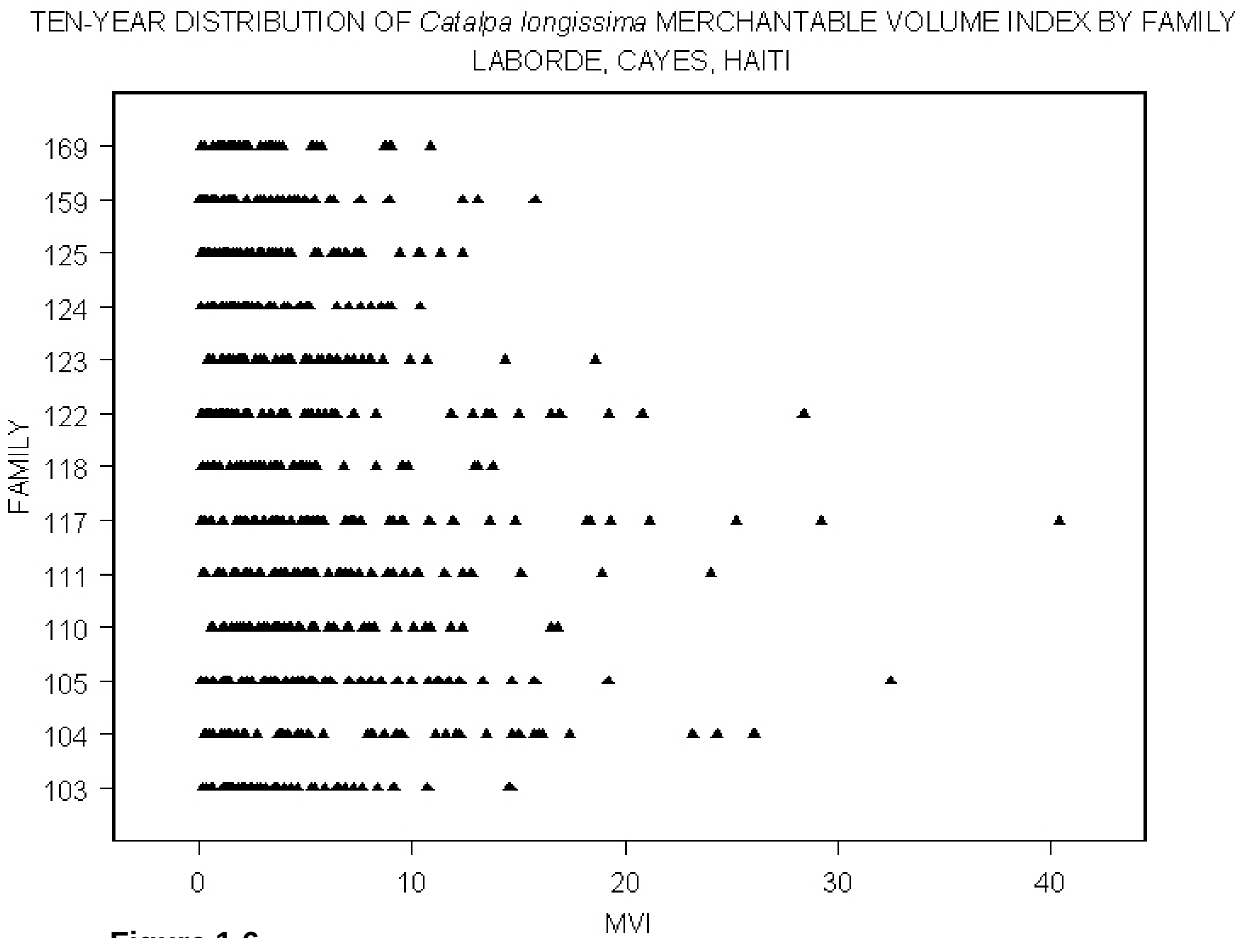

TEN-YEAR DISTRIBUTION OF *Catalpa longissima* MERCHANTABLE VOLUME INDEX BY FAMILY
LABORDE, CAYES, HAITI
FAMILY
169
159
125
124
123
122
118
117
111
110
105
104
103
0
10
20
30
40
MVI

Figure 1.6

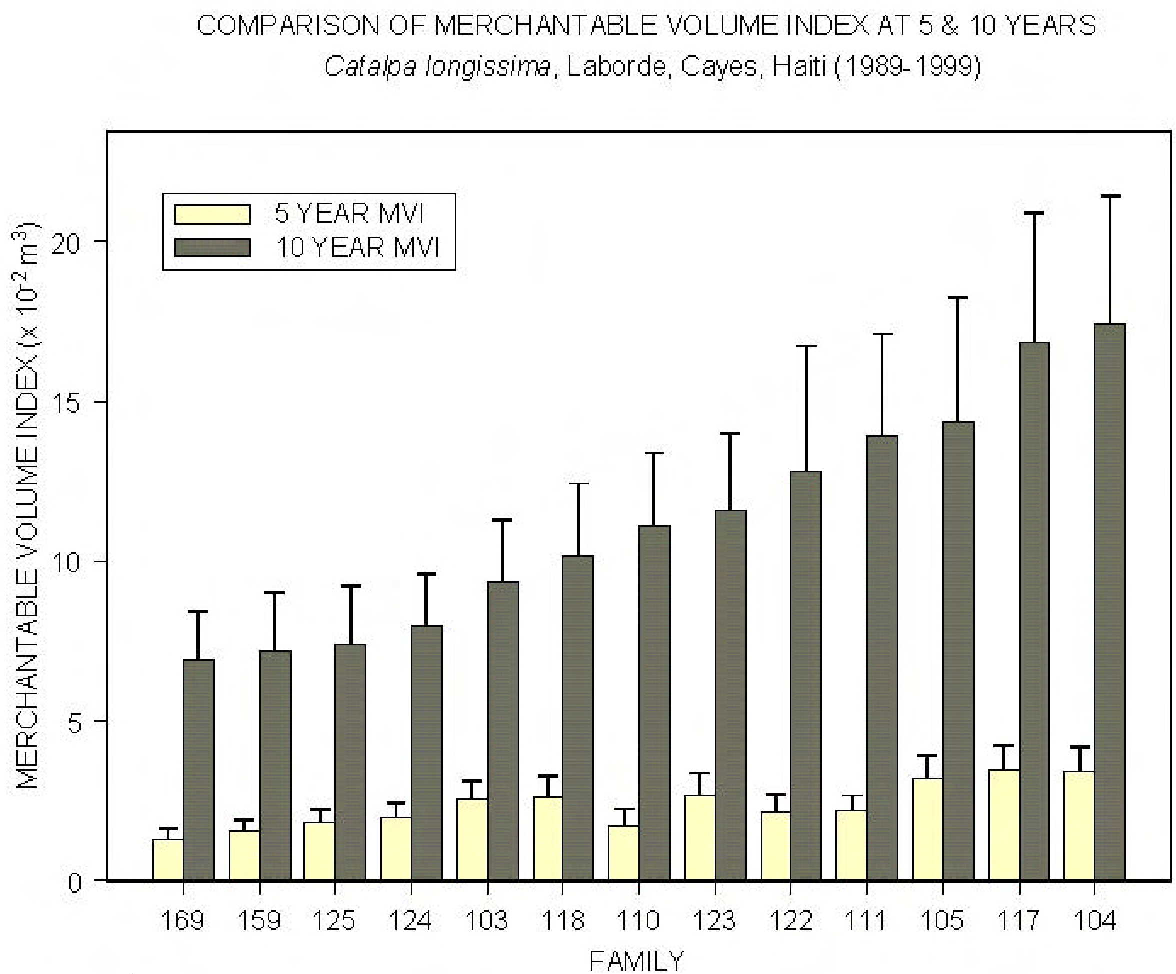

COMPARISON OF MERCHANTABLE VOLUME INDEX AT 5 & 10 YEARS
Catalpa longissima, Laborde, Cayes, Haiti (1989-1999)
5 YEAR MVI
10 YEAR MVI
MERCHANTABLE VOLUME INDEX (x 10-2 m3)
0
5
10
15
20
169
159
125
124
103
118
110
123
122
111
105
117
104
FAMILY

Figure 1.7

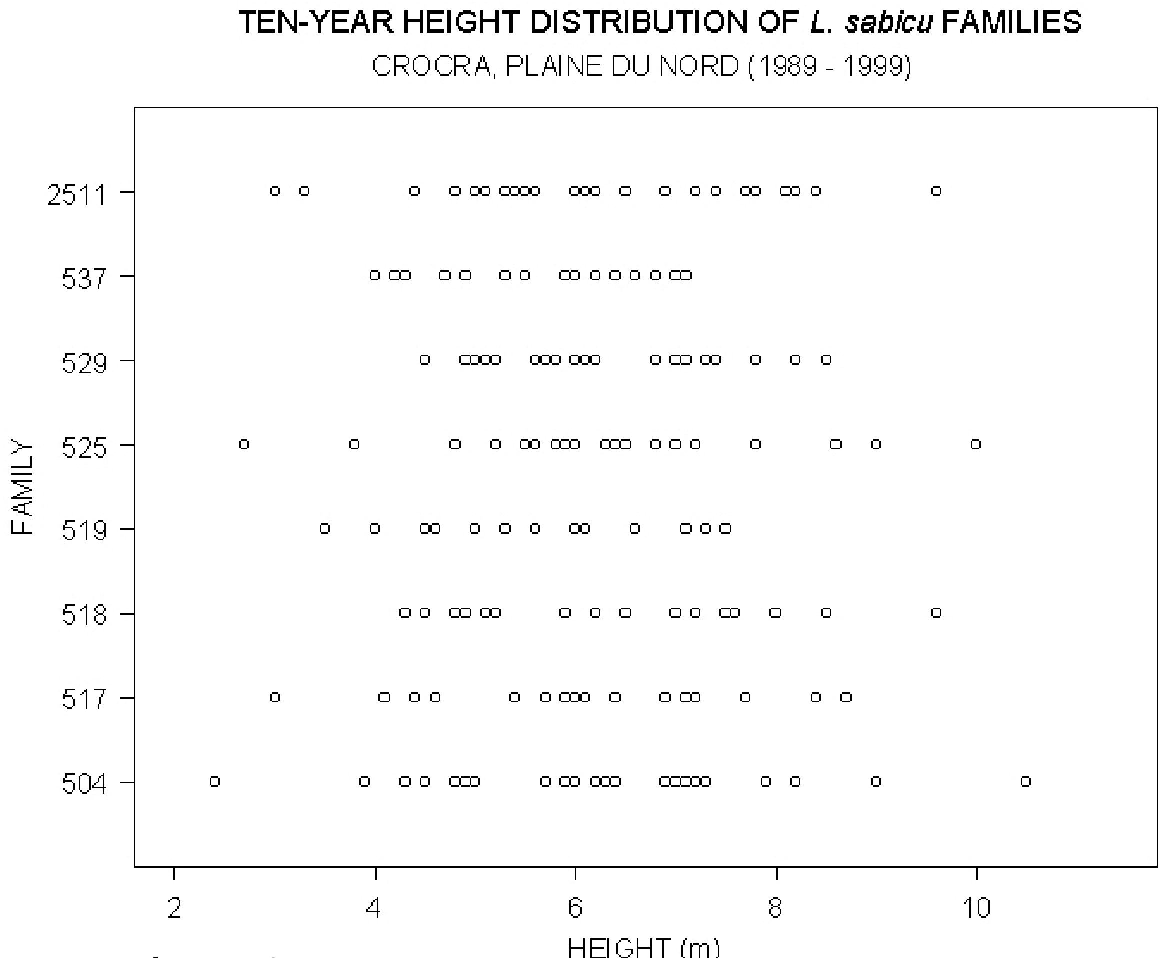

TEN-YEAR HEIGHT DISTRIBUTION OF *L. sabicu* FAMILIES
CROCRA, PLAINE DU NORD (1989 - 1999)
FAMILY
2511
537
529
525
519
518
517
504
2
4
6
8
10
HEIGHT (m)

Figure 1.8

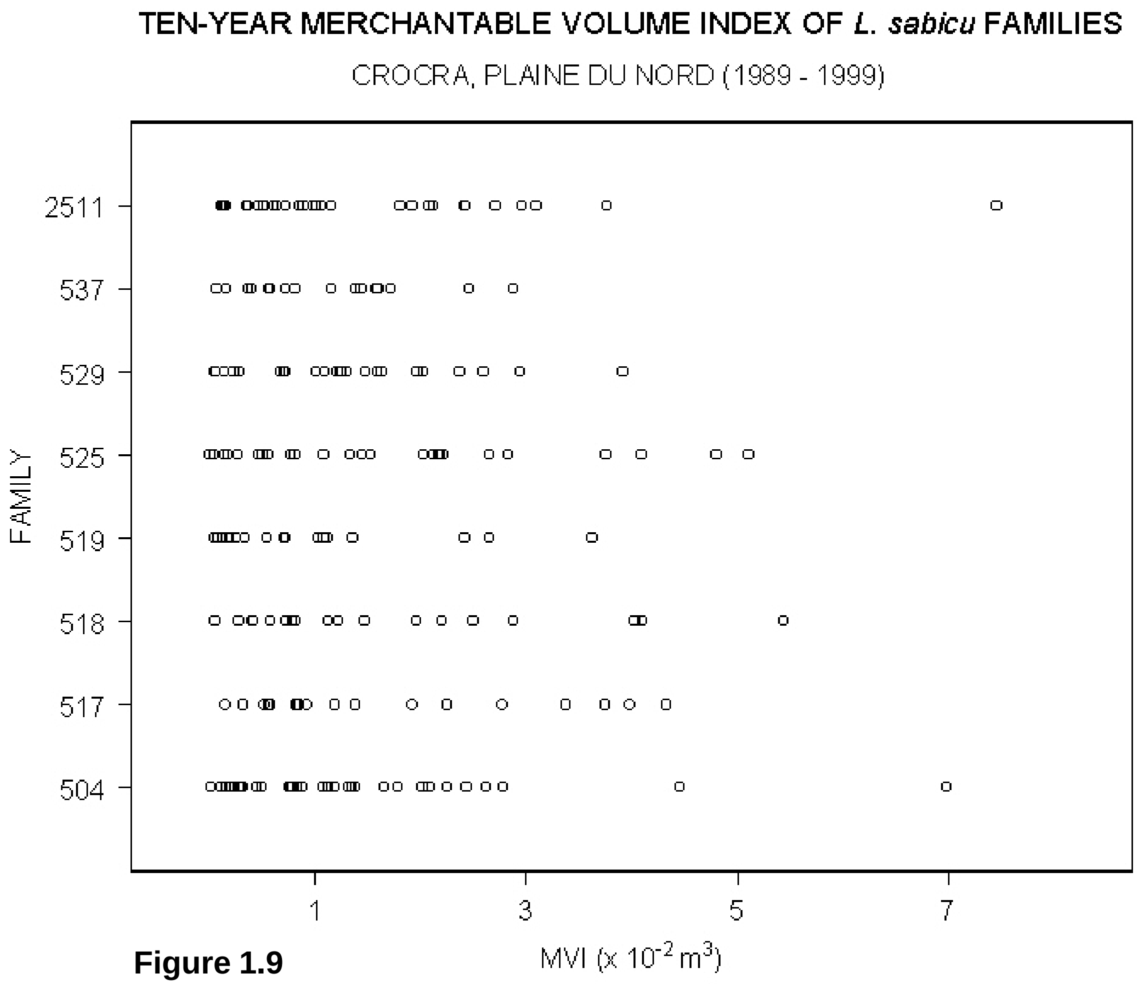

TEN-YEAR MERCHANTABLE VOLUME INDEX OF *L. sabicu* FAMILIES
CROCRA, PLAINE DU NORD (1989 - 1999)
FAMILY
2511
537
529
525
519
518
517
504
1
3
5
7
MVI (x 10-2 m3)

Figure 1.9

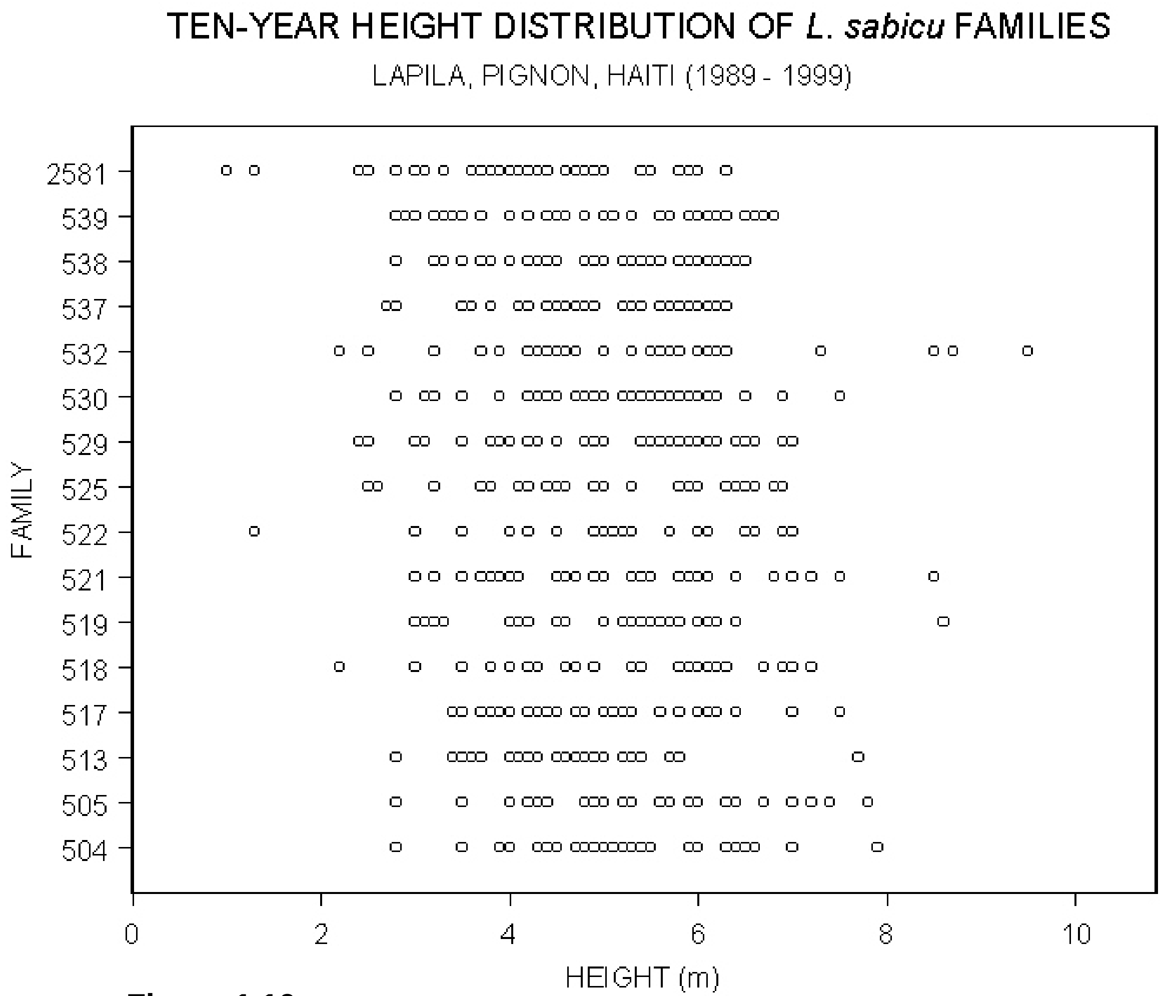

TEN-YEAR HEIGHT DISTRIBUTION OF *L. sabicu* FAMILIES
LAPILA, PIGNON, HAITI (1989 - 1999)
FAMILY
2581
539
538
537
532
530
529
525
522
521
519
518
517
513
505
504
0
2
4
6
8
10
HEIGHT (m)

Figure 1.10

TEN-YEAR DISTRIBUTION OF *L. sabicu* MERCHANTABLE VOLUME INDEX

LAPILA, PIGNON, HAITI (1989 - 1999)

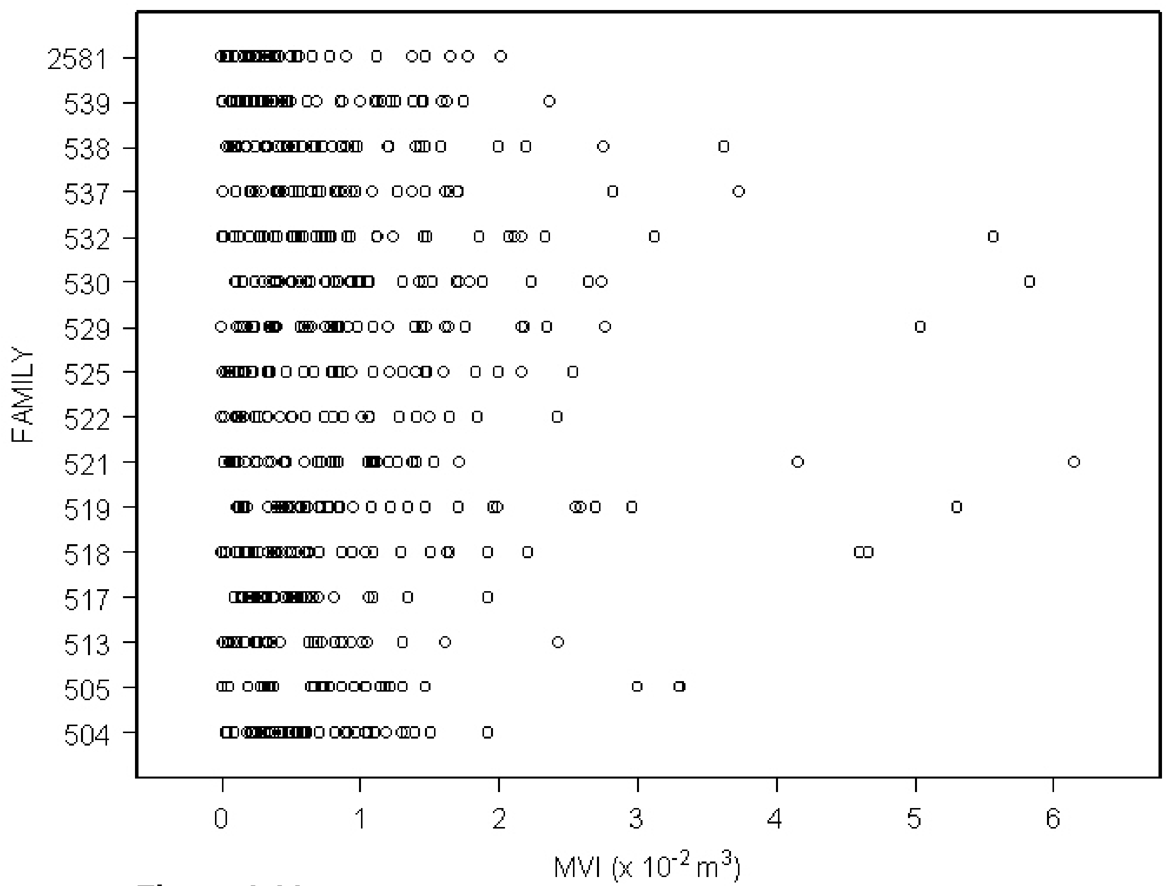


Figure 1.11

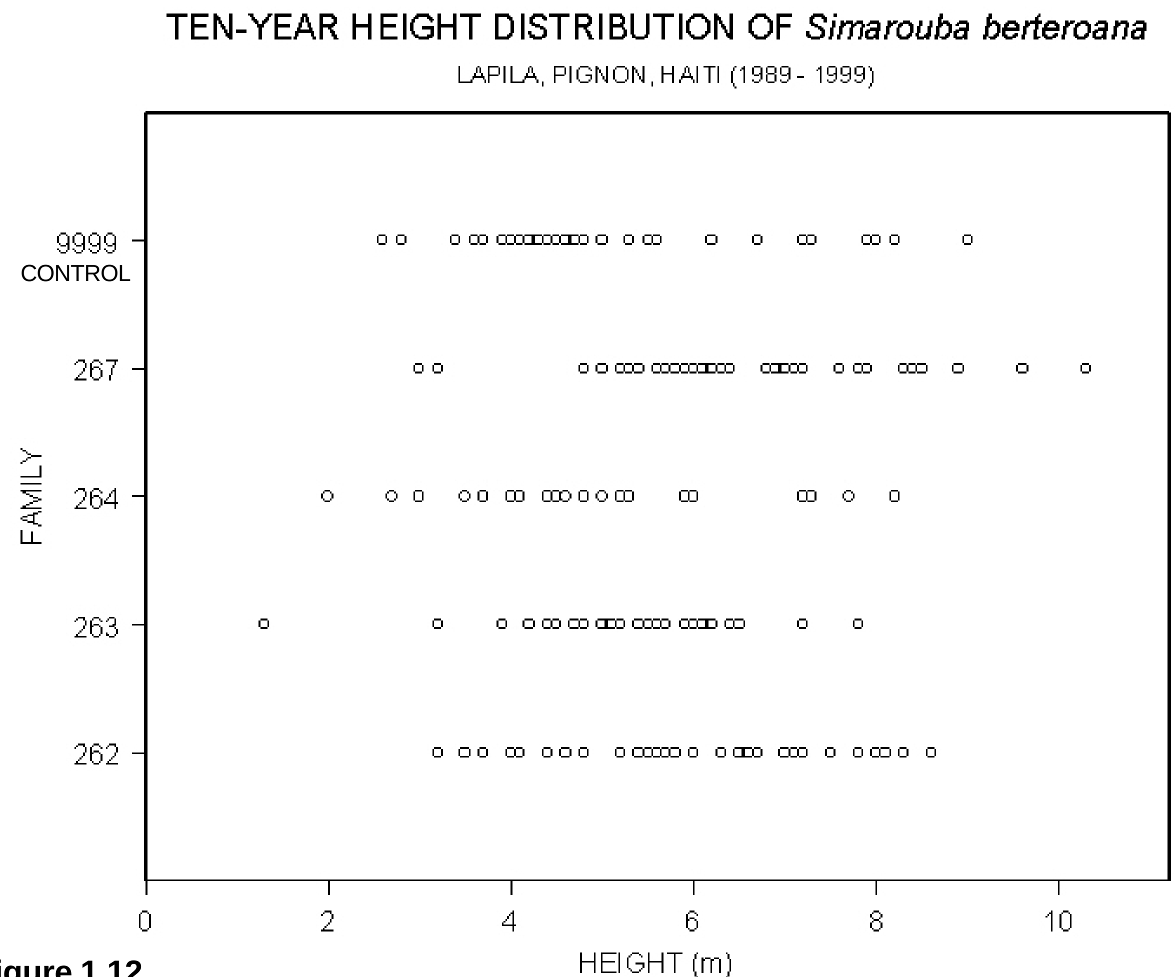

TEN-YEAR HEIGHT DISTRIBUTION OF *Simarouba berteroana*
LAPILA, PIGNON, HAITI (1989 - 1999)
FAMILY
9999
CONTROL
267
264
263
262
0
2
4
6
8
10
HEIGHT (m)

Figure 1.12

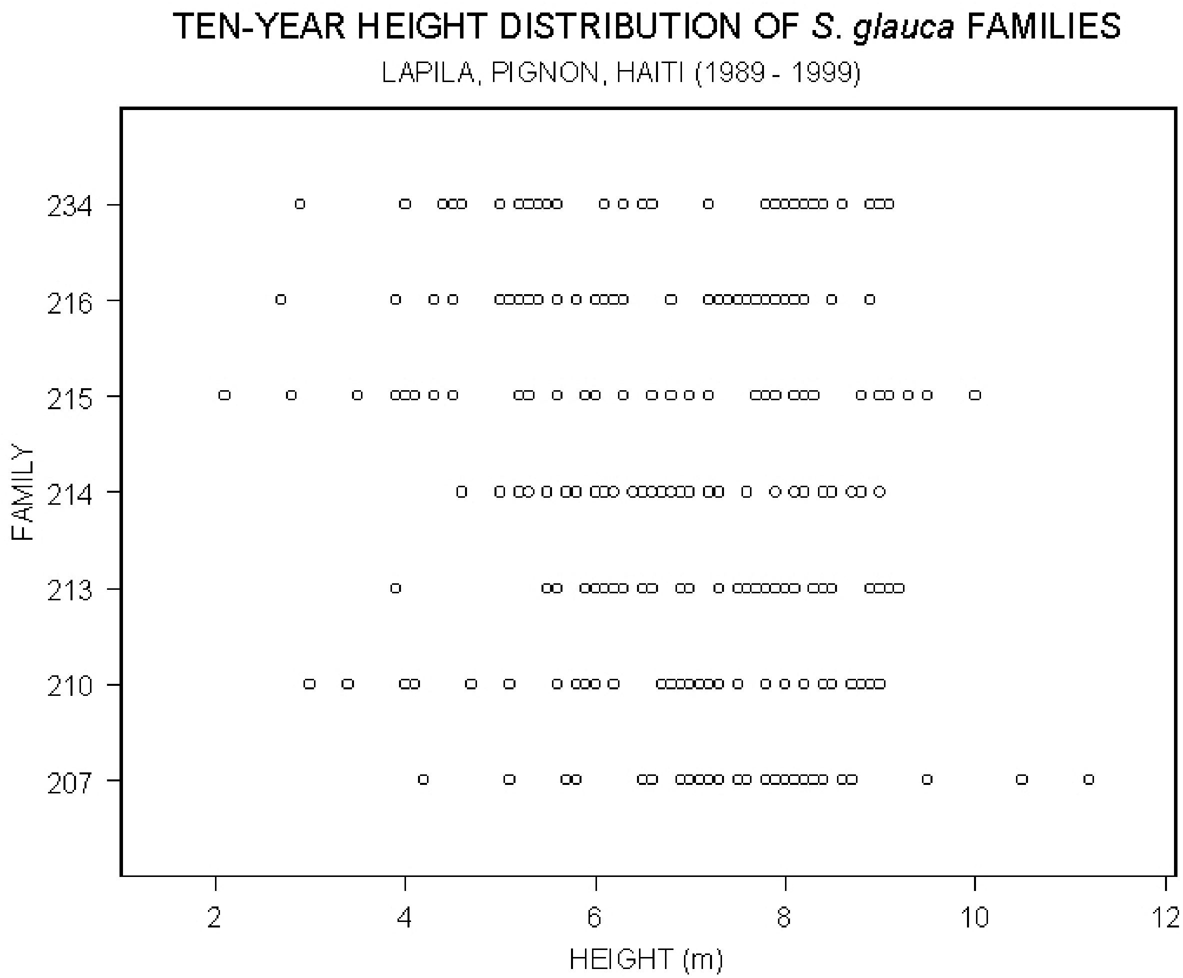

TEN-YEAR HEIGHT DISTRIBUTION OF S. glauca FAMILIES
LAPILA, PIGNON, HAITI (1989 - 1999)
FAMILY
234
216
215
214
213
210
207
2
4
6
8
10
12
HEIGHT (m)

Figure 1.13

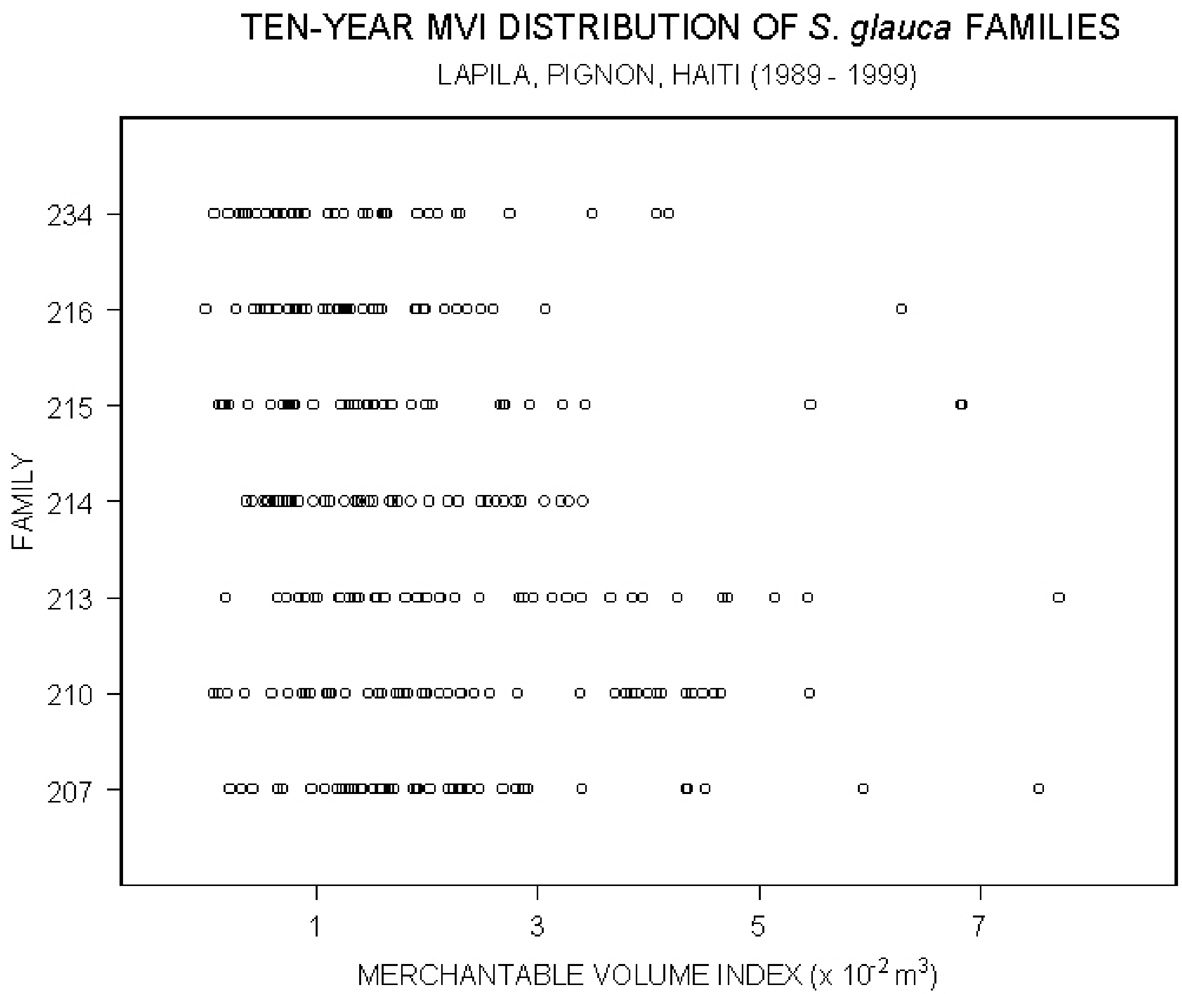
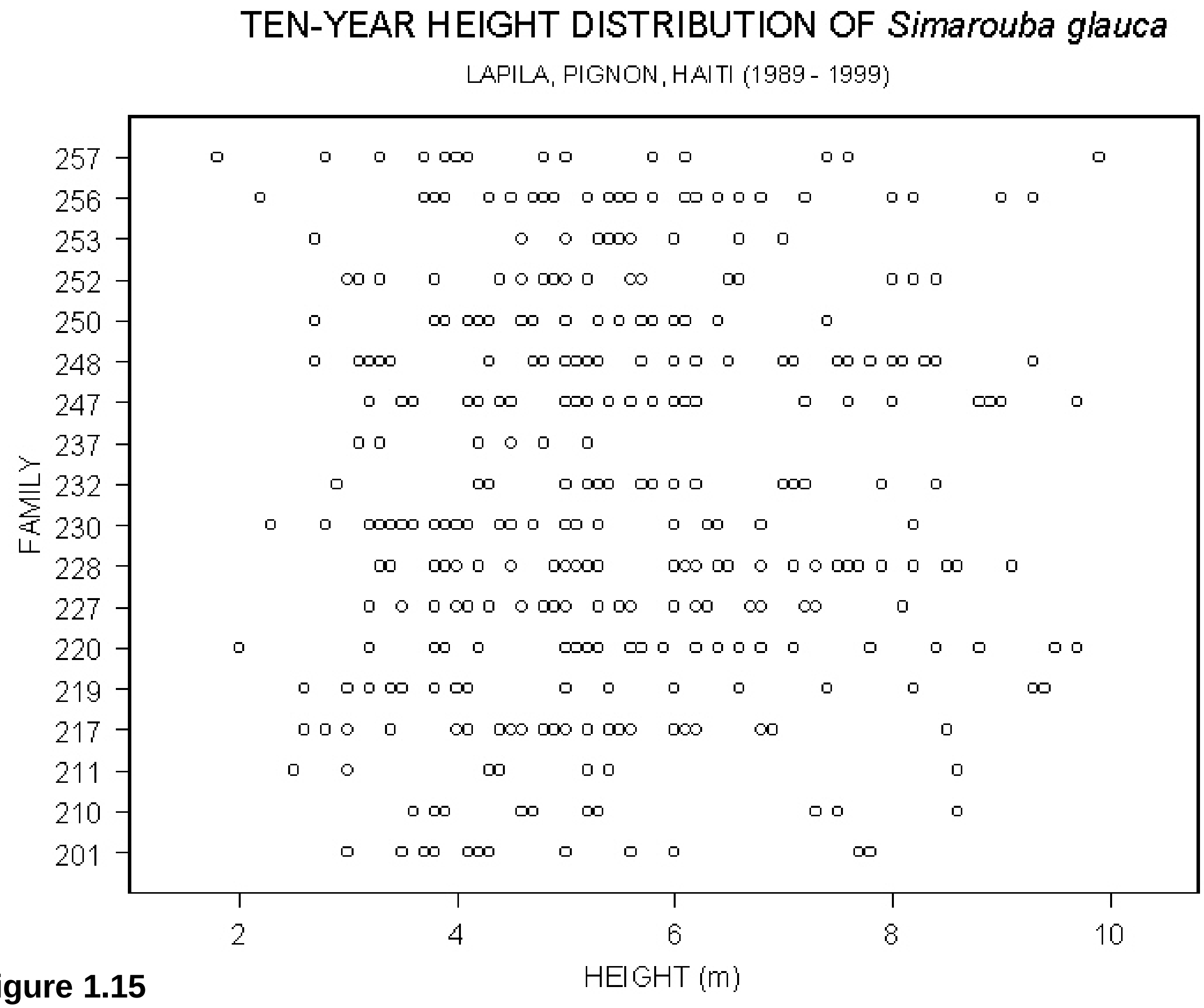

TEN-YEAR MVI DISTRIBUTION OF *S. glauca* FAMILIES
LAPILA, PIGNON, HAITI (1989 - 1999)
FAMILY
234
216
215
214
213
210
207
1
3
5
7
MERCHANTABLE VOLUME INDEX (x 10^{-2} m^3)

Figure 1.14



TEN-YEAR HEIGHT DISTRIBUTION OF *Simarouba glauca*
LAPILA, PIGNON, HAITI (1989 - 1999)
FAMILY
257
256
253
252
250
248
247
237
232
230
228
227
220
219
217
211
210
201
2
4
6
8
10
HEIGHT (m)

Figure 1.15

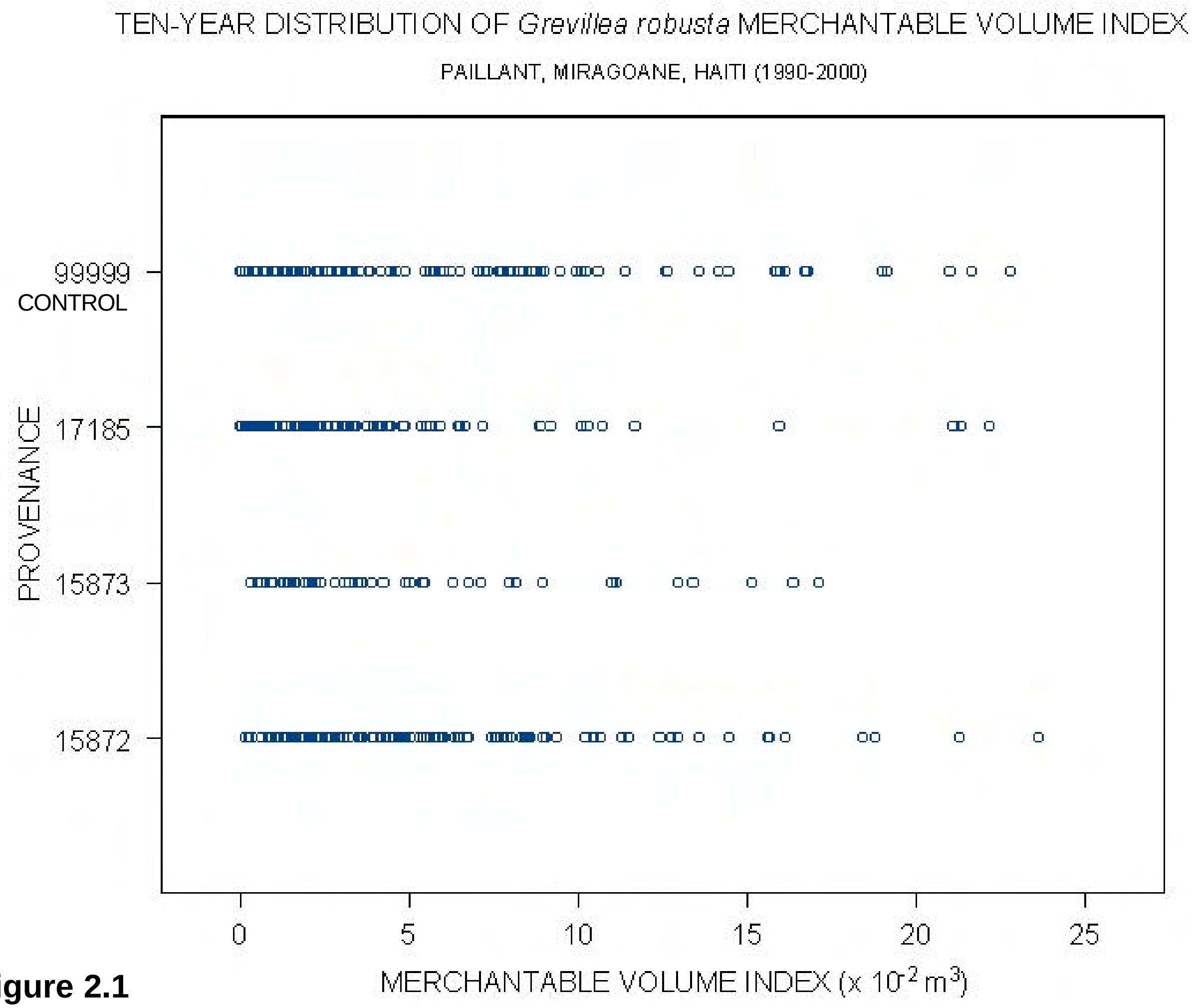

TEN-YEAR DISTRIBUTION OF *Grevillea robusta* MERCHANTABLE VOLUME INDEX
PAILLANT, MIRAGOANE, HAITI (1990-2000)
PROVENANCE
99999
CONTROL
17185
15873
15872
0
5
10
15
20
25
MERCHANTABLE VOLUME INDEX (x 10^{-2} m^3)

Figure 2.1

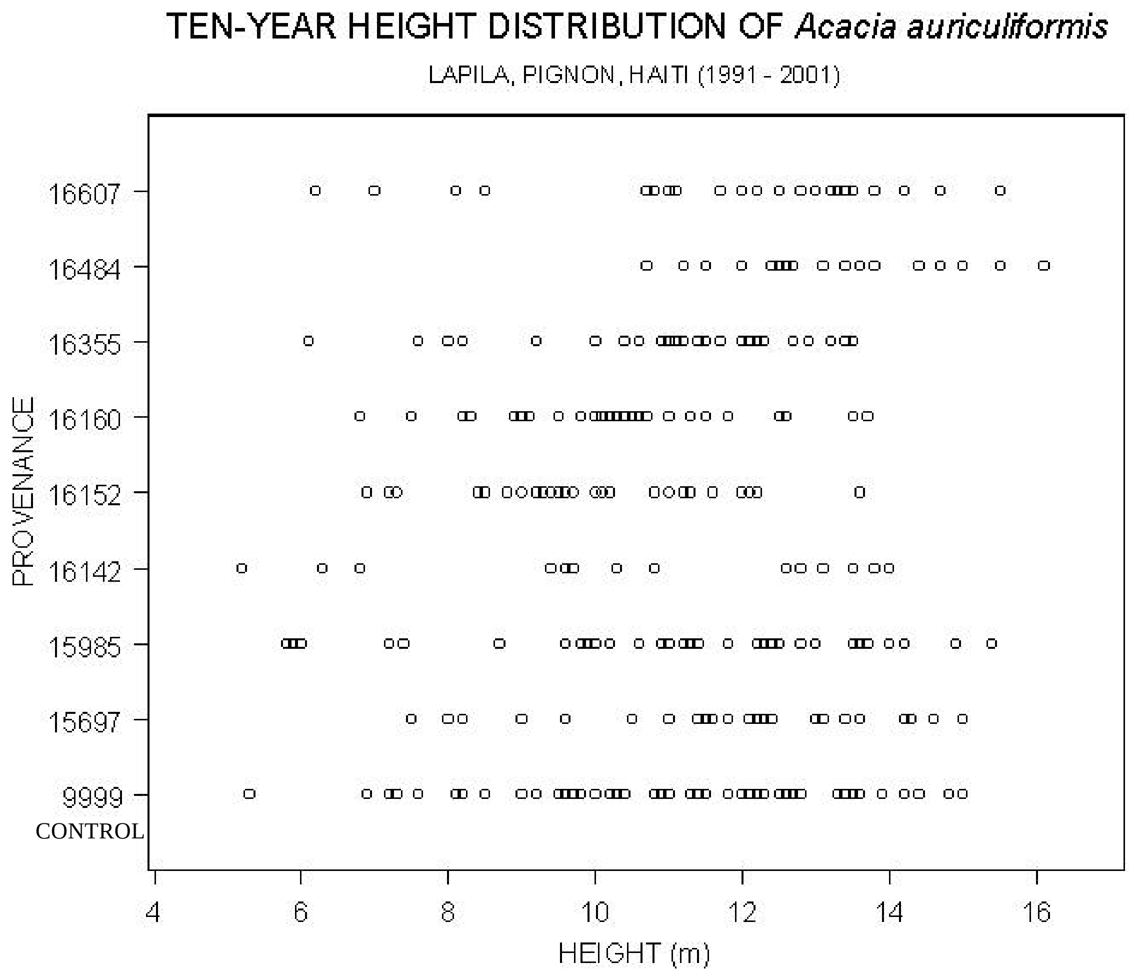

TEN-YEAR HEIGHT DISTRIBUTION OF *Acacia auriculiformis*
LAPILA, PIGNON, HAITI (1991 - 2001)
PROVENANCE
16607
16484
16355
16160
16152
16142
15985
15697
9999
CONTROL
4
6
8
10
12
14
16
HEIGHT (m)

Figure 3.1

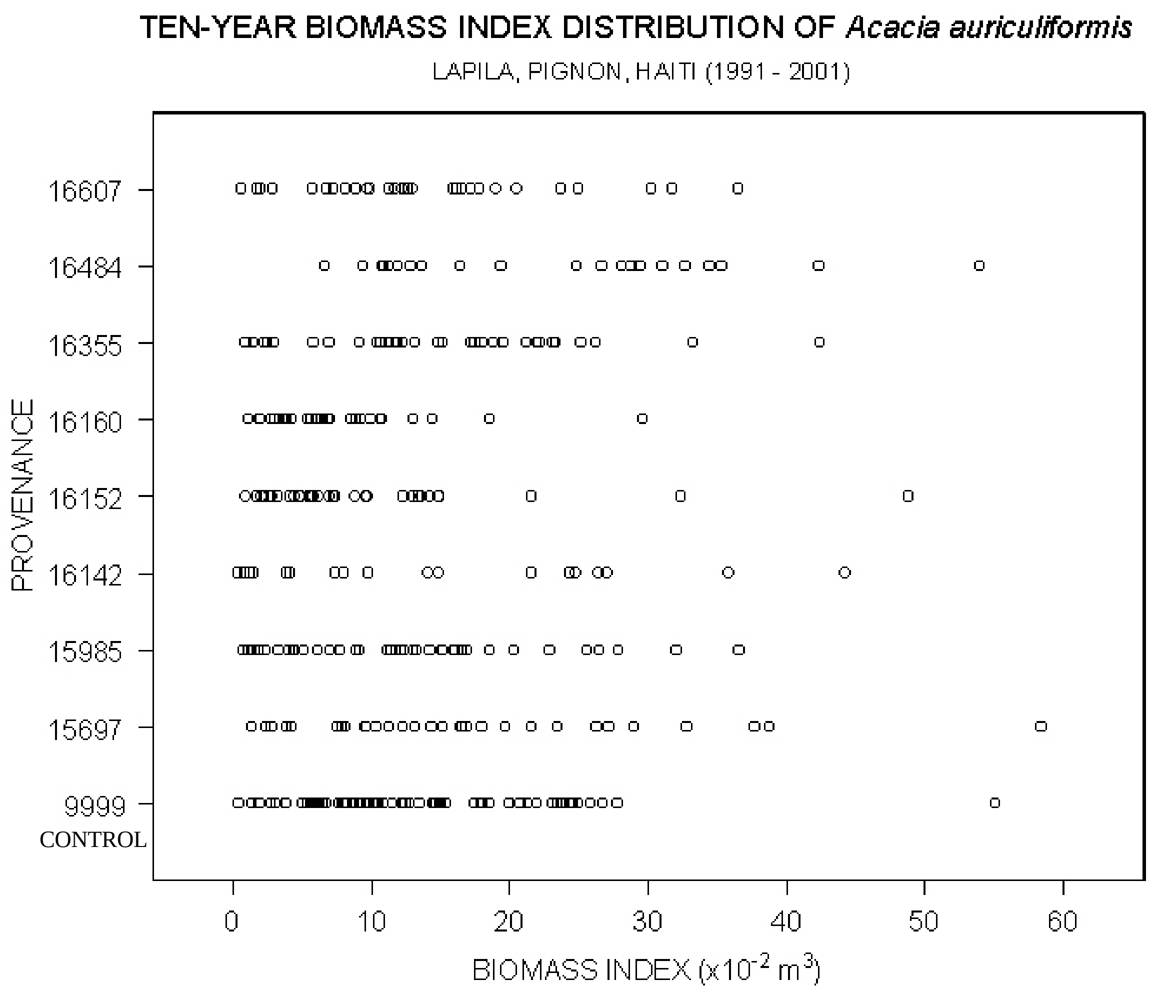

TEN-YEAR BIOMASS INDEX DISTRIBUTION OF *Acacia auriculiformis*
LAPILA, PIGNON, HAITI (1991 - 2001)
PROVENANCE
16607
16484
16355
16160
16152
16142
15985
15697
9999
CONTROL
0
10
20
30
40
50
60
BIOMASS INDEX (x10-2 m3)

Figure 3.2

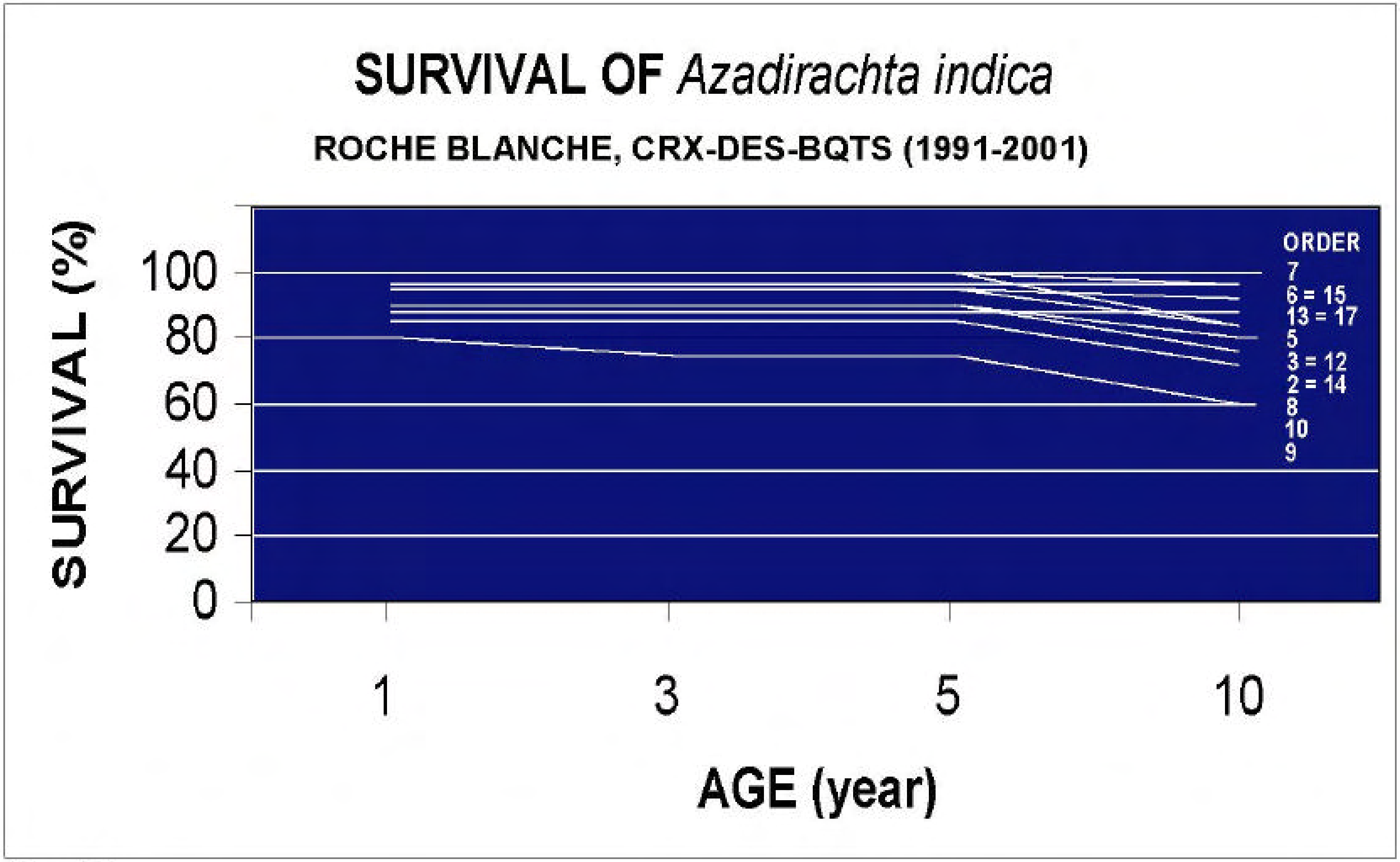

SURVIVAL OF Azadirachta indica
ROCHE BLANCHE, CRX-DES-BQTS (1991-2001)
SURVIVAL (%)
100
80
60
40
20
0
1
3
5
10
AGE (year)
ORDER
7
6 = 15
13 = 17
5
3 = 12
2 = 14
8
10
9

Figure 3.3

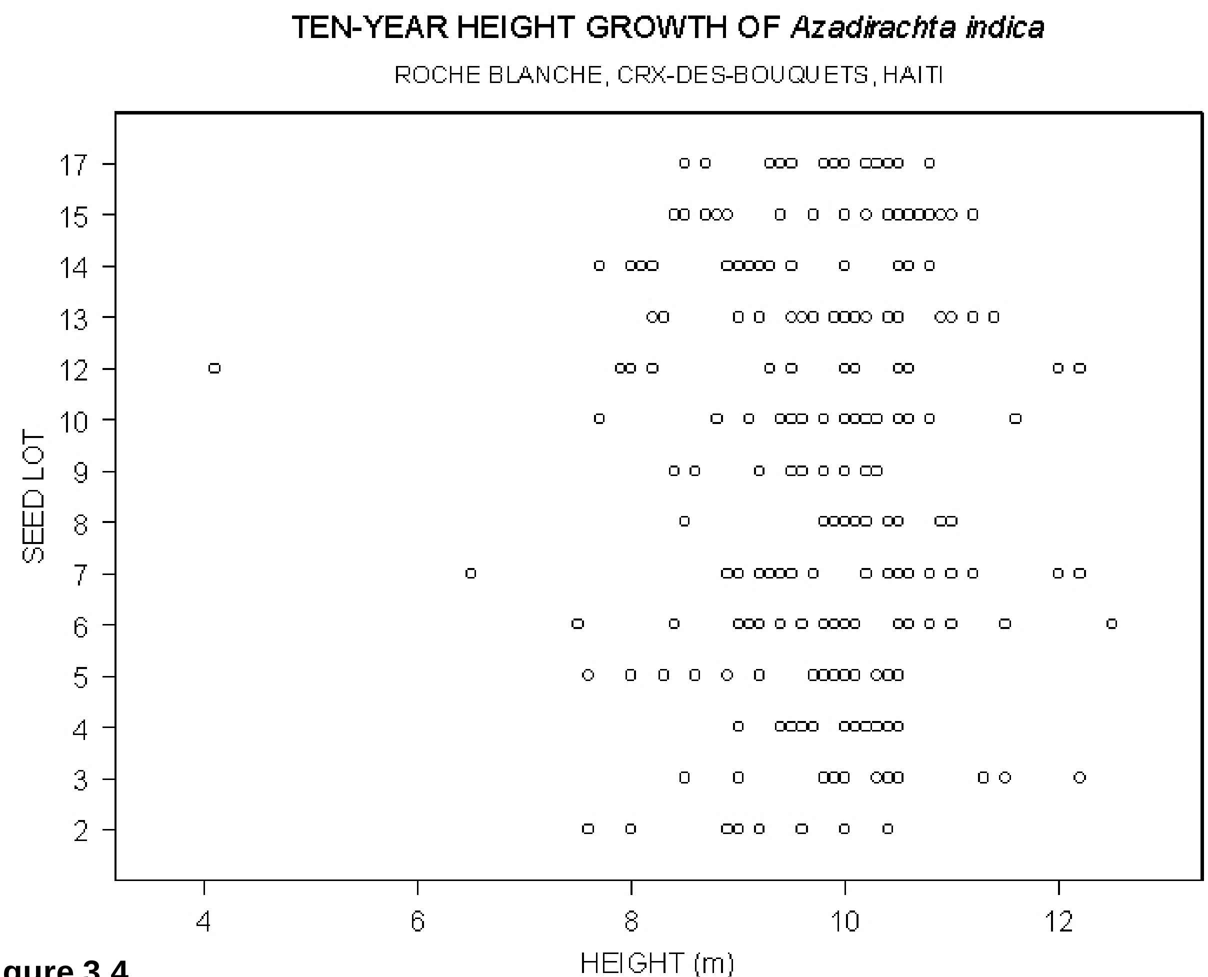

TEN-YEAR HEIGHT GROWTH OF *Azadirachta indica*
ROCHE BLANCHE, CRX-DES-BOUQUETS, HAITI
SEED LOT
17
15
14
13
12
10
9
8
7
6
5
4
3
2
4
6
8
10
12
HEIGHT (m)

Figure 3.4

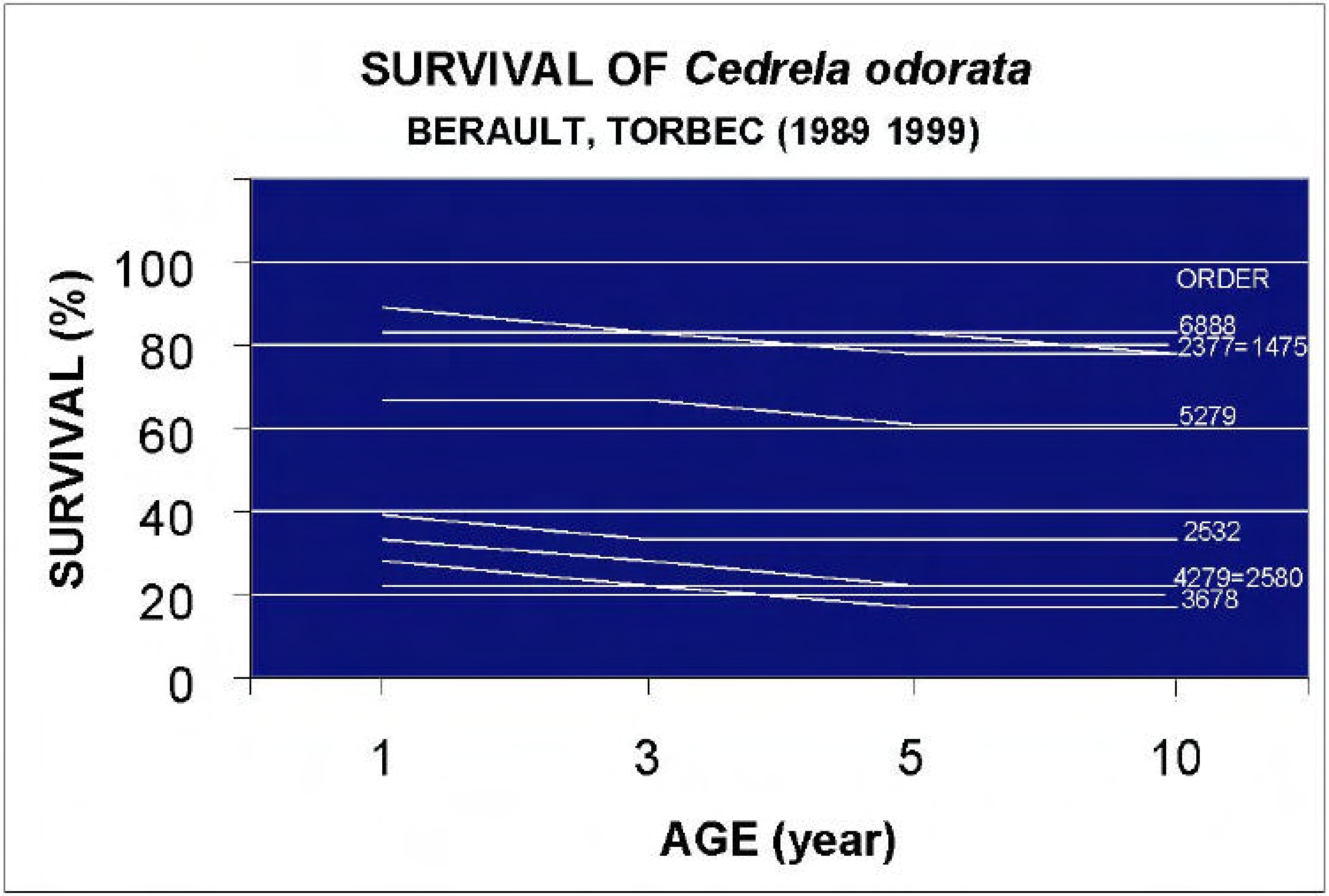

SURVIVAL OF Cedrela odorata
BERAULT, TORBEC (1989 1999)
SURVIVAL (%)
100
80
60
40
20
0
ORDER
6888
2377=1475
5279
2532
4279=2580
3678
1
3
5
10
AGE (year)

Figure 3.5

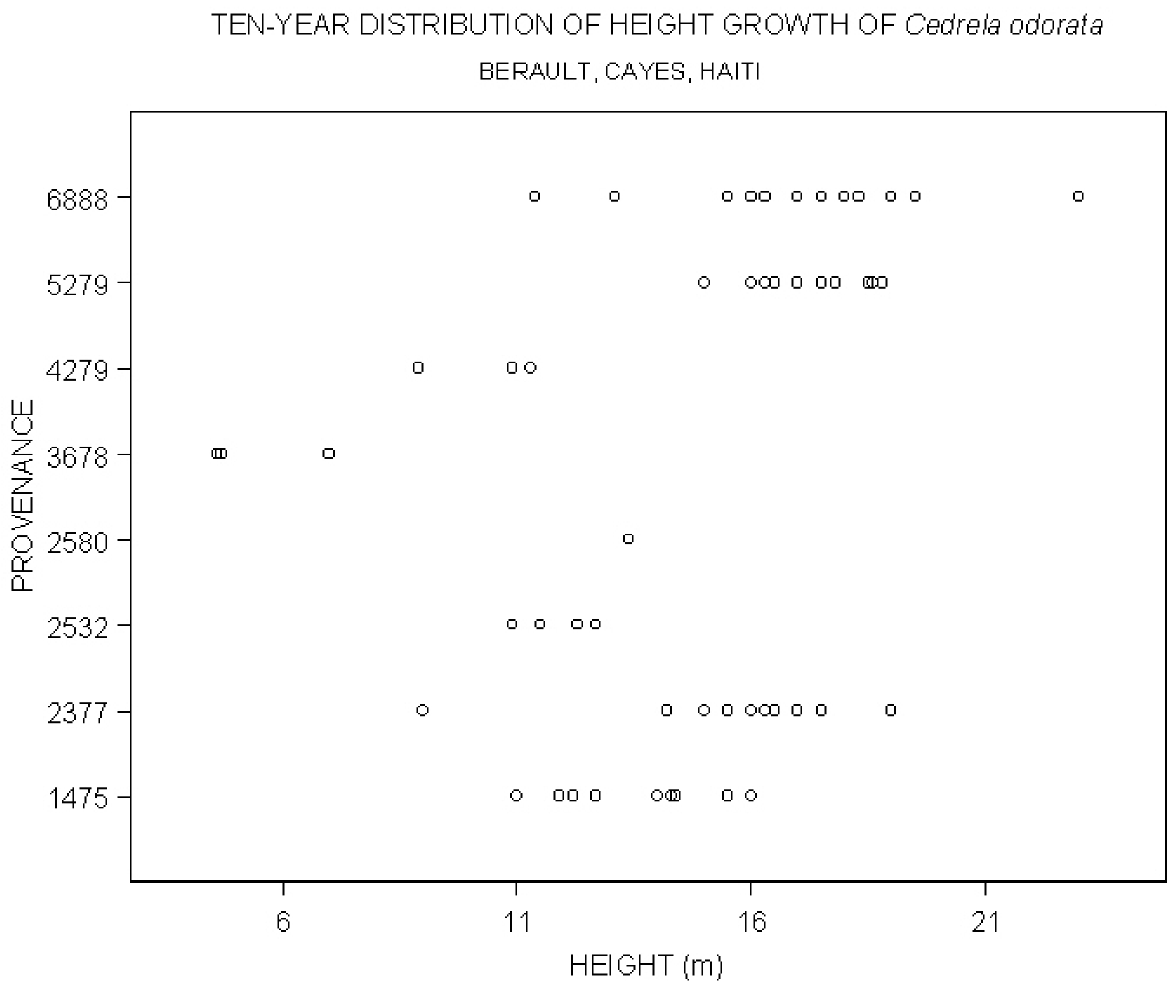

TEN-YEAR DISTRIBUTION OF HEIGHT GROWTH OF *Cedrela odorata*
BERAULT, CAYES, HAITI
PROVENANCE
6888
5279
4279
3678
2580
2532
2377
1475
6
11
16
21
HEIGHT (m)

Figure 3.6

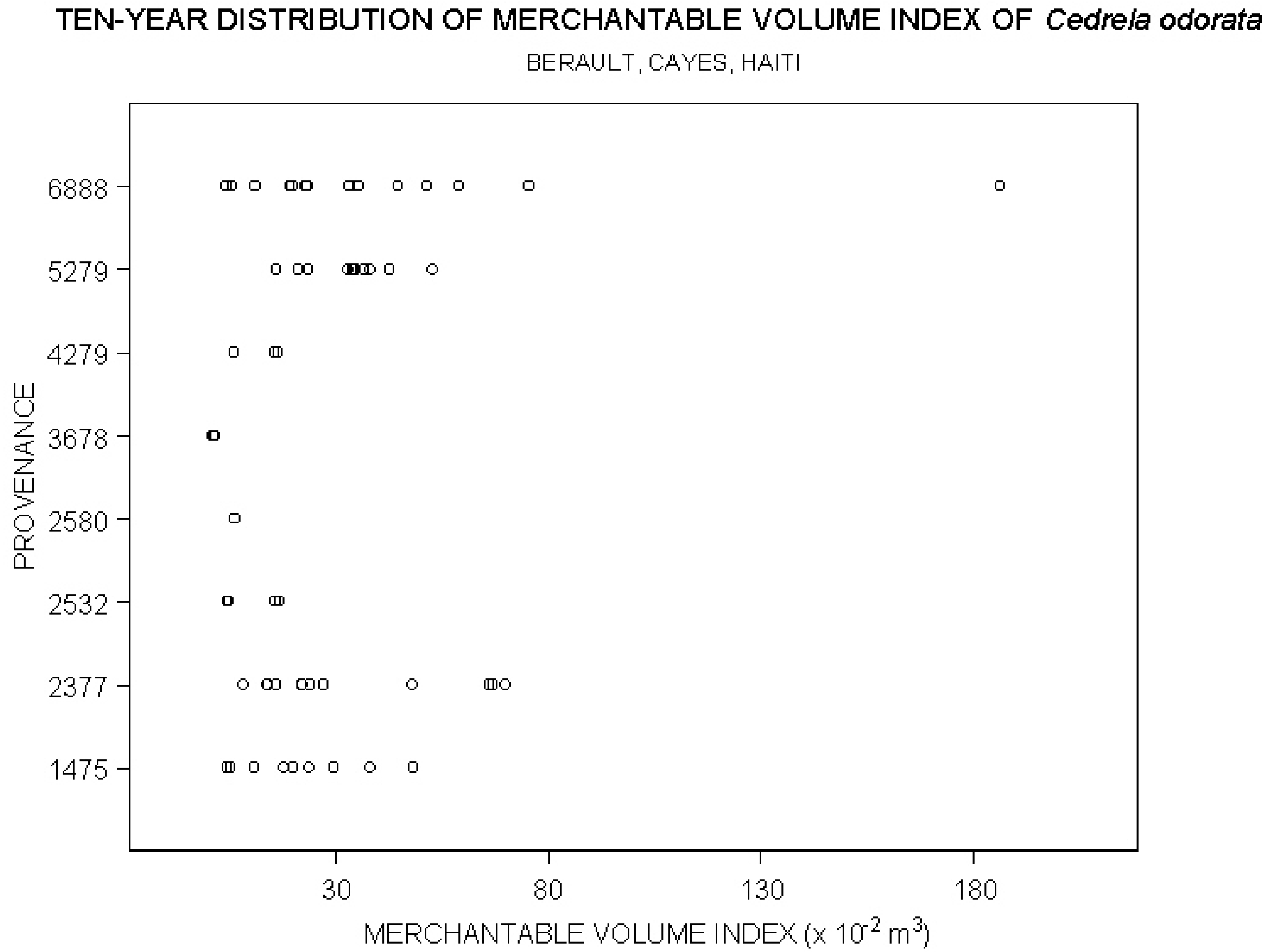

TEN-YEAR DISTRIBUTION OF MERCHANTABLE VOLUME INDEX OF *Cedrela odorata*
BERAULT, CAYES, HAITI
PROVENANCE
6888
5279
4279
3678
2580
2532
2377
1475
30
80
130
180
MERCHANTABLE VOLUME INDEX (x 10-2 m3)

Figure 3.7

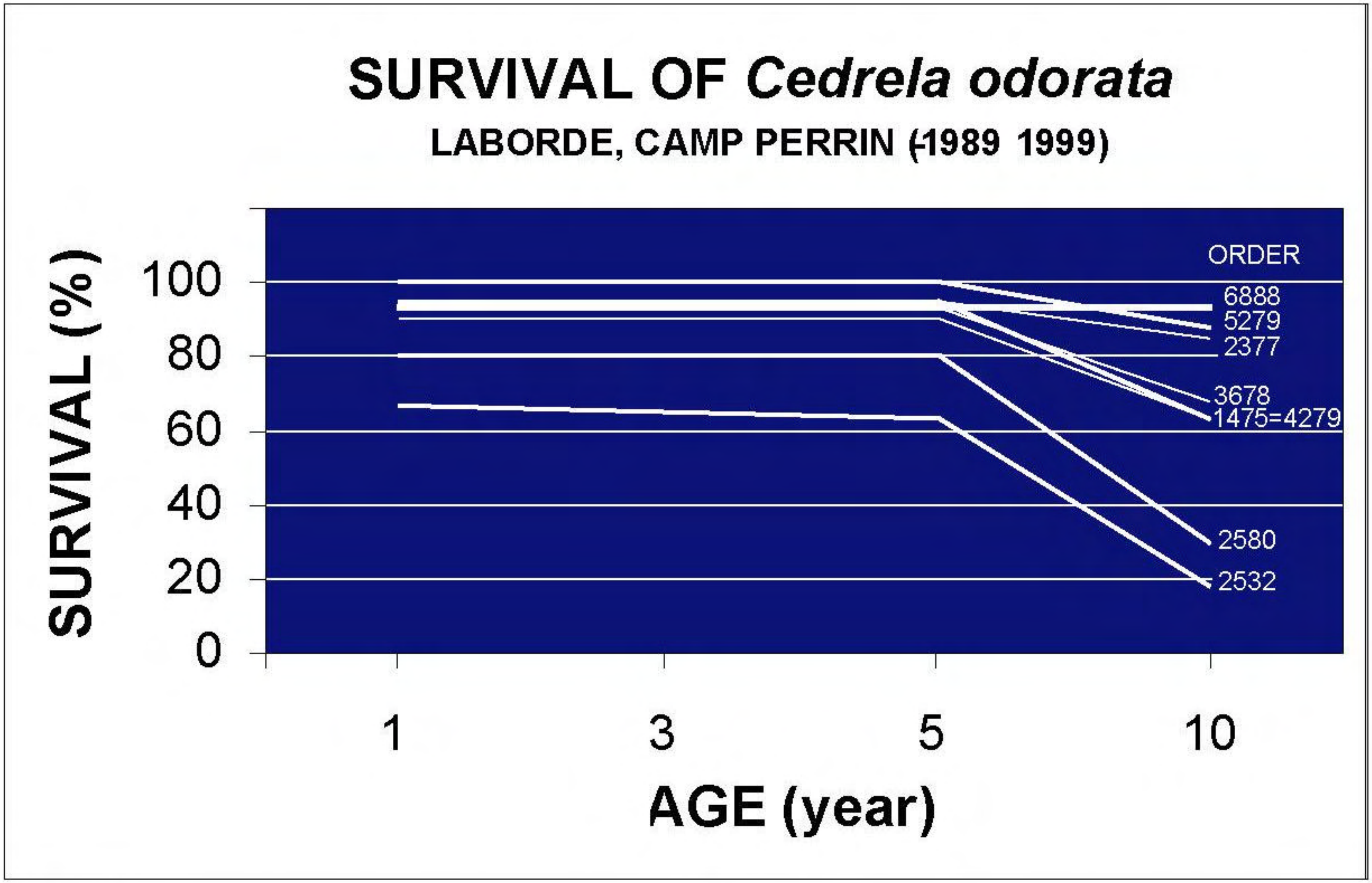

SURVIVAL OF *Cedrela odorata*
LABORDE, CAMP PERRIN (1989-1999)
SURVIVAL (%)
100
80
60
40
20
0
ORDER
6888
5279
2377
3678
1475=4279
2580
2532
1
3
5
10
AGE (year)

Figure 3.8

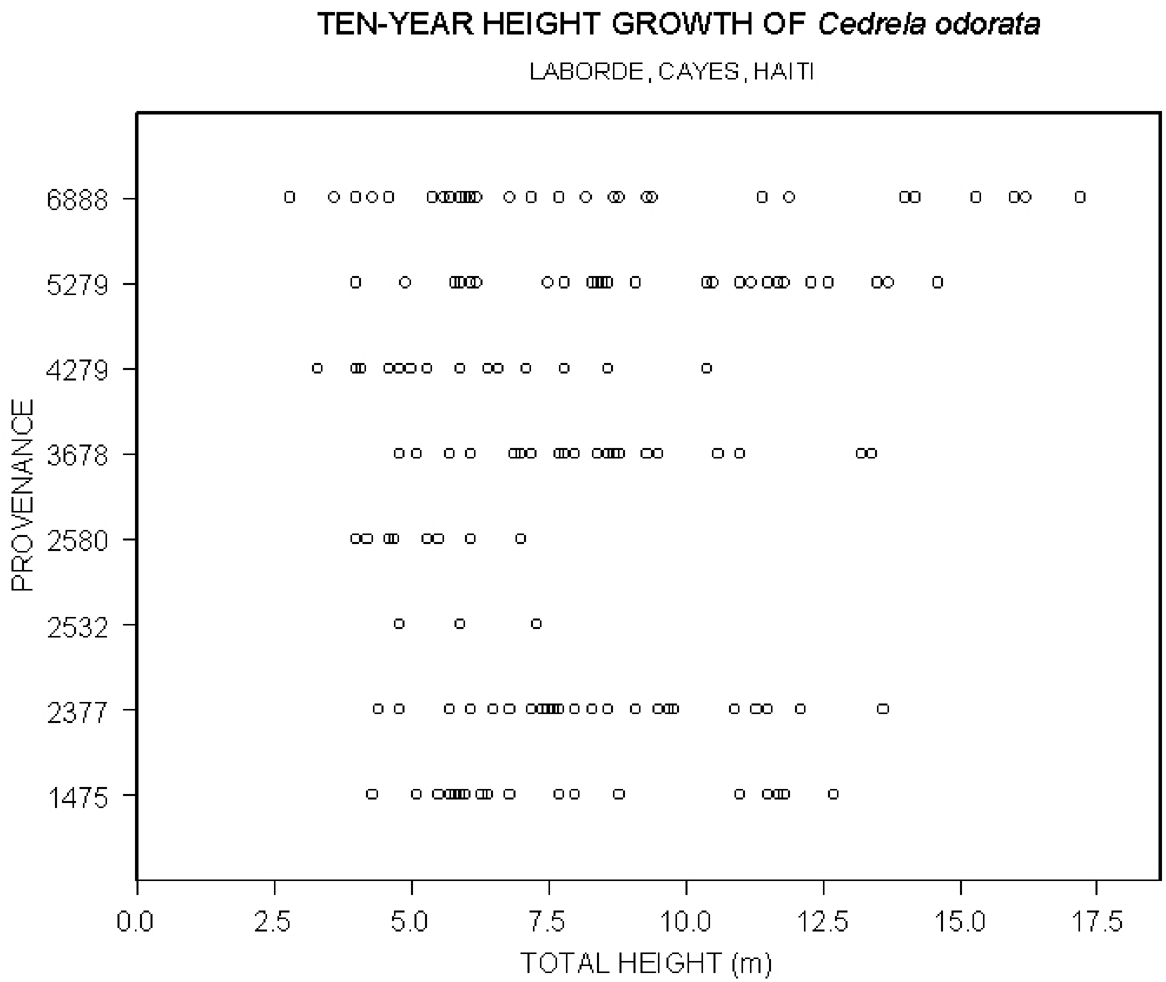

TEN-YEAR HEIGHT GROWTH OF *Cedrela odorata*
LABORDE, CAYES, HAITI
PROVENANCE
6888
5279
4279
3678
2580
2532
2377
1475
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
TOTAL HEIGHT (m)

Figure 3.9

TEN-YEAR DISTRIBUTION OF *Cedrela odorata* MERCHANTABLE VOLUME INDEX BY PROVENANCE

LABORDE, CAYES, HAITI

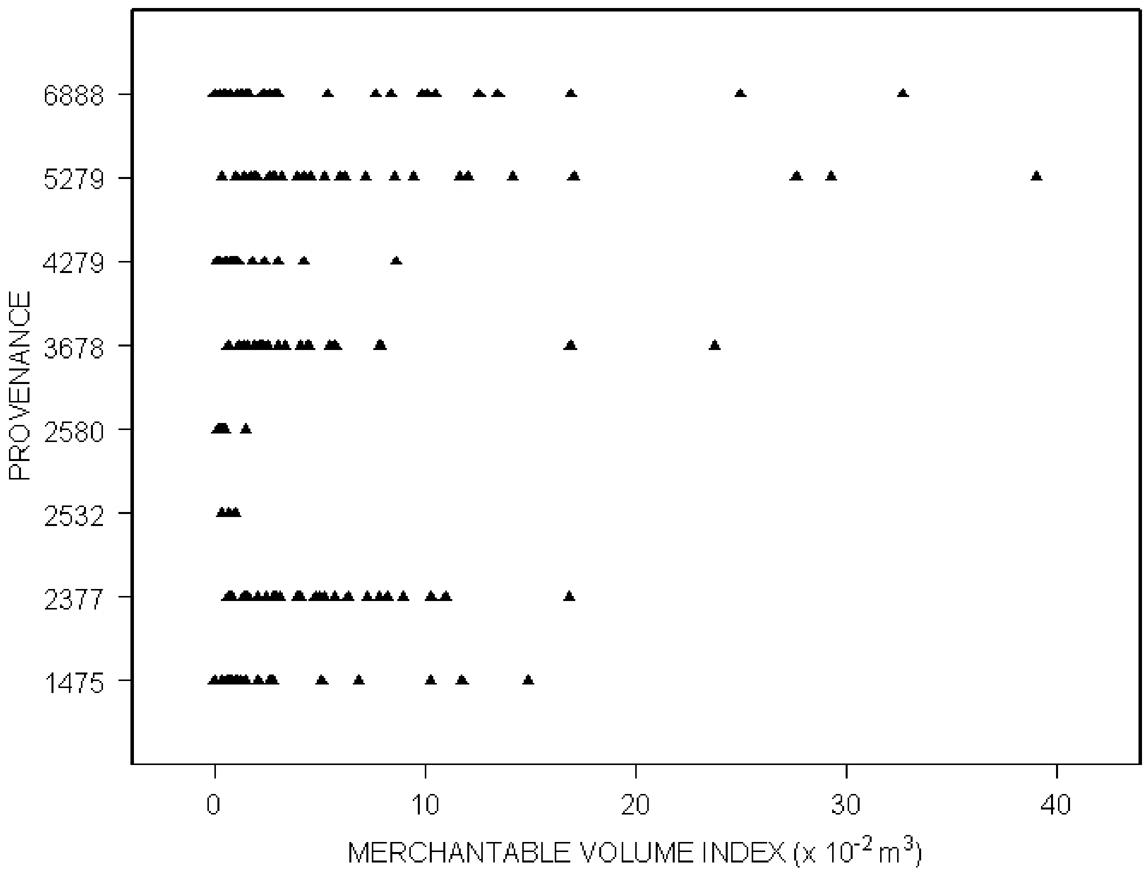


Figure 3.10

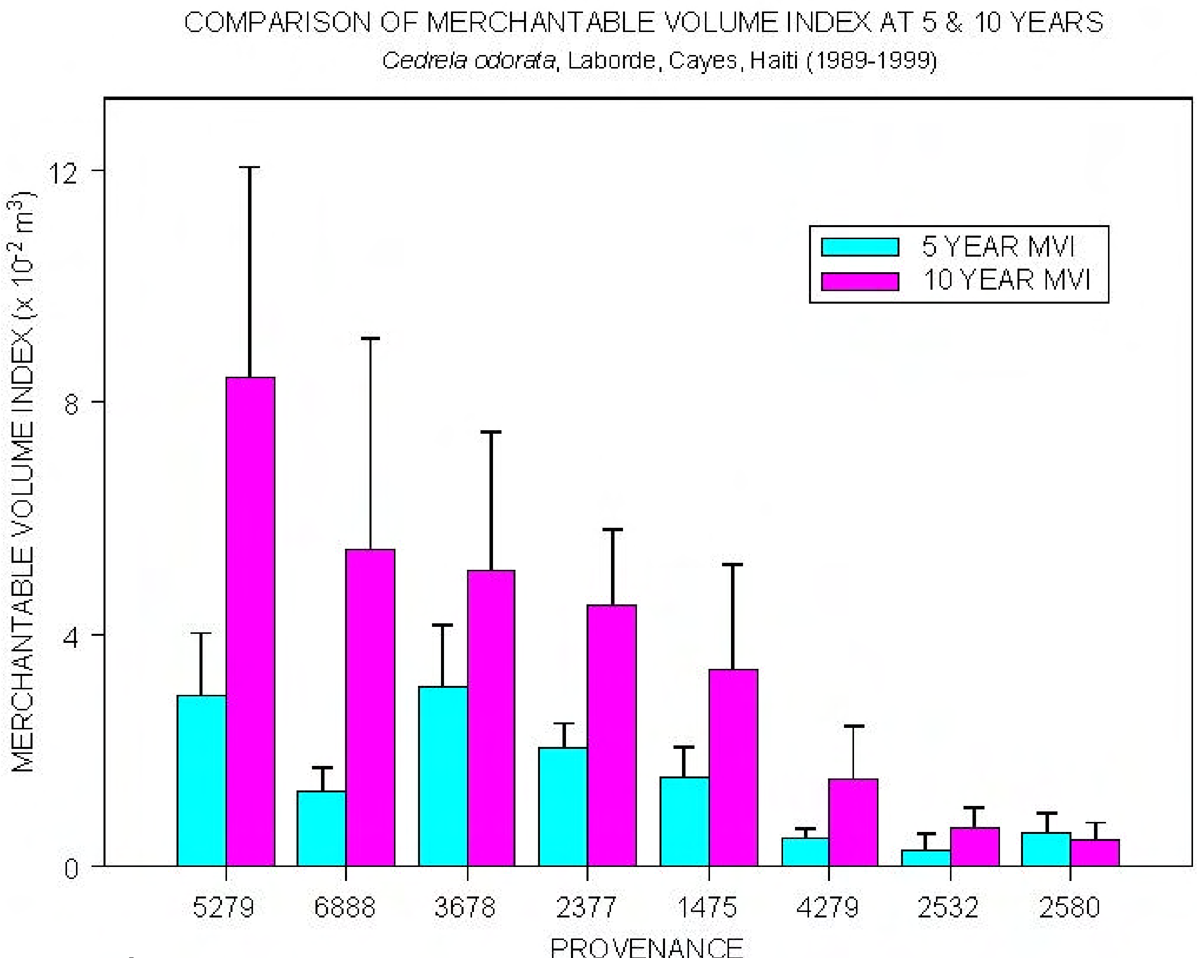

COMPARISON OF MERCHANTABLE VOLUME INDEX AT 5 & 10 YEARS
Cedrela odorata, Laborde, Cayes, Haiti (1989-1999)
MERCHANTABLE VOLUME INDEX (x 10-2 m3)
12
8
4
0
5 YEAR MVI
10 YEAR MVI
5279
6888
3678
2377
1475
4279
2532
2580
PROVENANCE

Figure 3.11

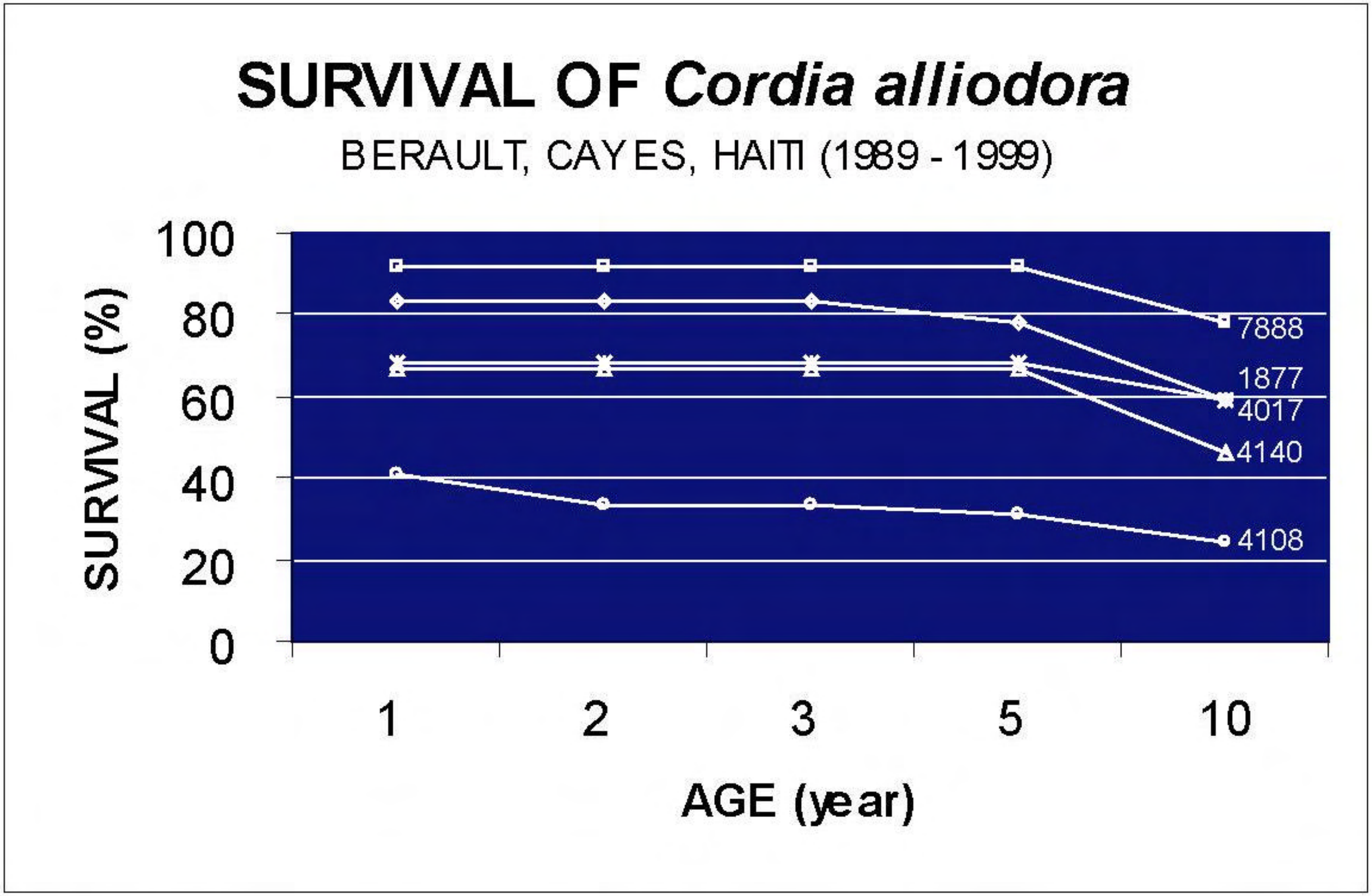

SURVIVAL OF *Cordia alliodora*
BERAULT, CAYES, HAITI (1989 - 1999)
SURVIVAL (%)
100
80
60
40
20
0
7888
1877
4017
4140
4108
1
2
3
5
10
AGE (year)

Figure 3.12

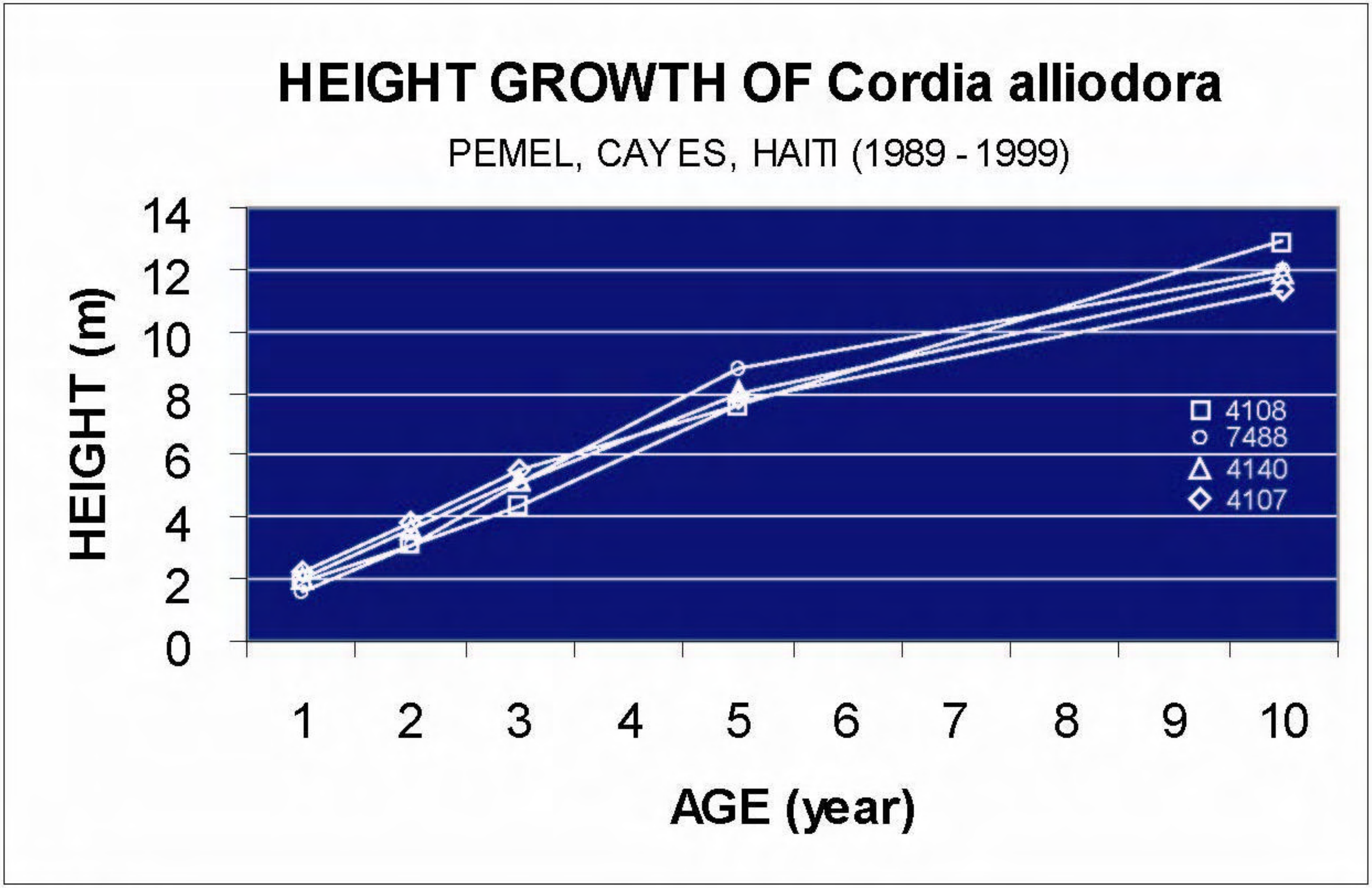

HEIGHT GROWTH OF Cordia alliodora
PEMEL, CAYES, HAITI (1989 - 1999)
HEIGHT (m)
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
AGE (year)
4108
7488
4140
4107

Figure 3.13

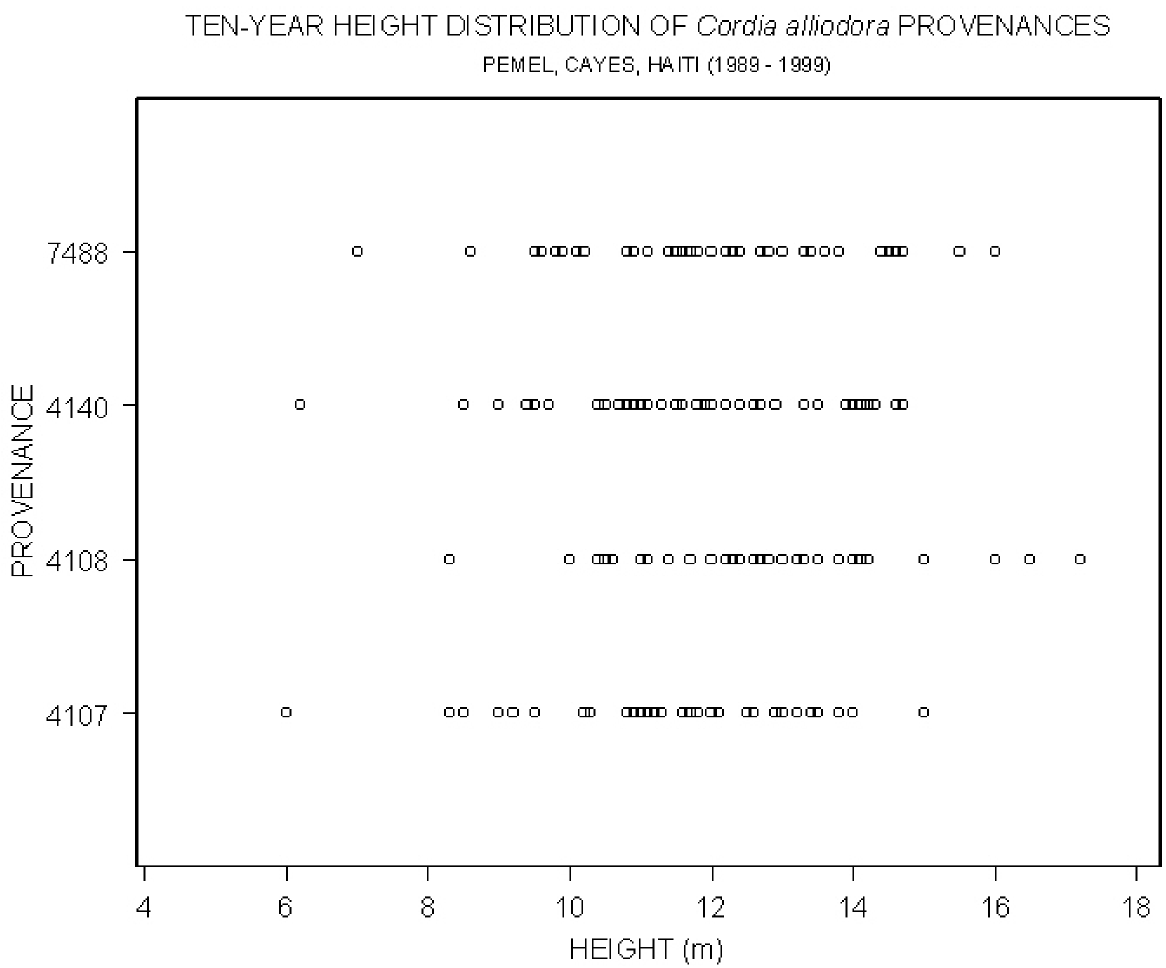

TEN-YEAR HEIGHT DISTRIBUTION OF *Cordia alliodora* PROVENANCES
PEMEL, CAYES, HAITI (1989 - 1999)
PROVENANCE
7488
4140
4108
4107
4
6
8
10
12
14
16
18
HEIGHT (m)

Figure 3.14

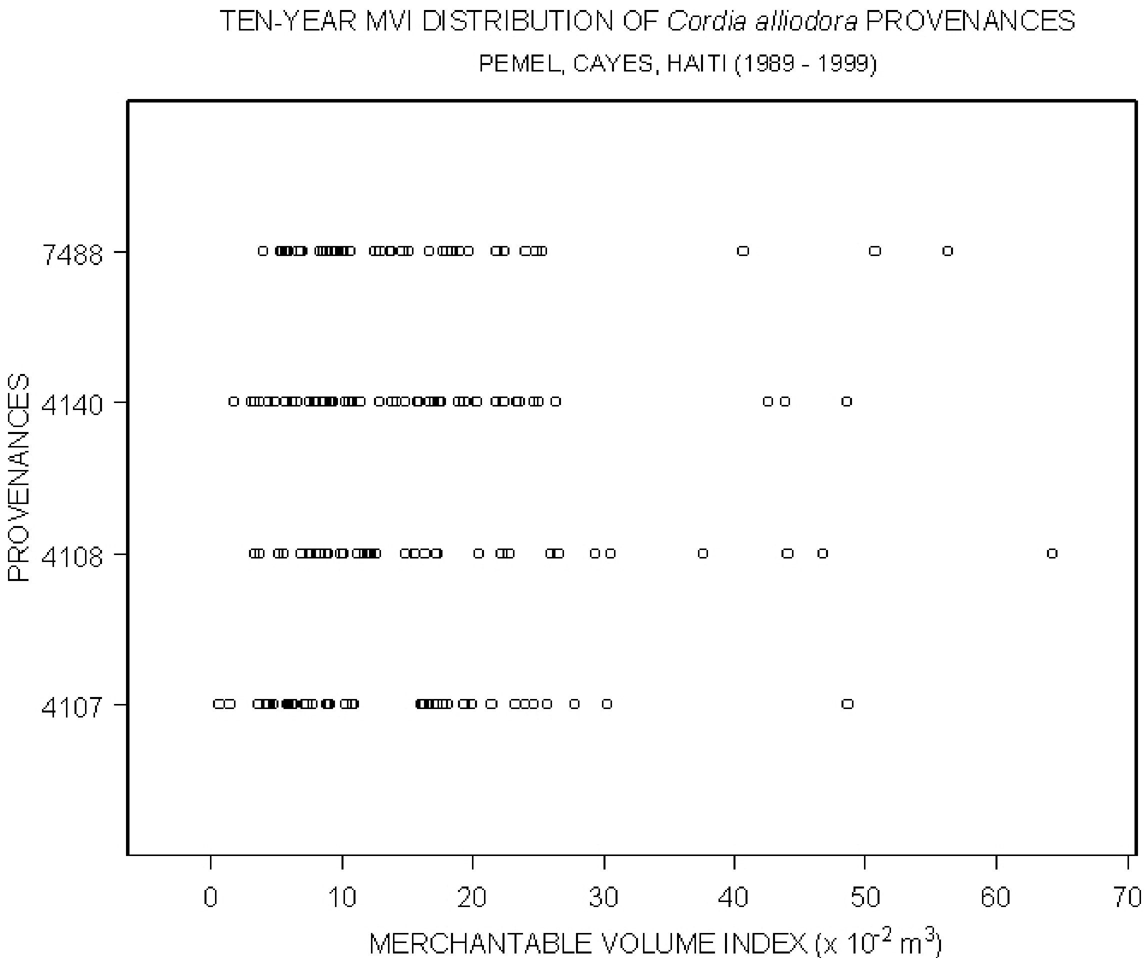

TEN-YEAR MVI DISTRIBUTION OF *Cordia alliodora* PROVENANCES
PEMEL, CAYES, HAITI (1989 - 1999)
PROVENANCES
7488
4140
4108
4107
0
10
20
30
40
50
60
70
MERCHANTABLE VOLUME INDEX (x 10^{-2} m^3)

Figure 3.15

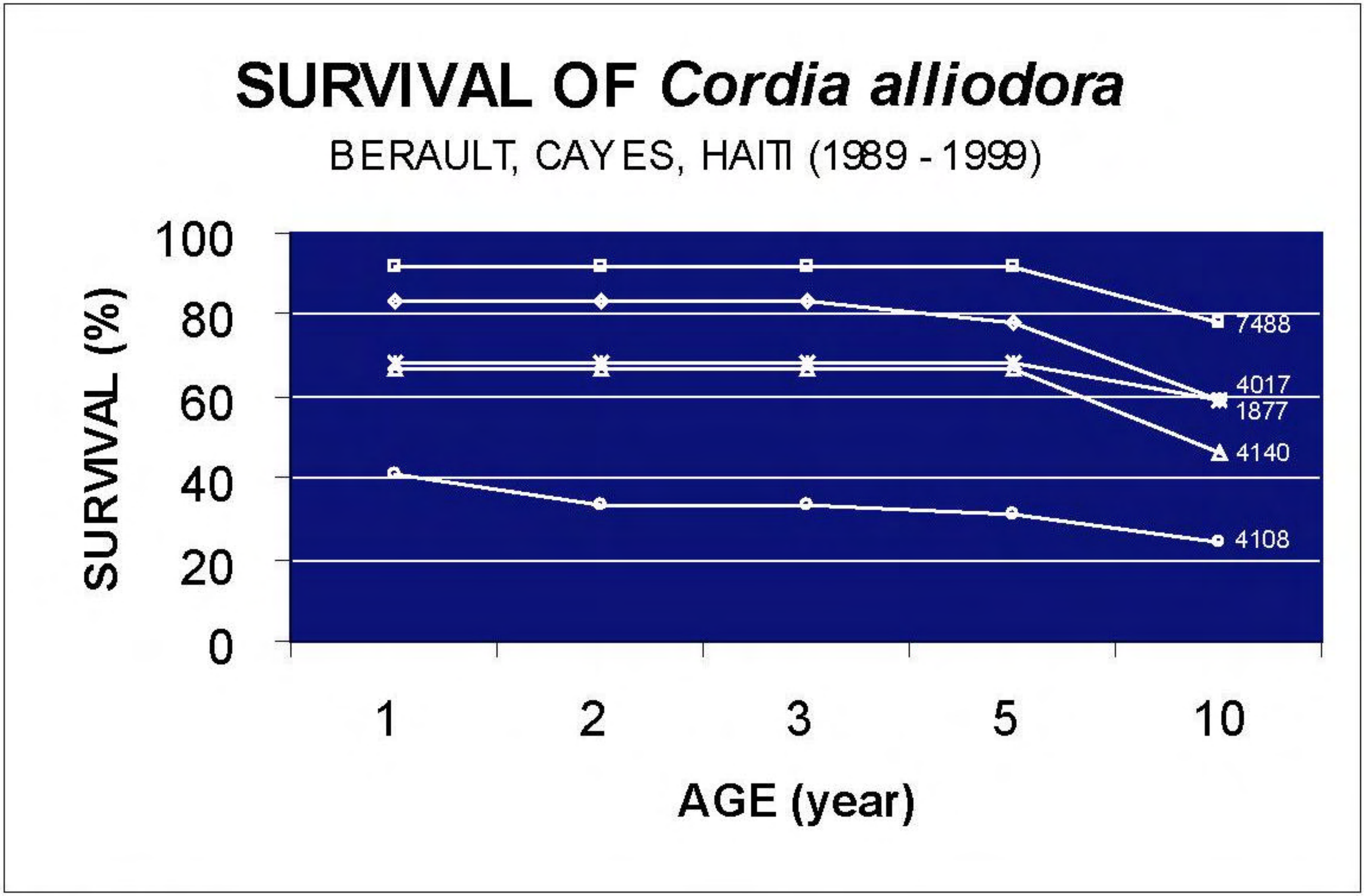

SURVIVAL OF *Cordia alliodora*
BERAULT, CAYES, HAITI (1989 - 1999)
SURVIVAL (%)
100
80
60
40
20
0
7488
4017
1877
4140
4108
1
2
3
5
10
AGE (year)

Figure 3.16

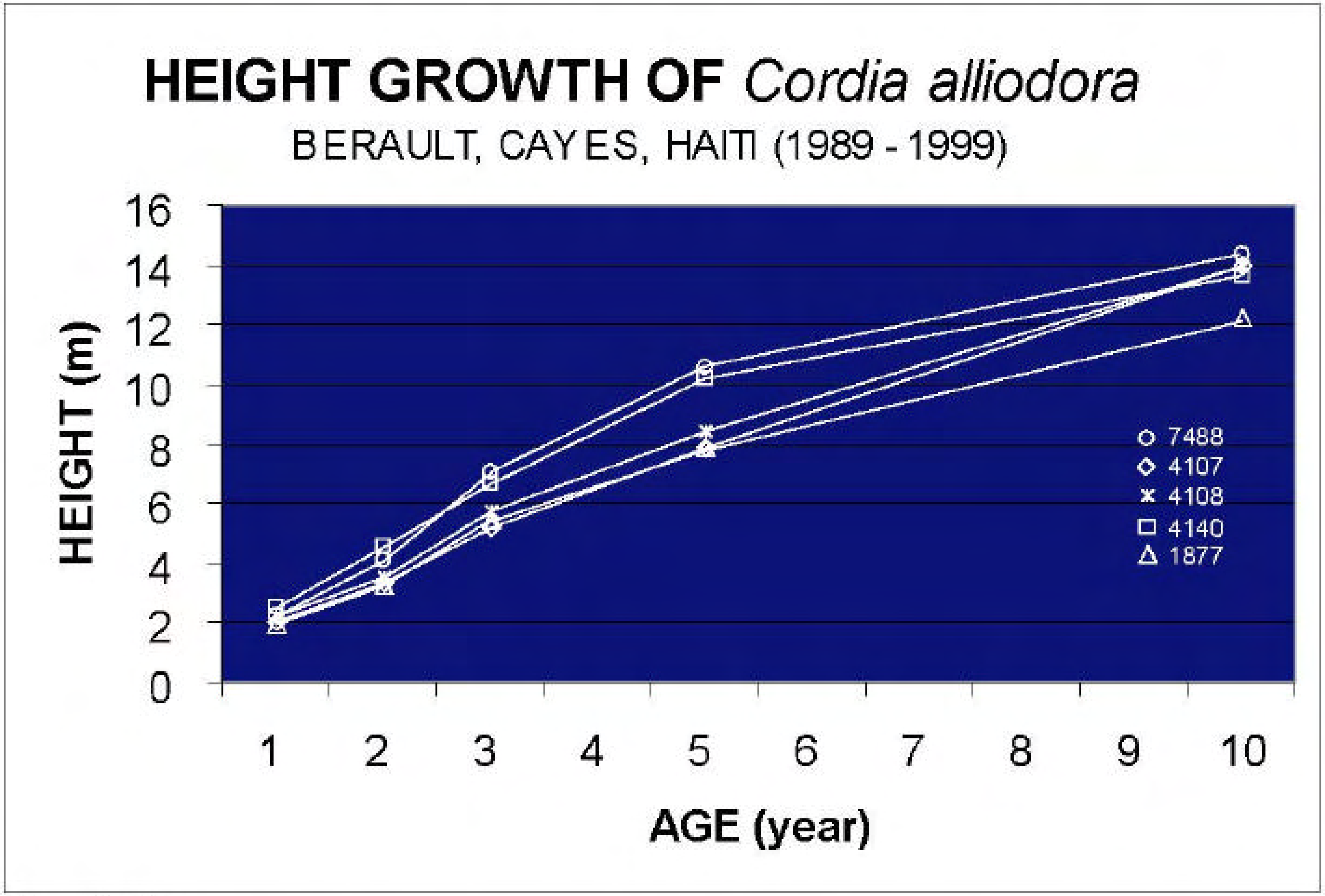

HEIGHT GROWTH OF *Cordia alliodora*
BERAULT, CAYES, HAITI (1989 - 1999)
HEIGHT (m)
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
AGE (year)
7488
4107
4108
4140
1877

Figure 3. 17

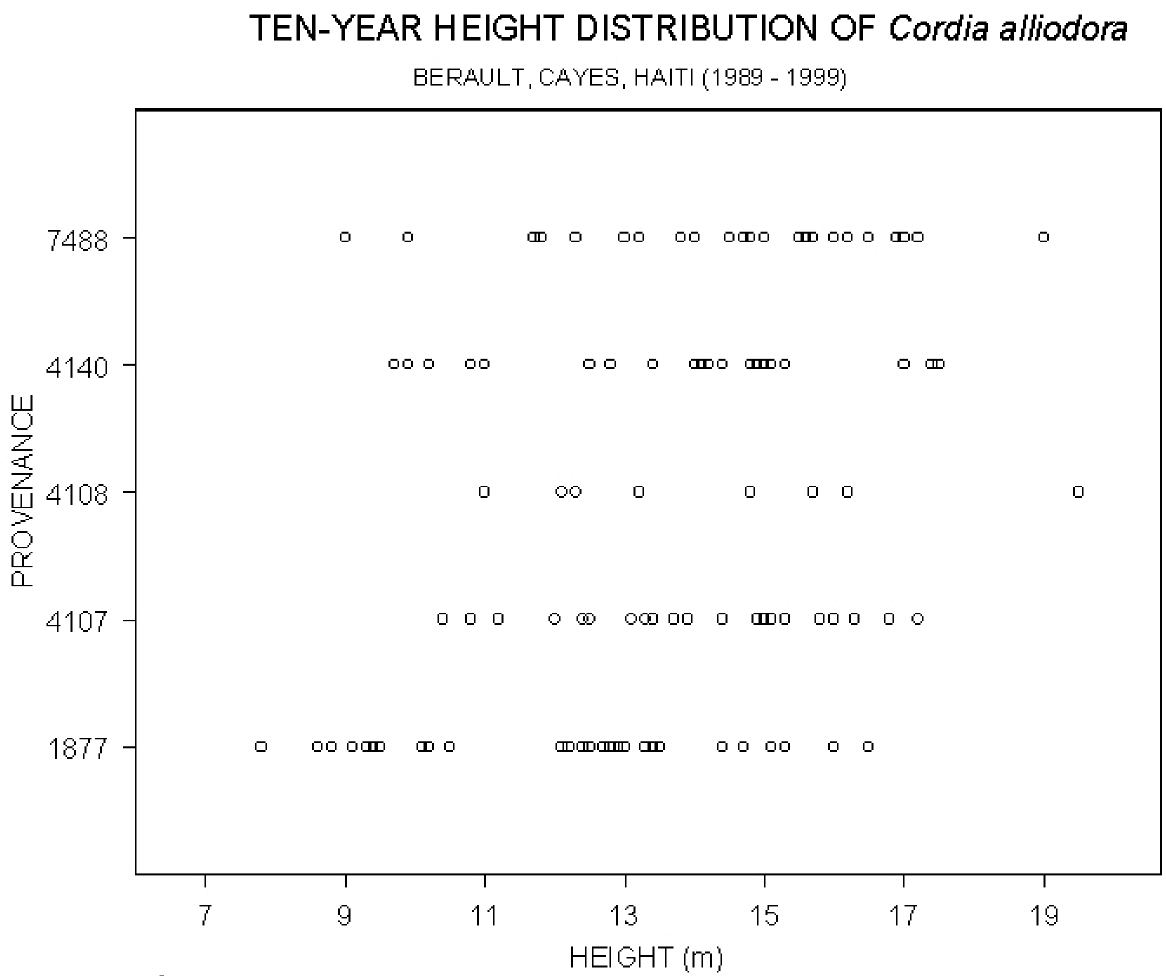

TEN-YEAR HEIGHT DISTRIBUTION OF Cordia alliodora
BERAULT, CAYES, HAITI (1989 - 1999)
PROVENANCE
7488
4140
4108
4107
1877
7
9
11
13
15
17
19
HEIGHT (m)

Figure 3.18

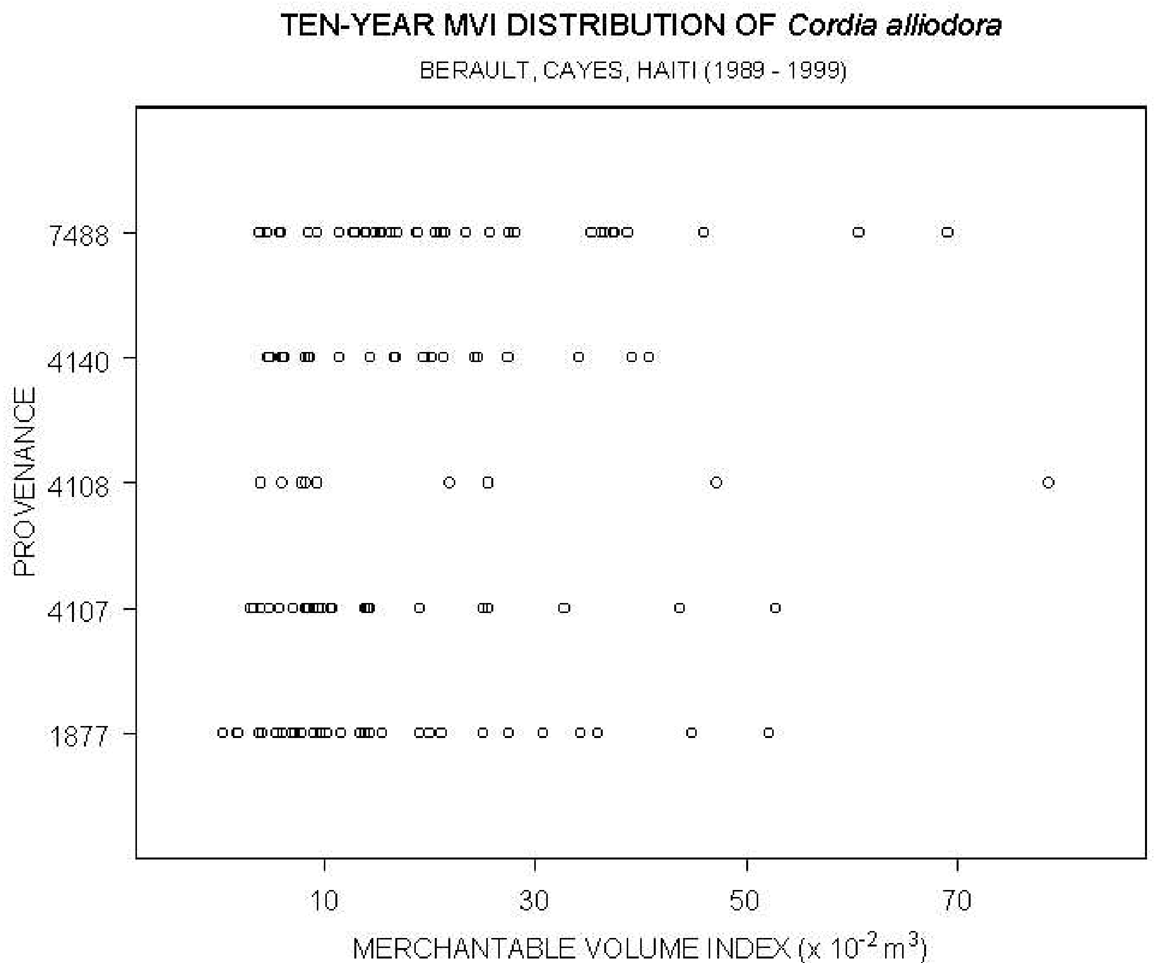

TEN-YEAR MVI DISTRIBUTION OF Cordia alliodora
BERAULT, CAYES, HAITI (1989 - 1999)
PROVENANCE
7488
4140
4108
4107
1877
10
30
50
70
MERCHANTABLE VOLUME INDEX (x 10-2 m3)

Figure 3.19

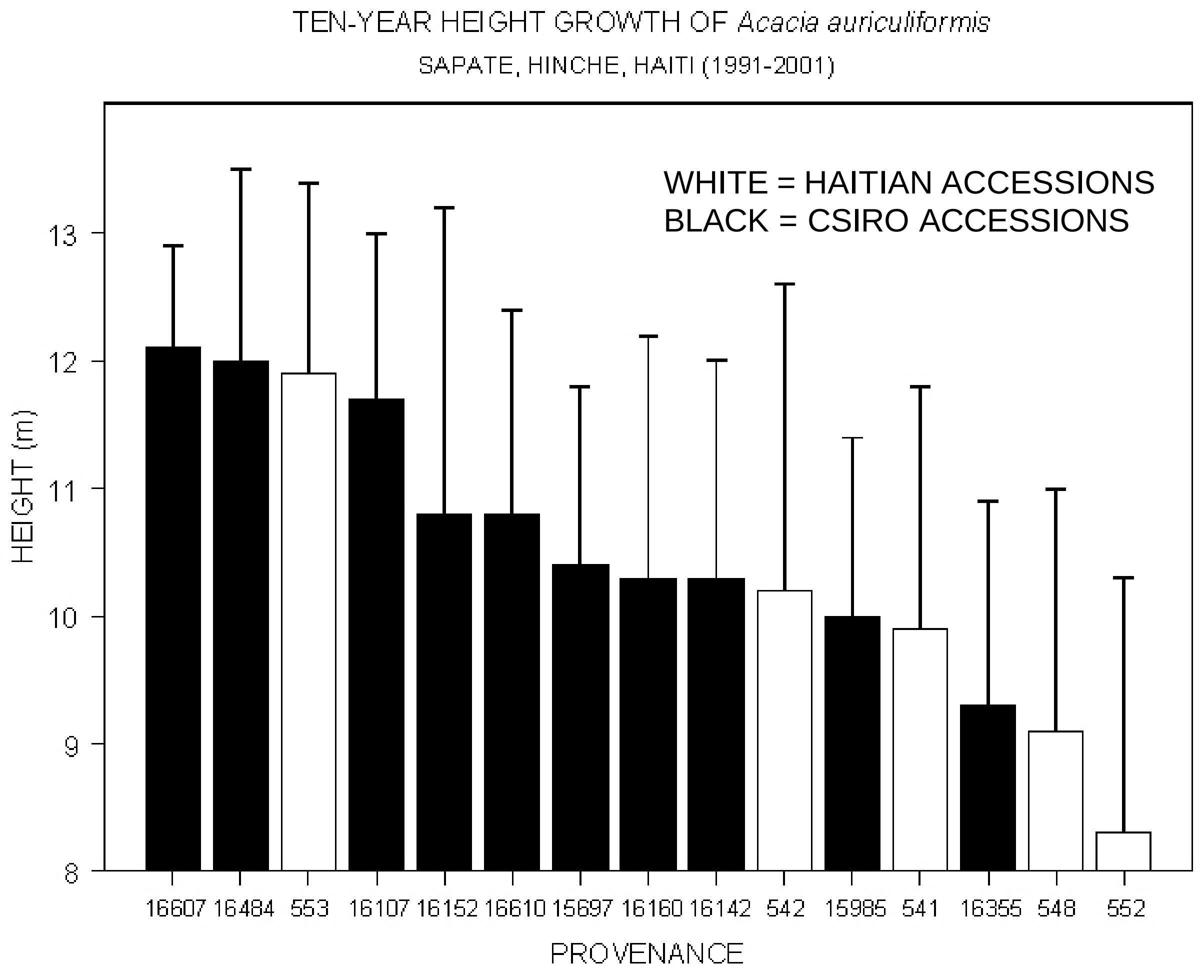

TEN-YEAR HEIGHT GROWTH OF Acacia auriculiformis
SAPATE, HINCHE, HAITI (1991-2001)
WHITE = HAITIAN ACCESSIONS
BLACK = CSIRO ACCESSIONS
HEIGHT (m)
8
9
10
11
12
13
16607
16484
553
16107
16152
16610
15697
16160
16142
542
15985
541
16355
548
552
PROVENANCE

Figure 4.1

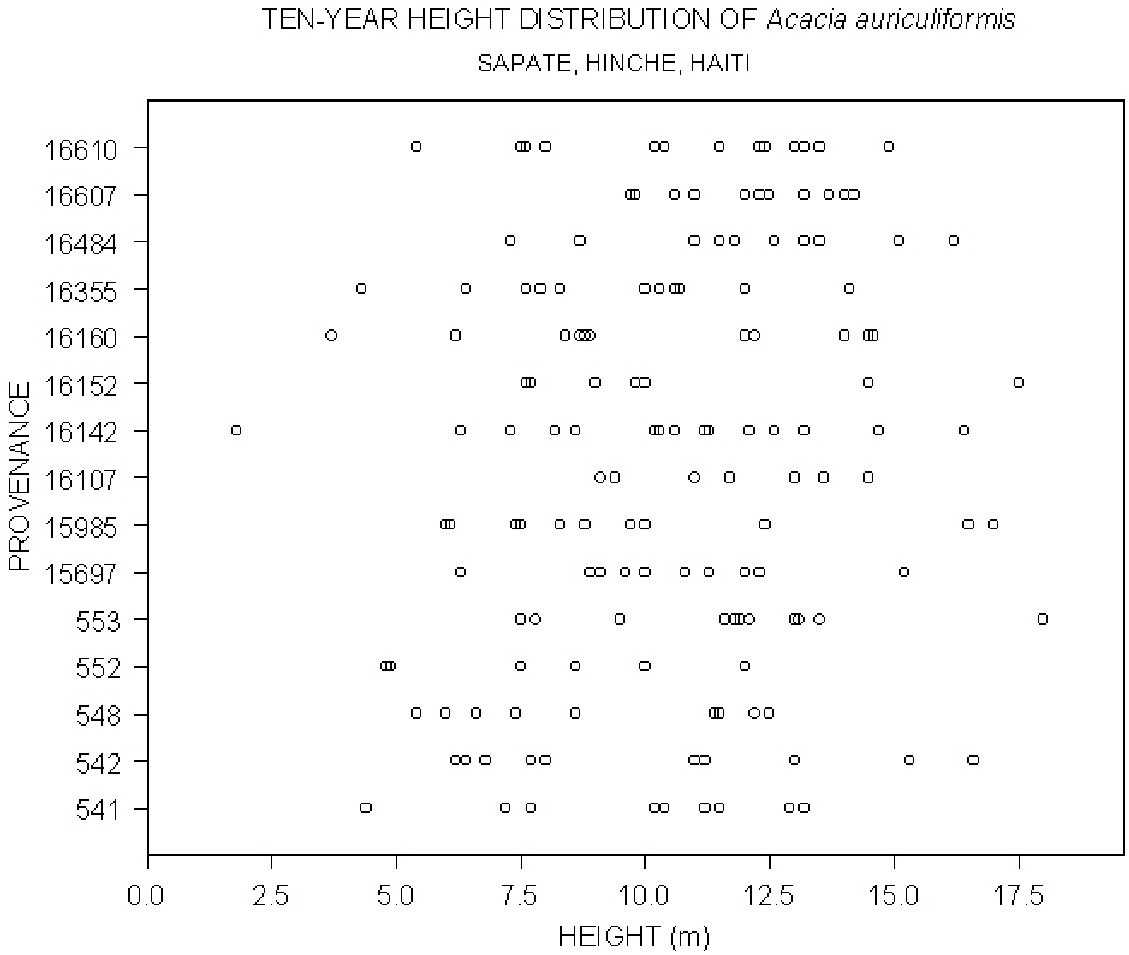

TEN-YEAR HEIGHT DISTRIBUTION OF *Acacia auriculiformis*
SAPATE, HINCHE, HAITI
PROVENANCE
16610
16607
16484
16355
16160
16152
16142
16107
15985
15697
553
552
548
542
541
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
HEIGHT (m)

Figure 4.2

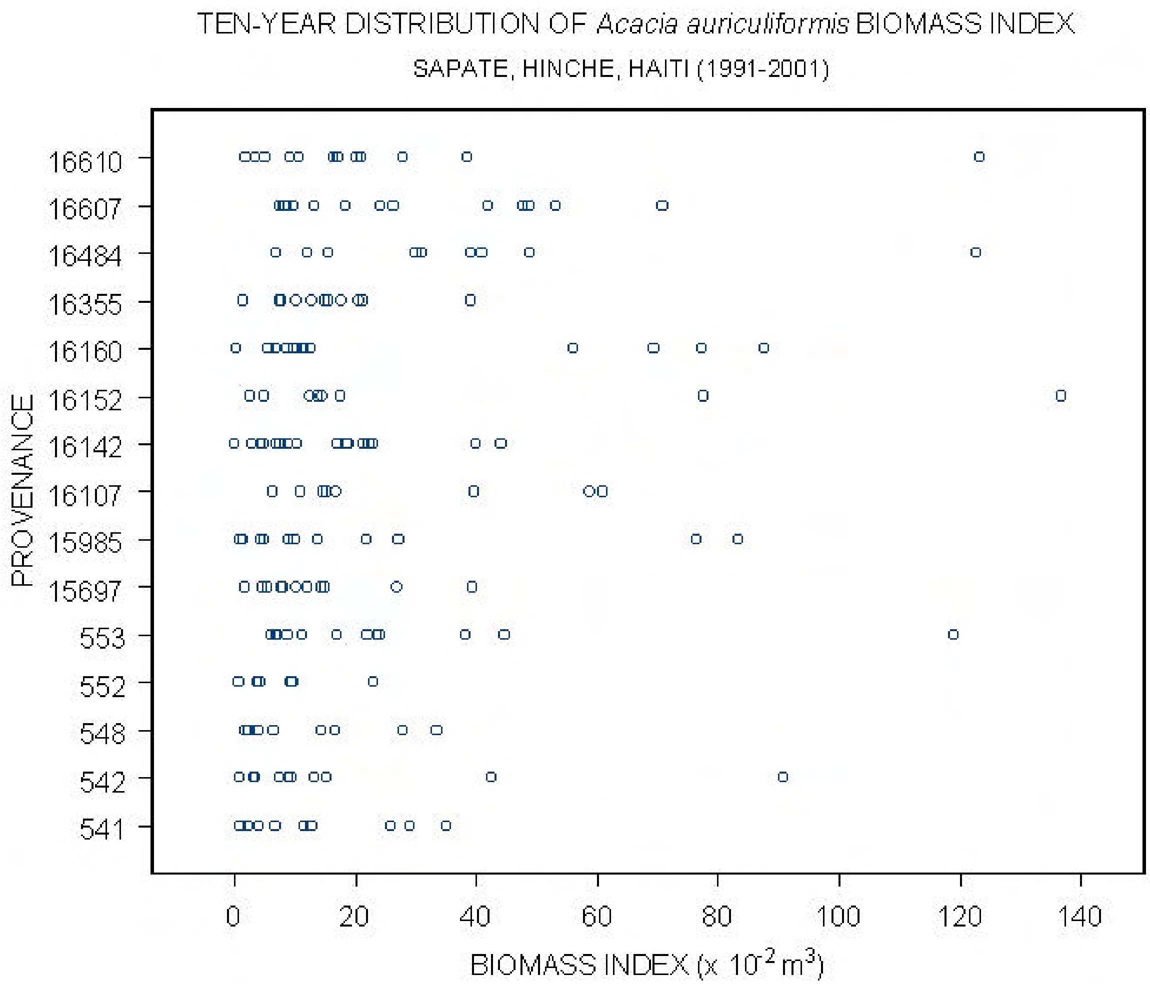

TEN-YEAR DISTRIBUTION OF Acacia auriculiformis BIOMASS INDEX
SAPATE, HINCHE, HAITI (1991-2001)
PROVENANCE
16610
16607
16484
16355
16160
16152
16142
16107
15985
15697
553
552
548
542
541
0
20
40
60
80
100
120
140
BIOMASS INDEX (x 10-2 m3)

Figure 4.3

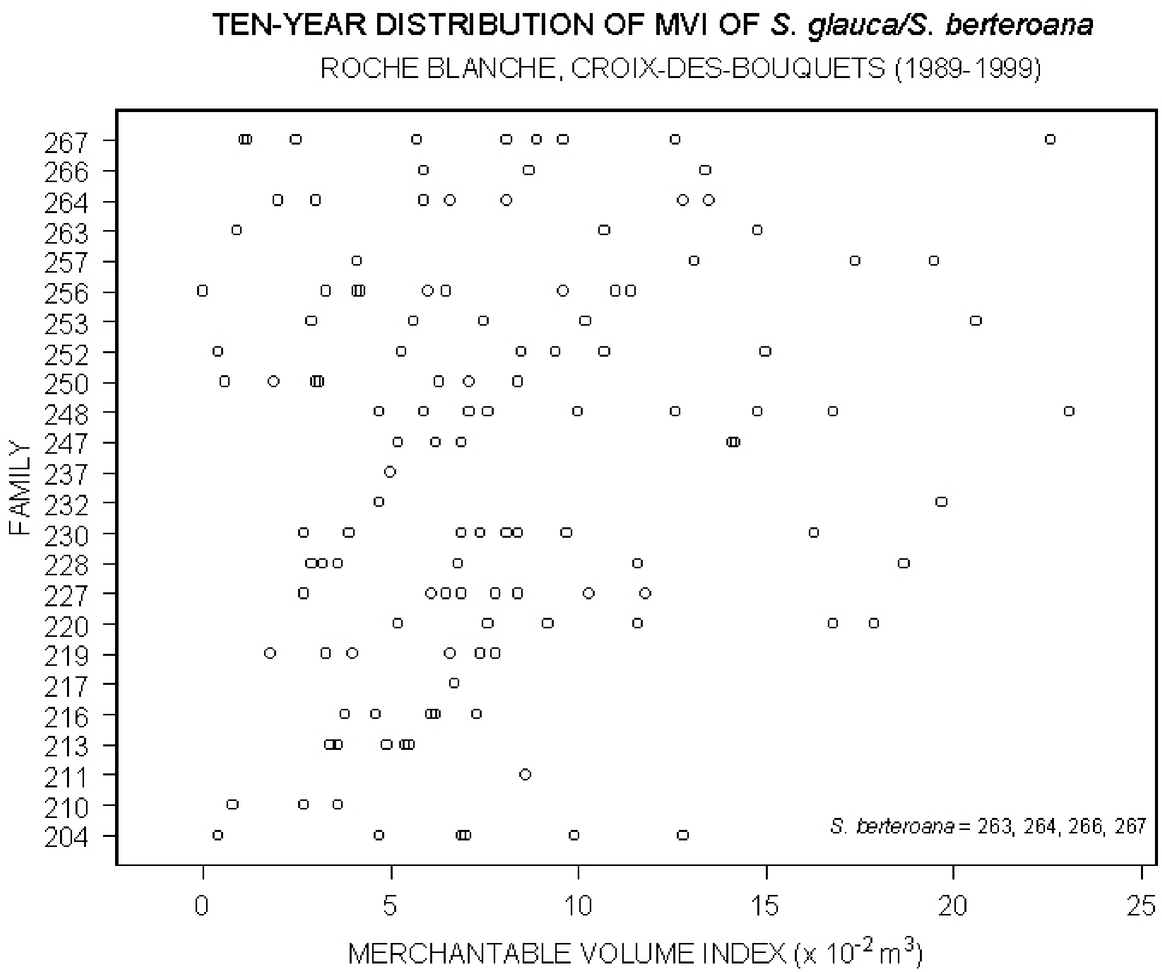

TEN-YEAR DISTRIBUTION OF MVI OF S. glauca/S. berteroana
ROCHE BLANCHE, CROIX-DES-BOUQUETS (1989-1999)
267
266
264
263
257
256
253
252
250
248
247
237
232
230
228
227
220
219
217
216
213
211
210
204
FAMILY
S. berteroana = 263, 264, 266, 267
0
5
10
15
20
25
MERCHANTABLE VOLUME INDEX (x 10-2 m3)

Figure 4.4

TEN-YEAR HEIGHT DISTRIBUTION OF *PINUS* PROVENANCES

VIARD, KENSCOFF, HAITI (1989 - 1999)

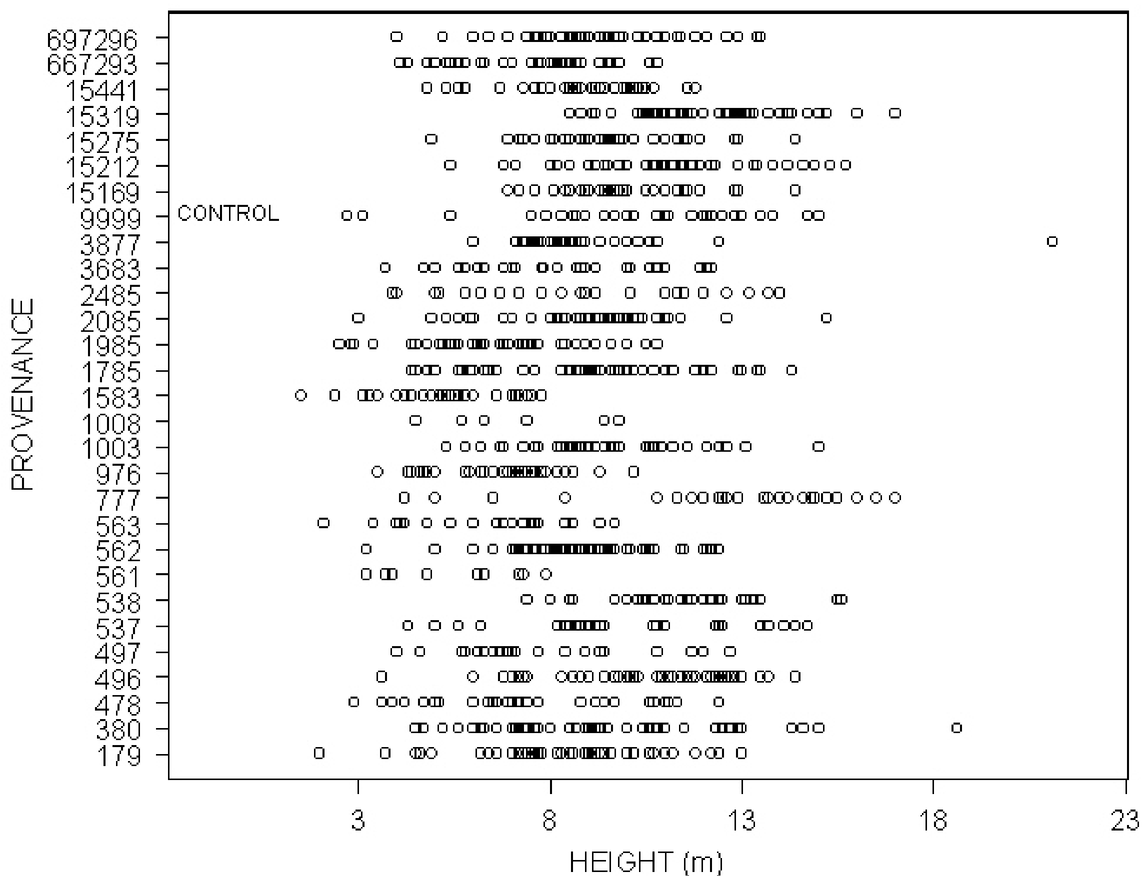


Figure 5.1

COMPARISON OF MERCHANTABLE VOLUME INDEX BY *PINUS* PROVENANCE

VIARD, KENSCOFF, HAITI (1989 - 1999)

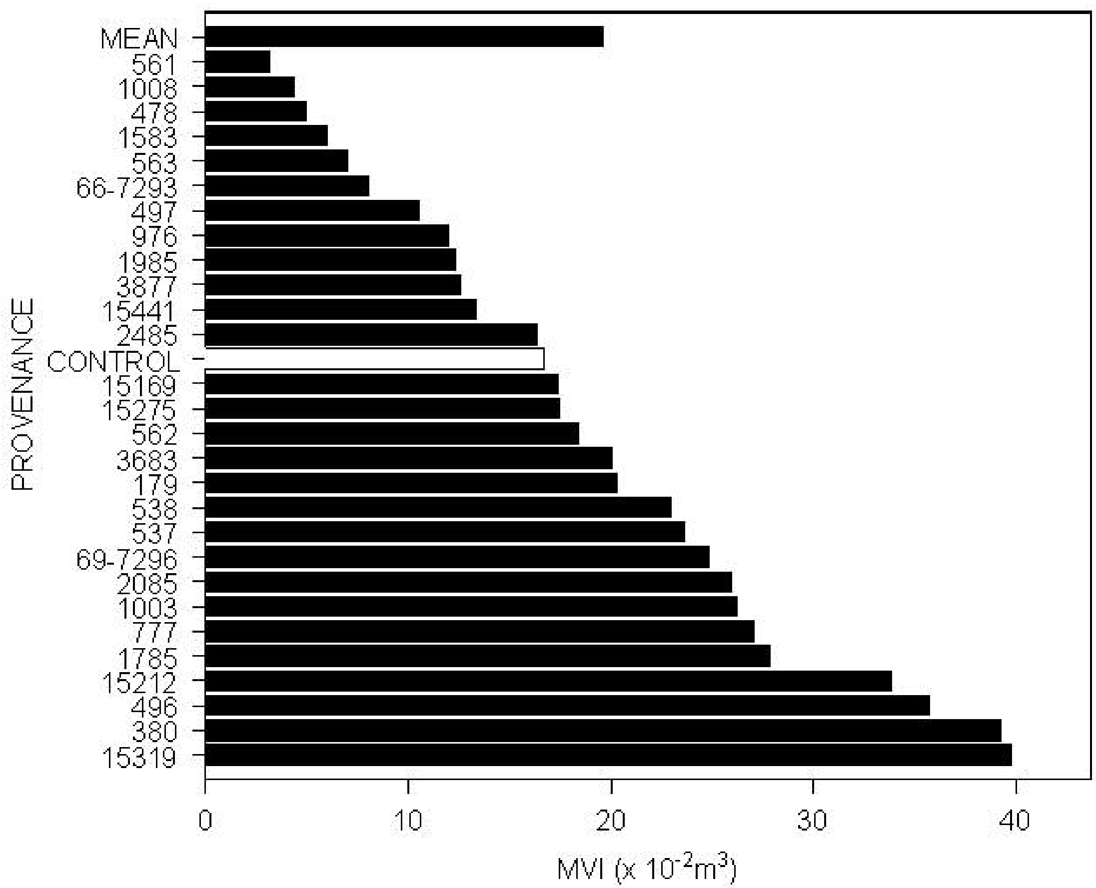


Figure 5.2