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Five Year Results of *Senna siamea* Trials in Haïti

by

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SUMMARY

Senna siamea (syn. *Cassia siamea*) was the most planted tree in Haiti during the period 1981–1991. Approximately 12 million trees were distributed during the USAID-funded Agroforestry Outreach (1981–1987) and Agroforestry II (1988–1991) projects (Timyan, 1996). It is primarily used as a source of wood for charcoal and construction wood, combined with shade and beauty. Trials were established to compare locally selected genotypes with seed originating from Central American and African sources. This report summarizes the performance of the earliest trials established in 1989 at 5 sites in Haiti.

Survival. Throughout the 5-year measurement period, there were no differences detected among the accessions at three of five trials. These were also the sites that the species grew the poorest, limited primarily by shallow and rocky soils (Lapila and Haut Camp) or low, erratic rainfall (Bombard). Differences were detected among the accessions at Mirebalais and Roche Blanche, the two most fertile sites. At Mirebalais, 1214 (Tanzania) achieved significantly higher survival than accessions from Haiti (1581), Costa Rica (4039) and Nicaragua (1564) at the 1- and 3-year stage. The trial was eliminated after 3 years because of uncontrolled harvesting of the species for polewood during the economic embargo of Haiti. At Roche Blanche, the accessions from Rwanda (554) and Nicaragua (1206) exhibited significantly higher survival than those from Haiti (1501, 1511, and 1581) and Costa Rica (4039) after 1 and 3 years. However, the lower survival rates of the Haitian seed lots was attributed to differences in seedling age and quality at the time of trial establishment. The effect of seed source on survival is not expected to make an important difference in the overall performance of the species in Haiti.

Height Growth. Differences among accessions were detected at all sites at least once during the 5-year period. Differences at three of the sites (Haut Camp, Lapila, and Roche Blanche) decreased with tree age, while the reverse was true for Bombard. Differences were shown at the Mirebalais site for both 1 and 3 year measurements. The slowest height growth of any site was achieved at Haut Camp, despite it being a moist site and exhibiting the highest survival. The site mean was 3.2 m after 5 years, equivalent to under 0.6 m yr^{-1}. The highest growth rates were exhibited at Roche Blanche, averaging 11 m for all accessions after 5 years, over 2 m yr^{-1}. Height growth differences were not consistent across sites. An accession which ranked high at any one site did not necessarily rank high at the other sites. The range in height growth among sites is much greater than that among accessions for any given site. The difference between Roche Blanche and Haut Camp was approximately 3-fold. The largest differences among accession means after 5 years was approximately 1.5 m at Bombard, Lapila and Roche Blanche. None of these height differences were shown to be significant at the 95% probability level.

Diameter Growth and Wood Yield. The Haitian sources, represented by PADF bulked seed lots 1511 and 1501, are beginning to show greater wood yields than imported seed sources of *S. siamea* (**Table 6**). They ranked first in wood yield after 5 years at the 3 trials (Bombard, Lapila, and Roche Blanche) where data was reliable. In all 3 trials, differences were significant, following the same rank and order as that for stem diameter. The top Haitian accession at these trials yielded twice the site mean and 3 times that of the least

productive accession. This supports the strategy to select local sources for *S. siamea* seed prior to purchasing an untested accession from abroad.

The following recommendations should be implemented to continue achieving positive results with *S. siamea*:

(1) Convert the *S. siamea* trials to in-country seed sources by selecting at the individual level and providing optimal conditions for seed production. The trials contain the broadest genetic base of the species in Haiti, though this base may still be relatively narrow compared to populations found within its native range. Always collect seed from the best-formed and healthy individuals.

(2) Make an effort to procure true provenance collections from countries of origin (e.g. Thailand and Burma), establish these collections on secure sites as in-country seed sources, and begin distributing this mix along with what is already being used.

(3) Continue monitoring the modified trials for a longer period, particularly for resistance to disease, pests and hurricanes, wood quality and other parameters that effect its potential economic impact to Haitian farmers.

(4) Emphasize the importance of selecting the optimal site conditions for the species and options that increase value-added wood products to improve its economic impact at the level of the Haitian farmer.

(5) Continue the investigation on the best silvicultural practices (propagation, thinning, pruning and harvesting) specific to the major agroforestry models (wood lots and charcoal gardens, boundary plantings, shade trees) in Haiti.

RESUME

Senna siamea (syn. *Cassia siamea*) fut l'une des espèces les plus plantées en Haïti au cours de la période 1981–1991. Approximativement, 12 millions d'arbres ont été distribuées durant les projets "Agroforestry Outreach Project" (1981-1987) et "Agroforestry II" (1988–1991) financés par l'USAID (Timyan, 1996). On l'utilise principalement comme source de bois de feu et de construction; il est utilisé également comme arbre d'ombrage et arbre ornemental. Les essais ont été établis dans le but de comparer les génotypes sélectionnés localement avec de semences originaires de l'Amérique Centrale et de sources Africaines. Ce rapport résume la performance des premiers essais établis en 1989 à travers cinq (5) sites en Haïti.

Survie. Après 5 ans de croissance, il n'y a pas eu de différences détectées parmi les provenances dans trois des 5 essais. Celles-ci répresentaient aussi les sites où l'espèce a eu la croissance la plus faible, due limité principalement par des sols peu profonds et rocailleux (Lapila et Haut Camp) ou par une pluviomètrie erratique et faible (Bombardopolis). Des différences ont été détectées entre les provenances à Mirebalais et à Roche Blanche, les deux sites les plus fertiles. A Mirebalais, la provenance 1214 (Tanzanie) a atteint un taux de survie significativement plus élevé que les génotypes d'Haïti (1581), de Costa Rica (4039) et de Nicaragua (1564) à l'âge d'un (1) et de trois (3) ans. L'essai a été éliminé après 3 ans dans ce site à cause de l'exploitation incontrôlée de l'espèce pour la fabrication de poteaux durant l'embargo économique qu'a connu Haïti. A Roche Blanche, les provenances de Rwanda (554) et de Nicaragua (1206) ont accusé une survie significativement plus élevée que celles d'Haïti (1501, 1511, 1581) et de Costa Rica (4039) après 1 et 3 ans. Cependant, les plus faibles taux de survie des lots de semences haïtiennes étaient attribués à des différences au niveau de l'âge et la qualité des plantules au moment de l'établissement de l'essai. Il est peu probable que la choix de semences, au niveau des banques de semence commerciale, peut montrer un différence notable dans les taux de survie de cette espèce en Haïti.

Croissance en Hauteur. Des différences parmi les accessions ont été détectées à travers tous les sites au moins une fois durant la période de 5 ans. Des différences dans 3 des sites (Haut Camp, Lapila, et Roche Blanche) ont diminué avec l'âge de l'arbre, tandis que le contraire était vrai pour Bombardopolis. Des différences étaient observées au site de Mirebalais pour les mensurations d'un (1) et de trois (3) ans. La plus faible croissance en hauteur a été observée à Haut Camp, en dépit d'une forte pluviométrie et du taux élevé de survie du site. La moyenne du site a été de 3,2 m après 5 ans, soit un taux d'accroissement de 0,6 m par an environ. Les taux de croissance les plus élevés ont été enregistrés à Roche Blanche, accusant une moyenne de 11 m pour toutes les provenances après 5 ans, soit un accroissement supérieur à 2 m par an. Les différences de croissance à travers les sites n'étaient pas évidentes. Une provenance qui a occupé un rang élevé dans un site quelconque, n'a pas occupé nécessairement un rang élevé dans les autres sites. La différence de croissance en hauteur entre les sites est plus évidente que celle entre les provenances dans un site donné. La hauteur moyenne à Roche Blanche a été 3 fois supérieure à celle observée à Haut Camp. Les plus grandes différences entre les moyennes des accessions après 5 ans fut approximativement 1,5 m à Bombardopolis, Lapila et Roche Blanche. Il n'y a pas eu de différences

significatives pour la croissance en hauteur dans les 3 sites pré-cités.

Croissance en Diamètre et Rendement de Bois. Les sources haïtiennes, représentant des lots récoltés par des fournisseurs du PADF, comme 1501 (Sud) et 1511 (Nord), ont commencé à montrer des rendements en bois supérieurs aux sources importées de semences de *S. siamea* **(Tableau 6)**. Elles occupaient les premières positions en rendement de bois après 5 ans dans les 3 sites (Bombardopolis, Lapila, et Roche Blanche) où les données étaient fiables. Dans tous les 3 sites, les différences étaient significatives, suivant la même classification que celle observée pour les diamètres de tige. La meilleure provenance haïtienne dans ces trois essais accusaient des rendements doubles de la moyenne du site et triples de celle la moins productive. Ceci confirme la stratégie de sélectionner les sources locales de semences de *S. siamea* avant d'importer une provenance non testée préalablement.

Recommandations. Les recommandations suivantes pourraient contribuer à obtenir des résultats positifs avec *S. siamea*:

(1) Convertir les essais de *S. siamea* en sources de semences locales par la sélection au niveau individuel et en créant des conditions optimales pour la production de semences. Les essais contiennent la plus large base génétique de l'espèce en Haïti, bien que cette base soit encore relativement restreinte par rapport aux populations rencontrées à l'intérieur de son aire de distribution naturelle. Collecter des semences à partir des individus bien conformés et en bonne santé.

(2) Déployer un effort afin de se procurer des provenances collectées directement dans les pays d'origine de l'espèce, par exemple Thailande et Mayamar (ex Birmanie). Etablir des vergers à partir de ces collections, sur des sites stables afin d'en faire des sources locales de semences, et distribuer ce matériel partout où son usage se révéle nécessaire.

(3) Poursuivre l'évaluation des essais modifiés pour une plus longue période, particulièrement pour la résistance aux pestes, maladies et ouragans, la qualité du bois et autres paramètres ayant un impact économique sur les fermiers haitiens.

(4) Mettre l'accent sur l'importance de la sélection des conditions optimales de site pour la croissance de l'espèce et des options qui augmentent la valeur des produits madérables en vue d'améliorer son impact économique au niveau du fermier haïtien.

(5) Poursuivre l'investigation sur les meilleures pratiques sylviculturales (propagation, éclaircie, élagage et exploitation) spécifiques aux meilleurs modèles agroforestiers (lots boisés, bosquets énergétiques ou *jadin chabon*, arbres d'ombrage) en Haïti.

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ACKNOWLEDGMENTS

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ACRONYMS

AU	Auburn University
CATIE	Centro Agronómico Tropical de Investigación y Ensenanza
COHDEFOR	Corporación Hondureña de Desarrollo Forestal
IRG	International Resources Group, Ltd.
ISAR	Institut Scientifique d'Agricole et de Recherche
ODH	Operation Double Harvest
OFI	Oxford Forestry Institute
PADF	Pan American Development Foundation
PLUS	Productive Land Use System
SECID	South East Consortium for International Development
USAID	United States Agency for International Development

INTRODUCTION

The over exploitation of the native forests of Haiti and conversion of forested lands to agriculture demands urgent action focussed on increasing the productivity of cultivated trees. Several exotic species, including *Senna siamea*, are beginning to play an important role in supplying the construction and fuelwood needs of Haitians that formerly was supplied by native species.

Senna siamea Irwin & Barneby (syn. *Cassia siamea*) was the most planted tree in Haiti during the period 1981–1991. Approximately 12 million trees were distributed during the USAID-funded Agroforestry Outreach (1981–1987) and Agroforestry II (1988–1991) projects (Timyan, 1996). It is primarily used as a source of wood for charcoal and construction wood combined with shade and beauty. Additional information on *S. siamea* in Haiti can be found in Timyan (1996).

As a fairly recent exotic to Haiti, it is imperative that as wide a genetic base of the species be introduced to offer the maximum selection potential possible for adaptation to the range of ecosystems common to Haiti. Though the species had been tested as a component of several species trials throughout the country, no seed source or provenance testing had been conducted to study the potential of genetic improvement on Haitian soil. This challenge was initiated in 1988 by International Resources Group, Ltd. under contract to USAID as part of a seed and germplasm improvement program. This program was incorporated under the SECID/Auburn University agroforestry research Project in 1990. The selection of superior phenotypes of the species began in 1988 in regions where the species has been exploited for lumber, poles and fuelwood. Trials were established to compare locally selected genotypes with seed originating from Central American and African sources. This report summarizes the performance of the earliest trials established in 1989.

OBJECTIVES

The major objectives of the *S. siamea* trials in Haiti included below.

(1) Broaden and improve the genetic base of *S. siamea* in Haïti by collecting seed from superior phenotypes, introducing a wide source of seed from throughout the tropics where the species is adapted, and establishing provenance and progeny trials in Haiti on a wide range of site.

(2) Identify *Senna siamea* provenances and seed sources that exhibit broad adaptability in Haiti and optimize economic returns to the Haitian farmer.

(3) Study the effect of site and genotype on survival, height growth and wood productivity of *S. siamea* in Haiti.

MATERIAL AND METHODS

Study Sites. The trial sites represent a diverse range of edaphic and physiographic conditions found in the low-elevation regions of Haiti (**Table 1**). A major consideration of site selection was land availability, relative ease of access, potential of full landowner cooperation with SECID/AU and land security. Optimal site matching and land use history are important factors in the success of any trial, though these were considered less a priority at this preliminary stage of genetic testing. The following table summarize the ecological characteristics of the study sites.

Table 1. Site characteristics of the *Senna siamea* trials in Haiti.

SITE PARAMETERS	BOMBARD	HAUT CAMP	MIREBALAIS	ROCHE BLANCHE	LAPILA
LATITUDE	19°40'	19° 25'	18°49'	18° 27'	19°18'
LONGITUDE	73°20'	73° 20'	72°60'	72° 59'	72°06'
ALTITUDE (m)	450	175	175	300	350
ANNUAL RAINFALL (mm)	950	2150	2150	1450	1250
RAINY SEASON	May - Oct	April - Nov	April - Oct	March - May; Aug - Oct	April -Oct
HOLDRIDGE LIFE ZONE	Subtropical Dry	Subtropical Moist	Subtropical Moist	Subtropical Dry	Subtropical Humid
SLOPE (%)	0-2	80–90	0-2	0-1	0-2
SOIL pH	7.8	6.7	6.7	8.2-8.3	7.3
% CLAY	10	10	10	17	10
SOIL P (ppm)	6	6	6	55.25	12
% ORGANIC MATTER	3.8	3.8	3.8	2.6 - 2.7	8.4
SITE LIMITATIONS	Erratic rainfall; 2–3 month severe drought	Rocky, shallow soils; steep slope	Tree security	None	Shallow, rocky soils; 3 month severe drought

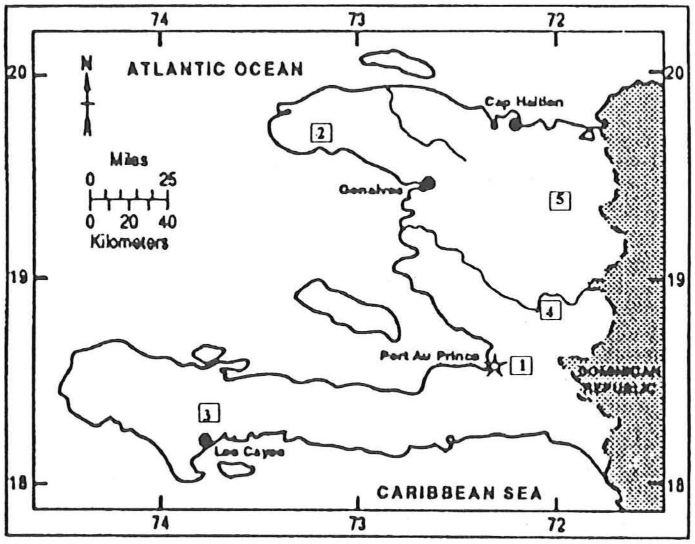


Figure 1. Location of the *S. siamea* trials in Haiti. 1=Roche Blanche, 2=Bombardopolis, 3=Haut Camp, 4=Mirebalais, 5=Lapila.

Seed Collection. Seed lots of *Senna siamea* were obtained from various international sources, both research and commercial seed companies. In addition to these collections, bulked seed lots harvested for the PADF containerized nurseries were included in four of trials as a local control. These are 1501, 1511, and 1581 from 3 regions of Haiti. **Table 2** summarize the source information of the accessions included in this study. "Accession" is distinguished from "provenance," as the seed lots were collected in regions where *S. siamea* has been introduced and probably naturalised. They should not be confused with provenance collections from a representative population within the native range of the species and where origin has been determined.

Table 2. Source information of *Senna siamea* accessions included in this study. Institutions: C = CATIE, I = IRG, R = ISAR. Number of trees harvested for a given seed lot, if known, is provided in parentheses.

NO.	SOURCE	TEMP	ALT (m)	LATITUDE	LONGITUDE	RAINFALL
R554	Cyangugu, Rwanda (20)	—	900	2° 15'S	29° 00'E	1100
C1206	Managua, Nicaragua	—	100	12° 08'N	86° 15'W	—
C1214	Dodoma, Tanzania	—	—	06° 00'S	36° 00'E	—
C1365	Leon, Nicaragua	27.4	110	12° 26'N	86° 55'W	1559
C1564	Leon, Nicaragua	27.0	100	12° 30'N	87° 00'W	1559
C2507	Guanacaste, Costa Rica	27.0	310	10° 05'N	85° 25'W	2230
C4039	Guanacaste, Costa Rica	27.0	325	10° 05'N	85° 25'W	2230
I1501	Cap-Haitien, Haiti	25.1	75	7° 50'N	76° 40'W	2266
I1511	Petit-Goave, Haiti	25.5	520	11° 54'N	86° 12'W	1514
I1581	Grand-Anse, Haiti	26.0	320	14° 33'N	91° 30'W	2906

Nursery Phase. The seedlings were raised at a private nursery owned and managed by Operation Double Harvest (ODH) located 7 km from Croix-des-Bouquets. The seedlings were propagated in Winstrip containers, a plastic container tray developed by Van Wingerden International that contains 90 cells, each with an approximate volume of 130 ml. The potting medium was prepared at ODH, known as "Haiti Mix," utilizing 75% bagasse, 15% rice hulls, 15% clayey loam and fertilizer. The treatment of seeds consisted of soaking in hot water for 24 hours.

The non-Haitian accessions were sown in the nursery in October, 1988. The Haitian accessions were sown in January, 1989, matching the sowing calendar of the PADF and CARE nurseries.

Experimental Design and Trial Establishment. The preparation of the trial sites differed depending on the sites conditions and proposed management of the trials, some of which were intercropped with annual crops during the first 2 growing seasons. At the Mirebalais and Bombard trials, seedlings were planted after the crop was sown and weeded under normal regimes with the garden. The Haut Camp, Lapila and Roche Blanche trials were not intercropped. In both cases, the sites were clear-weeded and holes dug prior to the onset of the rainy season. Periodic weeding of the trials was by contract with the landowner.

The trials were established as randomized complete block designs, generally with 3–6 blocks. The plots were established in rectangular form, with 6–24 plants per plot depending of trial. All trees within plot were measured throughout the study period. **Table 3** summarizes the information regarding each trial.

Table 3. Experimental design of *Senna siamea* trials in this study.

	BOMBARD	HAUT CAMP	MIREBALAIS	LAPILA	ROCHE BLANCHE
ESTABLISHMENT DATE	June 9, 1989	March 16, 1989	April 27, 1989	May 18, 1989	April 8, 1989
ACCESSIONS	8	5	8	7	10
REPLICATIONS	3	6	4	4	3
TREES/PLOT	5	12	6	24	24
SPACING (m)	1 x 1.5	2 x 3	2 x 2.5	1.5 x 2.5	1.5 x 2.5

Measured Variables and Observations. All trials were measured at 12 ,36 and 60 months from the establishment date. The parameters considered for measurement are as follows:

1) Survival, in %, at 12, 36 and 60 months.

2) Total height, in meters, measured with a telescopic height pole at 12, 36 and 60 months.

3) Diameter at 1,30 m above ground, in cm, measured with a cloth diameter tape at 36 and 60 months. This diameter is given as DBH.

4) Basal or Stump Diameter at 0.1 m above ground, in cm, measured with a cloth diameter tape at 60 months. This diameter is given as $D_{0.1}$.

Additionally, the status of each tree was evaluated and assigned a code that corresponded to a range of possible factors affecting its status. Any tree that was damaged due to non-natural causes, mostly human or animal damage, was eliminated from the data used to determine height and diameter statistics.

Statistical Analysis. The field data was entered into Lotus 123 spreadsheet and prepared for statistical analyses using SAS 6.04 (SAS, 1988). Survival data required an arcsin transformation procedure, as provided in Steel and Torrie (1980). Analysis of variance procedures were conducted for survival, height and stem diameters of each trial. The Waller-Duncan k-ratio test and Least Significant Difference (LSD) t-test were selected for means comparisons. Wood yields, for wood greater than 1-cm diameter, were estimated by a regression equation based on biomass studies conducted at Nan Marron (Timyan, 1996). For *S. siamea*, this equation is as follows: wood yield (kg) = $0.021h\sum d^2_n$, where h is equal to total tree height an d is equal to stem diameter at 0.3 m above ground. Stem diameter was calculated as the average of DBH and $D_{0.1}$. Graphics were prepared with DrawPerfect 1.1 and this document was compiled with WordPerfect 6.1.

RESULTS AND DISCUSSION

Survival. Throughout the 5-year measurement period, there were no differences detected among the accessions at three of five trials **(Annex 1)**. These were also the sites that the species grew the poorest, limited primarily by shallow and rocky soils (Lapila and Haut Camp) or low, erratic rainfall (Bombard). Despite the rocky site conditions at Haut Camp, this site achieved the highest overall survival of any sites, due in part to its receiving a moderately high rainfall and being a humid site. Differences were detected among the accessions at Mirebalais and Roche Blanche, the two most fertile sites.

At Mirebalais, 1214 (Tanzania) achieved significantly higher survival than accessions from Haiti (1581), Costa Rica (4039) and Nicaragua (1564) at the 1- and 3-year stage. The trial was eliminated after 3 years because of uncontrolled harvesting of the species for palate during the economic embargo of Haiti. Therefore, 5 year results were not reliable to confirm whether this trend was important over a longer period of time.

At Roche Blanche, the accessions from Rwanda (554) and Nicaragua (1206) exhibited significantly higher survival than those from Haiti (1501, 1511, and 1581) and Costa Rica (4039) after 12 and 36 months. 554 maintained its top position after 5 years and faired well enough at the other sites to be among the best survivors of any accession **(Table 4)**. It is important to note, however, that prior to assigning any significance to these trends in survival, other factors, particularly seedling quality at the time of trial establishment, should be taken into consideration. The Haitian accessions, though performing the poorest on the 3 sites in **Table 4**, were also the smallest and youngest seedlings when the trials were established. They were 2–3 months younger than the other accessions, though being the same age and quality as seedlings delivered by PADF and CARE in 1989. Rather than showing an effect of accession, the results more likely show an effect of seedling age and its corresponding difference in seedling quality at the time of outplanting. Taking this into account, no differences in survival were observed across sites in Haiti.

Table 4. Cross-site comparisons of survival rates (%) among 6 *S. siamea* accessions after 5 years in Haiti. Means followed by the same letter are not considered different at the 95% probability level of the arcsine-transformed data.

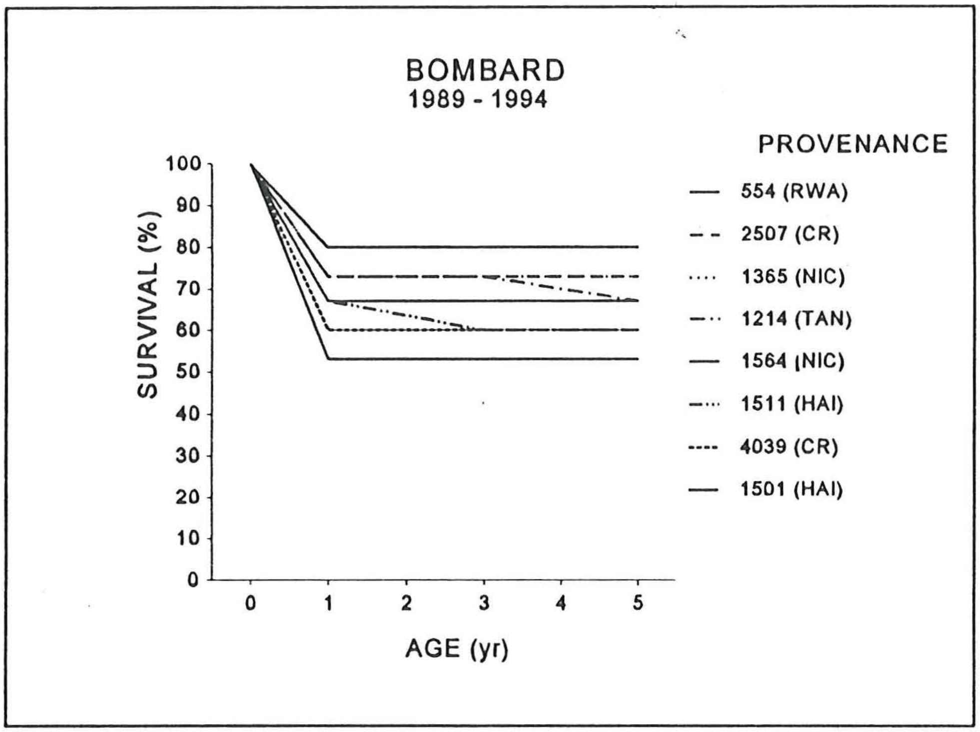
ACCESSION	BOMBARD	LAPILA	ROCHE BLANCHE	MEAN
	%			
1365 (NICARAGUA)	73	62	83	73 a
554 (RWANDA)	80	44	92	72 a
2507 (COSTA RICA)	73	51	89	71 ab
4039 (COSTA RICA)	60	55	65	60 ab
1511 (HAITI)	60	57	54	57 ab
1501 (HAITI)	53	46	61	53 b

Survival curves of the *Senna siamea* trials included in this study are provided in **Figures 2a** and **2b**. The Mirebalais trial is not shown because the effect of harvesting the trial between the 36- and 60-month could not be determined.

Height Growth. Height growth is a good indicator of an accession's adaptability to site and site quality differences among trials. Differences among accessions were detected at all sites at least once during the 5-year period (**Annex 2**). Differences at three of the sites (Haut Camp, Lapila, and Roche Blanche) decreased with tree age, while the reverse was true for Bombard. Differences were shown at the Mirebalais site for both 1 and 3 year measurements.

The slowest height growth of any site was achieved at Haut Camp, despite it being a moist site and exhibiting the highest survival. Early differences became negligible at 3 and 5 years. The site is extremely rocky, with shallow soils and a steep slope (80–90%). The site mean was 3.2 m after 5 years, equivalent to under 0.6 m yr^{-1}.

The highest growth rates were exhibited at Roche Blanche, averaging 11 m for all accessions after 5 years, over 2 m yr^{-1}. Though 1 year results showed differences, primarily between the older (non-Haitian) and younger (Haitian) seedlings at the time of outplanting, these differences disappeared after 5 years. In fact, the Haitian accession, 1501, ranked second in height growth, with a mean height of 11.5 m. The slowest-growing accessions at Roche Blanche were 1214 (Tanzania) and 4039 (Costa Rica), each with a mean height of 10.2 m. However, the Tanzanian accession ranked first at two other sites (Haut Camp and Mirebalais) and should not be eliminated as a potential seed source. 4039 ranked last at Mirebalais, but was mid-ranked at Lapila and Bombard. Another Costa Rican accession (2507) ranked near the bottom at 4 sites, but ranked first at Roche Blanche. Height growth differences were not consistent across sites. An



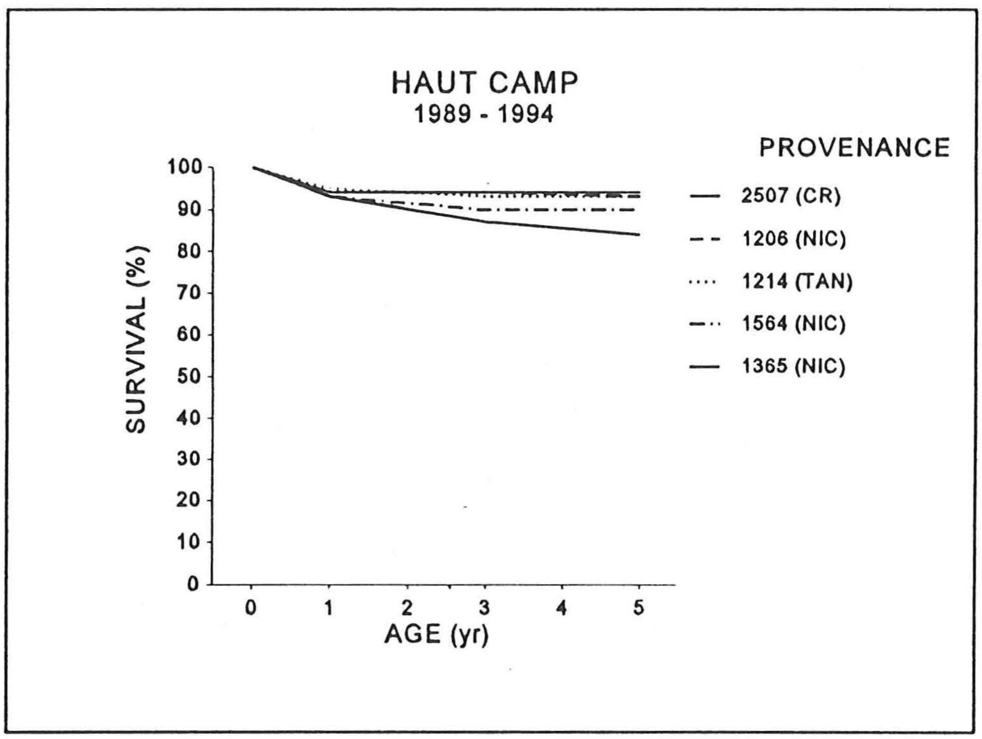
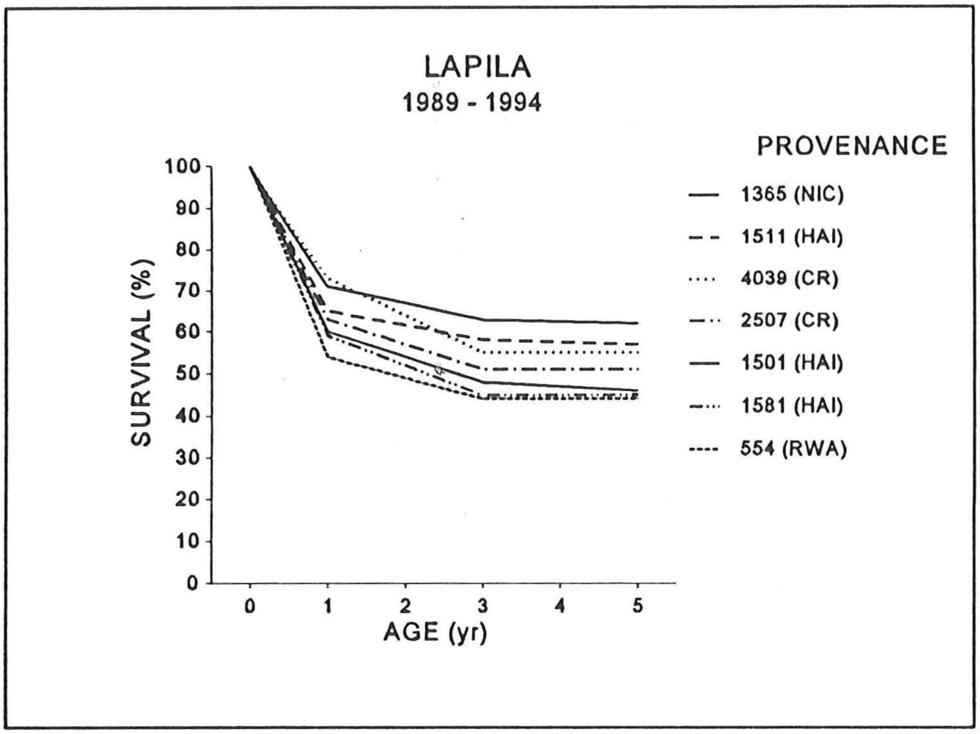


Figure 2a. Survival curves of the *S. siamea* accessions after 5 years at Bombard and Haut Camp.



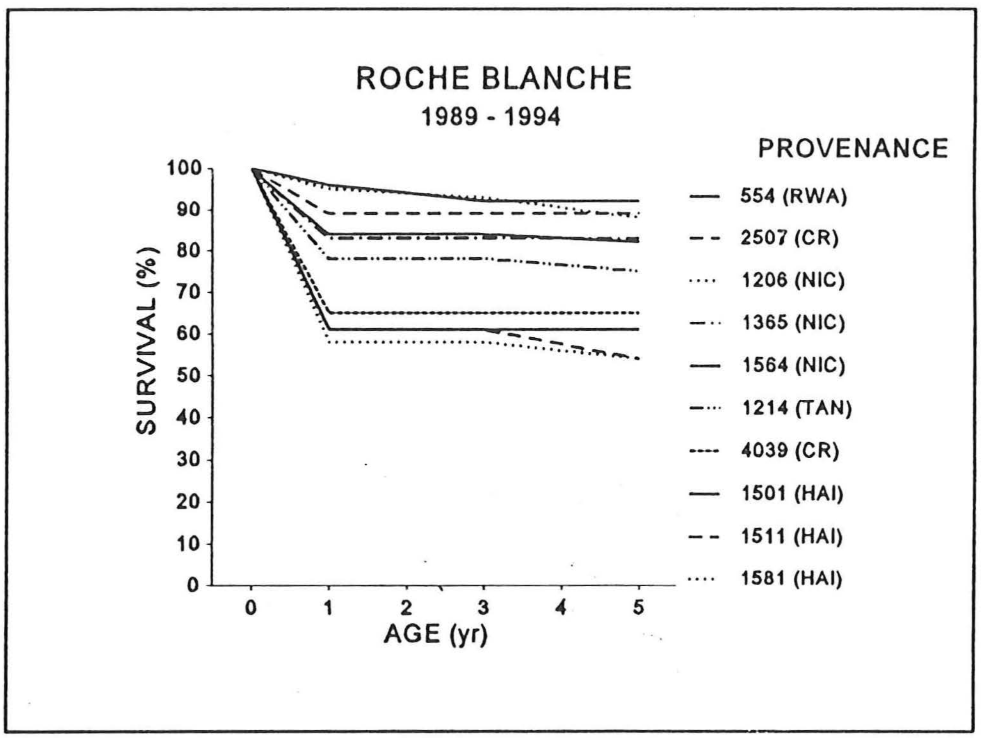


Figure 2b. Survival curves of the *S. siamea* accessions after 5 years at Lapila and Roche Blanche.

accession which ranked high at any one site did not necessarily rank high at the other sites (**Table 5**).

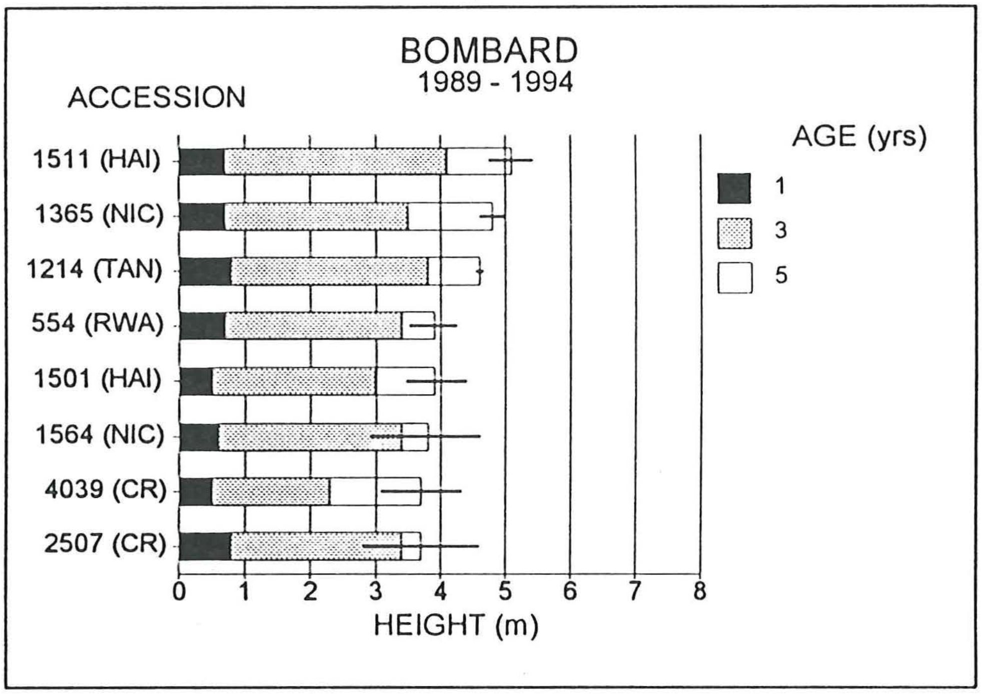
Table 5. Cross-site comparisons of height growth (m) among 6 accessions of *S. siamea* after 5 years in Haiti. Means followed by the same letter are not considered different at the 95% probability level.

ACCESSION	BOMBARD	LAPILA	ROCHE BLANCHE	MEAN
	m			
1511 (HAITI)	5.1	4.4	11.2	**6.9 a**
1501 (HAITI)	3.9	5.2	11.5	**6.9 a**
1365 (NICARAGUA)	4.8	4.0	10.9	**6.6 a**
554 (RWANDA)	3.9	4.9	10.3	**6.4 a**
2507 (COSTA RICA)	3.7	3.8	11.7	**6.4 a**
4039 (COSTA RICA)	3.7	4.5	10.2	**6.1 a**

The range in height growth among sites is much greater than that among accessions for any given site. In this study, the difference between Roche Blanche and Haut Camp was approximately 3-fold. The largest differences among accession means after 5 years was approximately 1.5 m at Bombard, Lapila and Roche Blanche. These differences were between the Haitian 1581 (5.1 m) and the Costa Rican 2507 (3.7 m) at Bombard; the Haitian 1501 (5.2 m) and the Costa Rican 2507 (3.8) at Lapila; and the Costa Rican 2507 (11.7 m) and both the Tanzanian 1214 and Costa Rican 4032 (10.2m) at Roche Blanche. None of these height differences were shown to be significant at the 95% probability level. A comparison of height growth among accessions after 1, 3 and 5 years is shown in **Figures 3a–3c**. The Mirebalais trial is shown only for 1 and 3 years, since the trial was partially harvested prior to the 5 year measurement period.

Diameter Growth and Wood Production. Any difference detected among *S. siamea* accessions with respect to stem diameter growth is related to wood production differences. These differences, either fuelwood or a combination of fuelwood and palate, are important when assessing the potential economic impact of making available an improved genotype to Haitian farmers. For purposes of statistical analyses, only wood yield, for wood greater than 2 cm diameter, were estimated using the equation developed at Nan Marron, near Bombard.

The Haitian sources, represented by PADF bulked seed lots 1511 and 1501, are beginning to show greater wood yields than imported seed sources of *S. siamea* (**Table 6**). They ranked first in wood yield after 5 years at the 3 trials (Bombard, Lapila, and Roche Blanche) where data was reliable. In all 3 trials, differencès were significant, following the same rank and order as that of the Haitian accessions at Bombard, but near the bottom at Roche Blanche. However, the yields at Roche Blanche were not significantly different from each other, with the exception of the Haitian accession, 1501. The other 2 Haitian accessions at Roche Blanche were mid-rank with the other imported accessions.



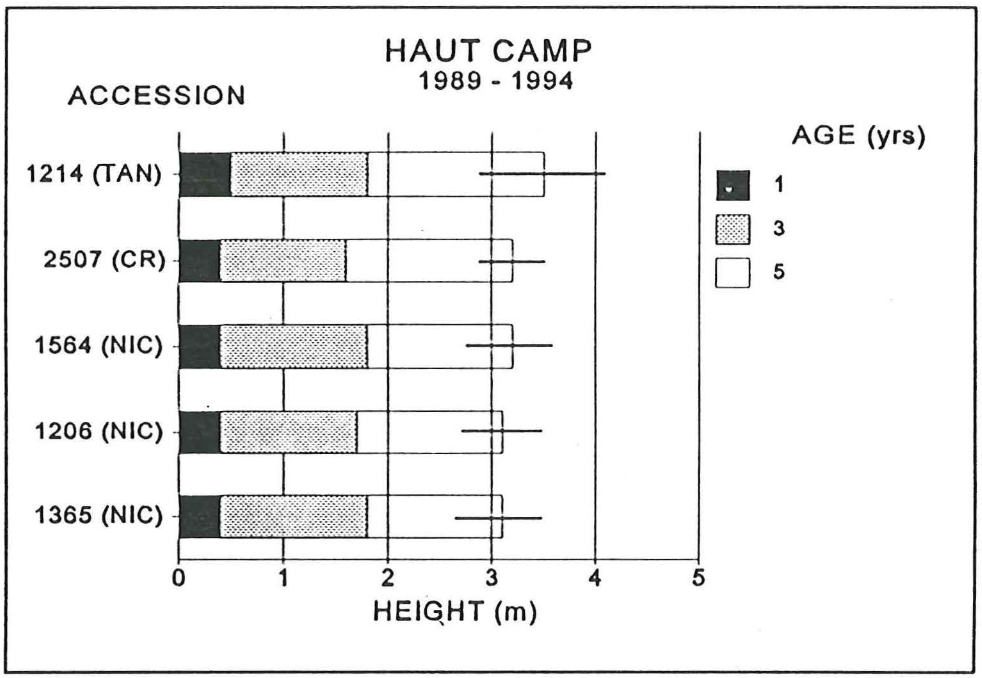
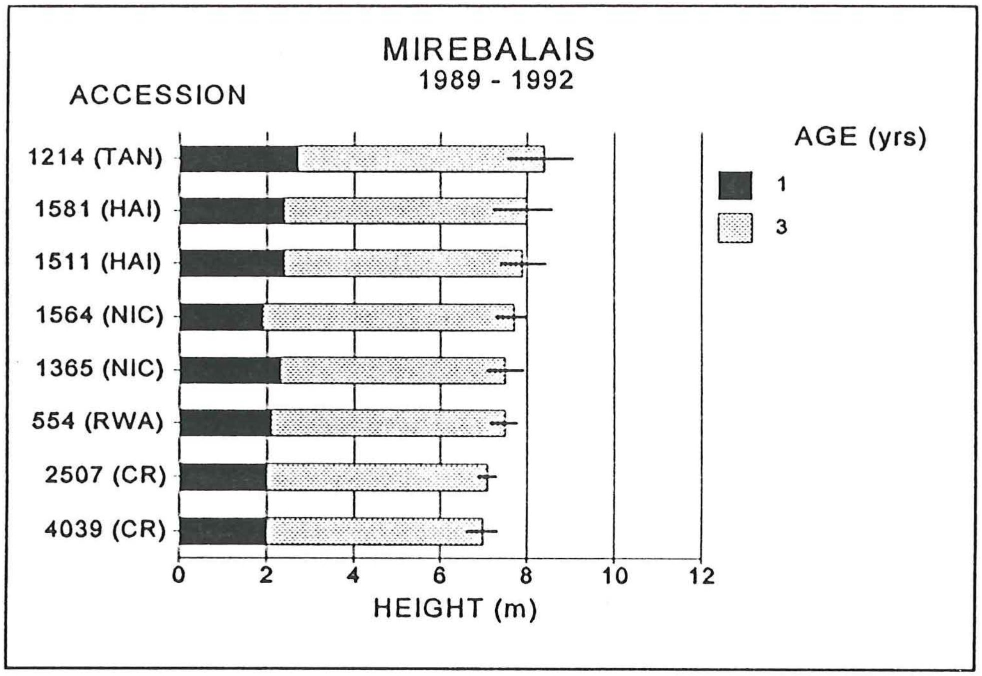


Figure 3a. Comparison of *Senna siamea* height growth after 1, 3, and 5 years at Bombard and Haut Camp.



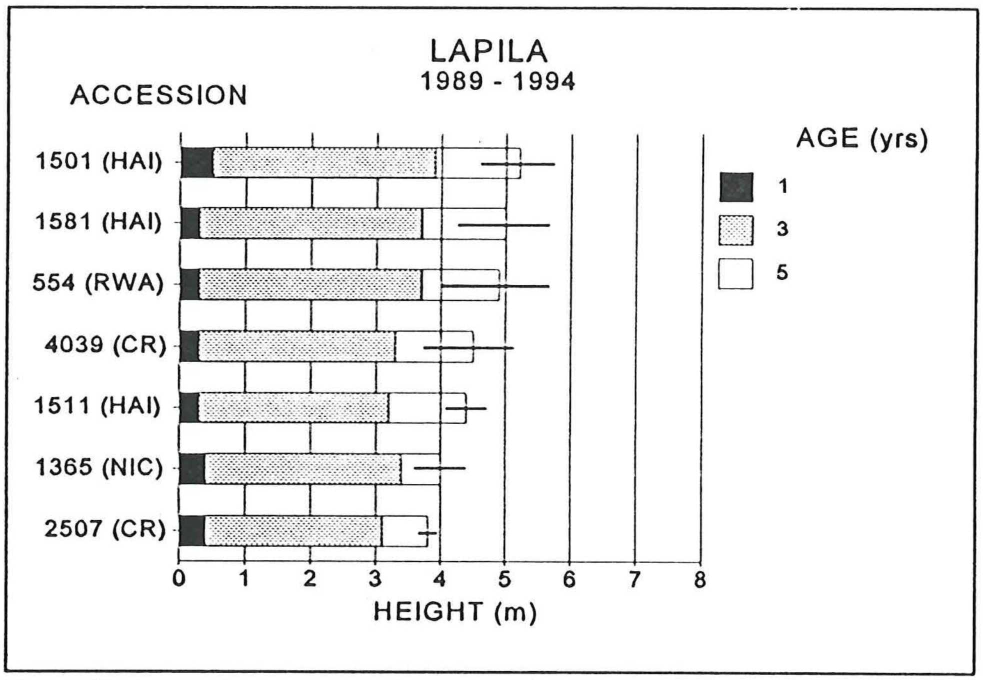


Figure 3b. Comparison of *Senna siamea* height growth after 1, 3, and 5 years at Mirebalais and Lapila.

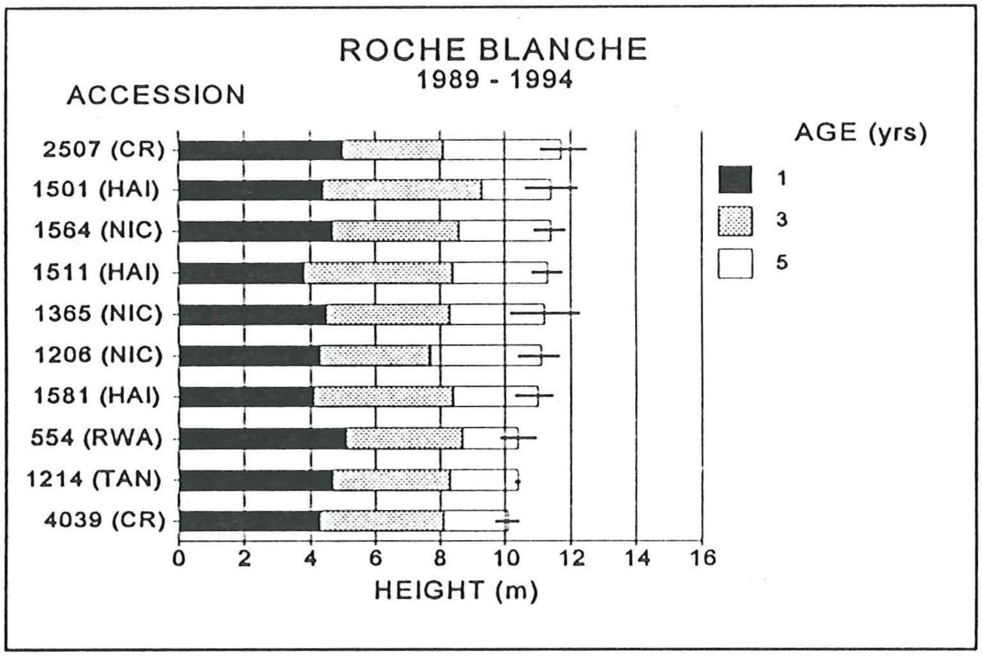


Figure 3c. Comparison of *Senna siamea* height growth after 1, 3, and 5 years at Roche Blanche.

Table 6. Wood yield means, in dry kg, of different *S. siamea* accessions after 5 years in Haiti. Means followed by the same letter are not significantly different at the 95% probability level by the LSD t-test, $\alpha = 0.05$.

		Site d'Essais			
		Bombard	Haut Camp	Lapila	Roche Blanche
No.	Source	kg/tree			
554	Rwanda	2.4 bc		5.7 ab	32.7 b
1206	Nicaragua		2.1 b		49.5 b
1214	Tanzania	3.8 ab	4.5 a		34.4 b
1365	Nicaragua	2.6 bc	2.5 b	3.6 ab	50.2 b
1501	Haiti	2.4 bc		7.6 a	73.7 a
1511	Haiti	5.3 a		4.1 ab	42.6 b
1564	Nicaragua	1.9 c	2.3 b		44.9 b
1581	Haiti			5.9 ab	42.5 b
2507	Costa Rica	2.9 bc	2.3 b	3.1 b	49.0 b
4039	Costa Rica	1.4 c		4.6 ab	33.7 b
X		2.83	2.74	4.92	45.33
SE		0.32	0.53	0.59	3.29
Pr>F		0.0161	0.0337	0.3613	0.0809
LSD...		1.89	1.60	—	24.31

By far the most productive site was Roche Blanche where the mean annual wood yield was 9 kg per tree and corresponding to 17.9 metric tons ha^{-1} yr^{-1}. The highest yielding accession from Haiti averaged close to 15 kg per tree per year. The other Haitian accessions (1511 and 1581) approached the site average. The least productive sites were Bombard and Haut Camp, with a mean annual yield of 0.5 kg per tree. The much higher stem density at Bombard resulted in wood yields 3 times that of Haut Camp, equivalent to 2.5 and 0.8 metric tons ha^{-1} yr^{-1}, respectively. The Haitian accession, 1511, averaged over 1 kg per tree per year at Bombard, while the Tanzanian accession, 1214, averaged 0.9 kg per tree per year at Haut Camp.

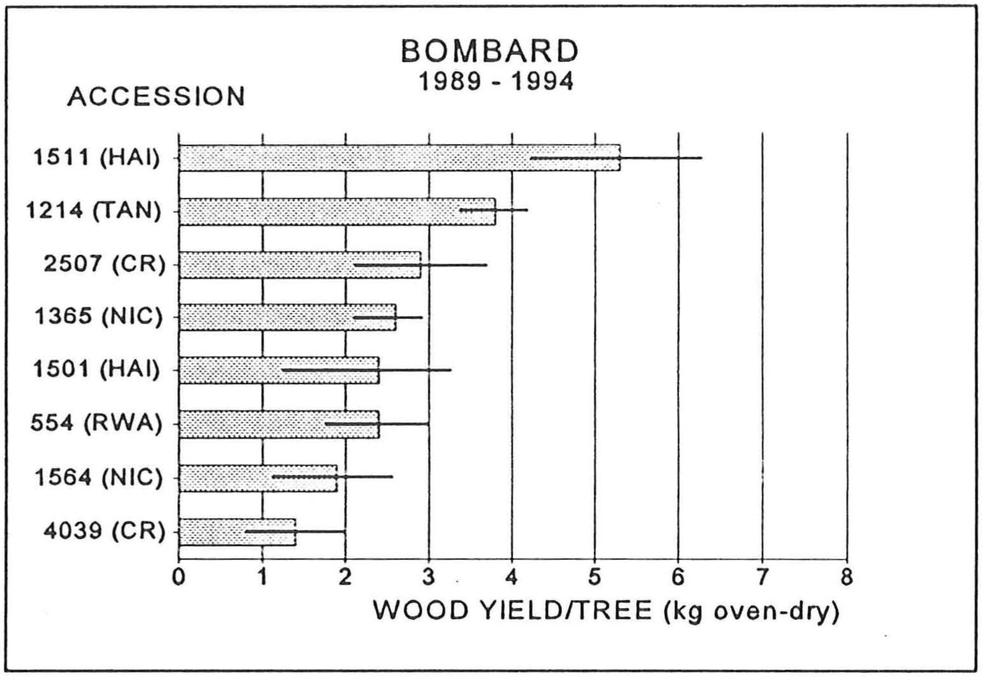
It is interesting to note the difference in yield performance between two of the Haitian accessions at Bombard. While 1511 was the most productive, 1501 was below the site mean. The difference between the two accessions was more than 2-fold and significant at the 95% probability level. In contrast, 1501 was the best producer at Lapila and Roche Blanche. One cannot assume that selecting a particular Haitian seed source will guarantee the highest production in the country at any one site. However, taken everything into consideration, selecting a good mix of Haitian seed sources will always be safer option than importing untested accessions from abroad. The chances of choosing a superior accession, like the Tanzanian 1214 at Haut Camp, is unlikely given the wide selection opportunities available from commercial seed sources. The comparison of 5-year wood yields at the various sites is illustrated in **Figures 4a** and **4b**. Yields for the Mirebalais trial are not shown since the trial was partially harvested between 3 and 5 years.

CONCLUSIONS

The comparison of imported *Senna siamea* seed source with the local sources used by PADF and CARE nurseries have shown significant differences for all the parameters measured. Stem diameter and wood yield differences are greater among seed sources than survival and height growth differences. Site conditions have a far greater impact than seed source for *S. siamea* in terms of survival, wood yield and harvest value. The fact that all imported seed sources were from countries where the species is not native might mean that the genetic base of *S. siamea* being tested in this study is relatively homogenous.

It is encouraging that Haitian seed sources were the top wood producers at 3 sites and at least performed adequately when not occupying the top rank. Locally adapted seed sources should be considered prior to purchasing and importing seed from other countries. However, seed from the native range of the species (SE Asia) should be introduced to broaden and invigorate the local genetic base, in particular resistance to diseases such as the widespread problem of leaf spot caused by *Cercospora*.

In terms of guaranteeing the best performance of *S. siamea*, PLUS should examine the positive effect that site conditions has on the form and resulting wood value of the species. The species does not perform well on semi-arid, alkaline sites or sites with extremely shallow and rocky soils. The best form of the species has been observed on sandy loams typical of many regions of the Central Plateau and basaltic soils scattered throughout Haiti. Proper site selection for the species will have a greater economic impact for the farmer than genetic selection in the foreseeable future.



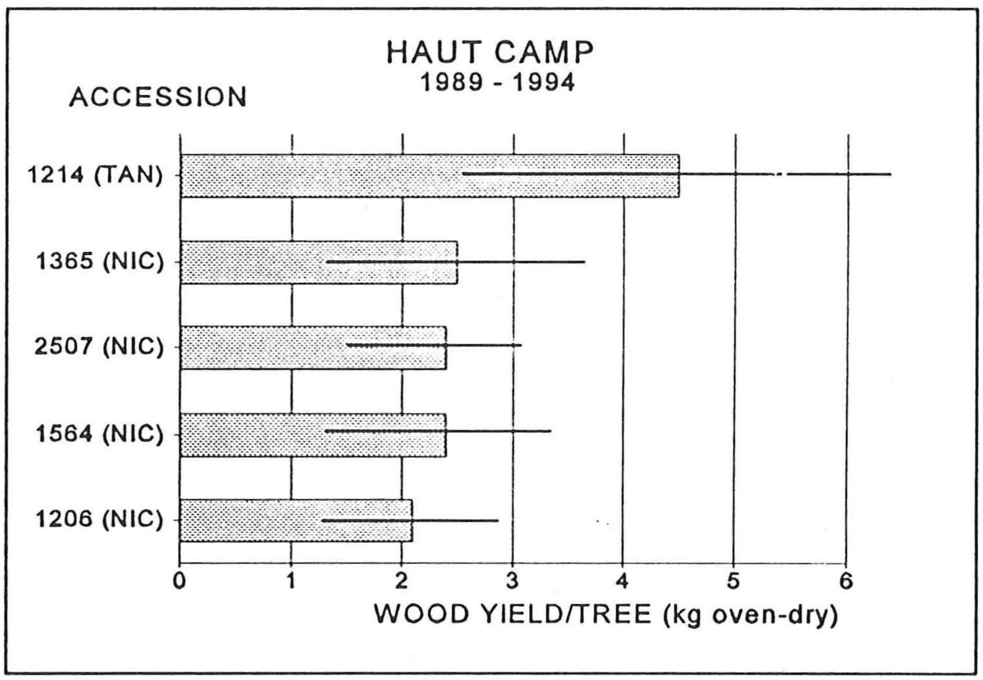
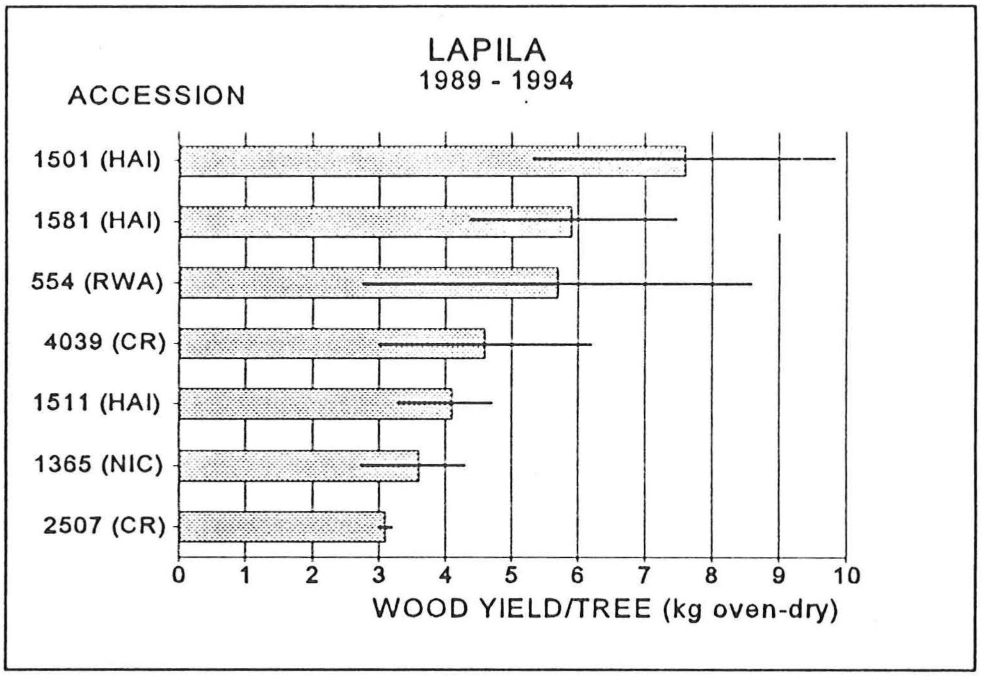


Figure 4a. Wood yield comparisons among *S. siamea* accessions after 5 years at Bombard and Haut Camp.



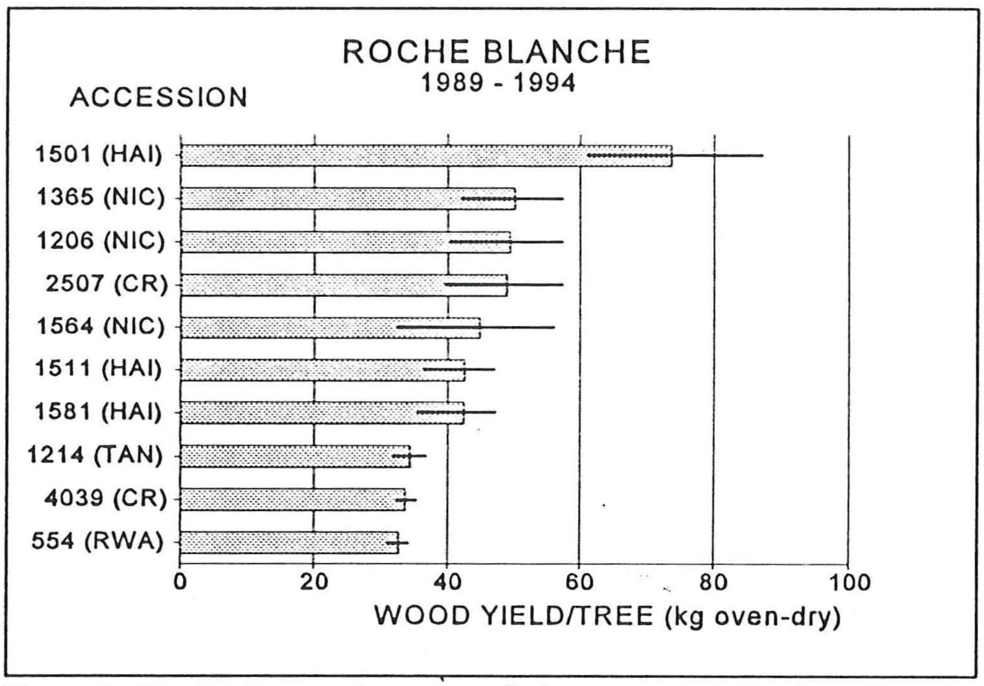


Figure 4b. Wood yield comparisons among *S. siamea* accessions after 5 years at Lapila and Roche Blanche.

RECOMMENDATIONS

The following recommendations should be implemented to continue achieving positive results with *S. siamea*:

(1) Convert the *S. siamea* trials to in-country seed sources by selecting at the individual level and providing optimal conditions for seed production. The trials contain the broadest genetic base of the species in Haiti, though this base may still be relatively narrow compared to populations found within its native range. Always collect seed from the best-formed and healthy individuals;

(2) Make an effort to procure true provenance collections from countries of origin (e.g. Thailand and Burma), establish these collections on secure sites as in-country seed sources, and begin distributing this mix along with what is already being used.

(3) Continue monitoring the modified trials for a longer period, particularly for resistance to disease, pests and hurricanes, wood quality and other parameters that effect its potential economic impact to Haitian farmers;

(4) Emphasize the importance of selecting the optimal site conditions for the species and options that increase value-added wood products to improve its economic impact at the level of the Haitian farmer; and

(5) Continue the investigation on the best silvicultural practices (propagation, thinning, pruning and harvesting) specific to the major agroforestry models (wood lots and charcoal gardens, boundary plantings, shade trees) in Haiti.

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Annex 1. Survival mean of various seed lots of *Senna siamea* after 5 years in Haiti. Survival means followed by the same letter are not significantly different at the 95% probability level of arsine-transformed data.

		Trial Site														
		Bombard			Haut Camp			Lapila			Mirebalais			Roche Blanche		
		12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	60 Mo.†	12 Mo.	36 Mo.	60 Mo.
No.	Origine	%														
554	Rwanda	80 a	80 a	80 a				54 a	44 a	44 a	83 ab	79 b	58 a	96 a	92 a	92 a
1206	Nicaragua				94 a	94 a	93 a							95 a	93 a	88 abc
1214	Tanzania	73 a	73 a	67 a	95 a	93 a	93 a				100 a	100 a	71 a	78 bc	78 abc	75 bcde
1365	Nicaragua	73 a	73 a	73 a	93 a	87 a	84 a	71 a	63 a	62 a	83 ab	83 ab	83 a	83 abc	83 abc	83 abcd
1501	Haiti	53 a	53 a	53 a				60 a	48 a	46 a				61 c	61 c	61 cde
1511	Haiti	67 a	60 a	60 a				65 a	58 a	57 a	87 ab	87 ab	71 a	61 c	61 c	54 e
1564	Nicaragua	67 a	67 a	67 a	93 a	90 a	90 a				67 b	67 b	50 a	84 abc	84 abc	82 abcd
1581	Haiti							59 a	45 a	45 a	79 b	75 b	58 a	58 c	58 c	54 de
2507	Costa Rica	73 a	73 a	73 a	94 a	94 a	94 a	63 a	51 a	51 a	83 ab	83 ab	66 a	89 ab	89 ab	89 ab
4039	Costa Rica	60 a	60 a	60 a				73 a	55 a	55 a	67 b	67 b	42 a	65 c	65 bc	65 cde
X		68.0	67.0	67.0	94	92	91	64.0	52.0	52.0	81.2	80.2	62.5	77.0	76.4	74.4
SE		4.1	4.1	4.4	1.0	1.5	1.9	2.9	4.0	4.0	3.1	3.1	6.6	3.5	3.4	3.6
Pr>F		0.842	0.805	0.880	0.994	0.831	0.870	0.753	0.867	0.873	0.091	0.047	0.545	0.010	0.030	0.015

†Survival is an underestimate due to uncontrolled harvesting between 36 and 60 months.

Annex 2. Comparison of height growth of *Senna siamea* seed sources in Haiti, between 1989–1994. Means followed by the same letter are not significantly different at the 95% probability level.

		Trial Site													
		Bombard			Haut Camp			Lapila			Mirebalais[†]		Roche Blanche		
		12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	60 Mo.	12 Mo.	36 Mo.	12 Mo.	36 Mo.	60 Mo.
No.	Origin	m													
554	Rwanda	0.7 a	3.4 ab	3.9 a				0.3 bc	3.7 a	4.9 a	2.1 bcd	7.5 ab	5.1 a	8.7 ab	10.3 a
1206	Nicaragu				0.4 b	1.7 a	3.1 a						4.3 bc	7.7 b	11.4 a
1214	Tanzania	0.8 a	3.8 ab	4.6 a	0.5 a	1.8 a	3.5 a				2.7 a	8.4 a	4.7 ab	8.3 ab	10.2 a
1365	Nicaragu	0.7 a	3.5 ab	4.8 a	0.4 ab	1.8a	3.1 a	0.4 ab	3.4 a	4.0 a	2.3 bc	7.5 ab	4.5 ab	8.3 ab	10.9 a
1501	Haiti	0.5 a	3.0 bc	3.9 a				0.5 a	3.9 a	5.2 a			4.4 ab	9.3 a	11.5 a
1511	Haiti	0.7 a	4.1 a	5.1 a				0.3 bc	3.2 a	4.4 a	2.4 ab	7.9 ab	3.8 b	8.4 ab	11.2 a
1564	Nicaragu	0.6 a	3.4 ab	3.8 a	0.4 b	1.8 a	3.2 a				1.9 d	7.7 ab	4.7 ab	8.6 ab	11.4 a
1581	Haiti							0.3 c	3.7 a	5.0 a	2.4 ab	8.0 ab	4.1 ab	8.4 ab	11.0 a
2507	Costa	0.8 a	3.4 ab	3.7 b	0.4 b	1.6 a	3.2 a	0.4 ab	3.1 a	3.8 a	2.0 cd	7.1 b	5.0 a	8.1 ab	11.7 a
4039	Costa	0.5 a	2.3 c	3.7 b				0.3 abc	3.3 a	4.5 a	2.0 cd	7.0 b	4.3 ab	8.1 b	10.2 a
X		0.66	3.37	4.17	0.42	1.74	3.23	0.35	3.46	4.53	1.98	7.63	4.48	8.40	10.98
SE		0.04	0.13	0.18	0.02	.08	0.17	0.02	0.15	0.22	0.09	0.15	0.12	0.13	0.21
Pr>F		0.2867	0.016	0.3362	0.038	0.450	0.568	0.0058	0.820	0.616	0.002	0.212	0.336	0.400	0.730
$LSD_{0.05}$		0.34	0.84	1.49	.06	0.22	0.57	0.10	1.36	1.78	0.37	1.10	1.06	1.19	2.09

[†] Height means at 5 years were not determined due to excessive harvesting of best formed individuals within the trial.

Annex 3. Comparison of stem diameter growth of *Senna siamea* seed sources in Haiti, between 1989–1994. DBH = Diameter at 1.3 m above ground; $D_{0.1}$ = Diameter at 0.1 m above ground. Means followed by the same letter are not significantly different at the 95% probability level.

		Trial Site													
		Bombard			**Haut Camp**			**Lapila**			**Mirebalais**[†]		**Roche Blanche**		
		DBH	**DBH**	**$D_{0.1}$**	**DBH**	**DBH**	**$D_{0.1}$**	**DBH**	**DBH**	**$D_{0.1}$**	**DBH**	**$D_{0.1}$**	**DBH**	**DBH**	**$D_{0.1}$**
No.	**Origin**	cm													
554	Rwanda	3.1 abc	3.8 ab	5.9 bc				3.6 a	4.8 a	7.9 ab	7.3 ab	17.1 a	8.5 b	10.2 b	14.2 b
1206	Nicaragu				1.5 a	3.1 a	6.2 b						8.5 b	11.9 b	16.6 b
1214	Tanzania	3.5 ab	4.2 ab	7.5 ab	1.8 a	4.1 a	7.3 a				7.9 a	17.1 a	9.1 b	10.4 b	14.6 b
1365	Nicaragu	3.1 abc	3.6 ab	6.3 abc	1.6 a	3.1 b	6.2 b	3.5 a	3.8 b	7.4 b	7.2 ab	15.8 a	8.6 b	11.9 ab	16.9 b
1501	Haiti	2.6 bc	3.3 ab	6.0 bc				4.0 a	5.4 ab	9.6 a			10.6 a	14.0 a	20.1 a
1511	Haiti	4.1 a	5.3 a	8.3 a				3.0 a	3.9 ab	7.7 ab	7.0 ab	14.5 a	8.3 b	11.0 b	15.4 b
1564	Nicaragu	3.1 abc	2.9 b	4.8 c	1.6 a	3.3 b	6.0 b				7.1 ab	15.6 a	8.5 b	10.9 b	15.5 b
1581	Haiti							4.7 a	4.7 ab	8.6 ab	7.2 ab	15.9 a	9.6 ab	11.2 b	15.6 b
2507	Costa	3.7 a	3.7 b	6.4 abc	1.5 a	3.2 b	6.3 ab	3.1 a	4.0 ab	7.9 ab	6.4 b	14.1 a	8.9 b	11.5 b	16.1 b
4039	Costa	2.0 c	2.4 b	5.0 c				3.2 a	4.2 ab	7.8 ab	6.3 b	15.2 a	8.5 b	10.3 b	14.8 b
X		3.15	3.64	6.28	1.60	3.39	6.40	3.57	4.41	8.13	7.05	15.67	8.90	11.31	15.97
SE		0.17	0.23	0.35	0.12	0.27	0.33	0.27	0.22	0.26	0.20	0.44	0.18	0.27	0.39
Pr>F		0.036	0.042	0.0486	0.3257	0.0786	0.1136	0.7729	0.4417	0.3083	0.3730	0.5641	0.0523	0.0446	0.0293
$LSD_{0.05}$		1.13	1.54	2.14	0.32	0.81	1.02	—	—	2.03	1.41	3.61	1.36	2.11	2.96

[†] Only stump diameter means at 5 years were determined due to excessive harvesting of best formed individuals within the trial.

HAITI PRODUCTIVE LAND USE SYSTEMS PROJECT

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