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Five Year Results of the *Pinus* Trial near Kenscoff, Haiti

by

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RESUME

Le genre *Pinus* est l'une des sources les plus importantes de bois dans le monde. Il est représenté en Haiti par *P. occidentalis*, une espèce endémique à l'île d'Hispaniola. La demande croissante pour les produits ligneux, ainsi que le défrichement des forêts de pins en Haiti pour l'agriculture, a sérieusement réduit les populations natives de *P. occidentalis*. Les besoins économiques sans cesse croissants des paysans portent à tester des provenances améliorées de pins qui peuvent offrir des produits de plus grande valeur et qui peuvent être plus efficacement gérées dans les systèmes agroforestiers en cours dans les montagnes de haute altitude.

En 1989, 29 lots de semences, représentant 12 espèces de pins, ont été établis dans un essai espèce/provenance à Viard, près de Kenscoff (alt. 1.500 m.). Le dessin expérimental utilisé était le bloc complètement au hasard avec 3 répétitions. Des données ont été recueillies sur la survivance, la hauteur et le diamètre de tige à 1, 2 et 5 ans après l'établissement de l'essai. Le volume marchand a été estimé à 7 ans.

Survivance

Le taux de survivance, pour tous les lots de semences, était de 80% après 5 ans. Après une première année où le taux de mortalité était de 10%, une diminution moyenne de 2,5% chaque année, a été observée. L'espèce qui a donné le taux le plus élevé de survivance était le *P. Taeda* (90,3%), comparativement au *Pinus sp.* de Cuba, qui a accusé le taux le plus bas (62,7%). La seule différence statistique décelée au niveau de l'espèce était au stade de 3 ans quand le *P. taeda* (91,9%) s'est montré supérieur au *Pinus sp.* de Cuba (67,0%).

De grandes différences ont été observées parmi les lots de semences, bien qu'aucune différence significative n'ait été détectée en analysant les lots séparément. Les trois meilleurs lots de semences au point de vue survivance, étaient représentés par *P. taeda* (94,7%, 93,3% et 90,7%), comparativement à ceux ayant le plus bas taux de survivance, 60,5%, accusé par un lot de *P. hondurensis*, obtenu d'un fournisseur commercial de semences au EUA.

Le taux moyen de survivance du contrôle (78,0%) était à près le même que celui de tout le site (79,6%) et approximativement classé au milieu de tous les lots testés. Le contrôle, un *P.occidentalis* en provenance de Seguin, Haiti, n'a virtuellement montré aucune différence de survivance avec les deux autres lots venant de la République Dominicaine (76,7% pour les deux).

Croissance en hauteur

La hauteur totale moyenne pour le site, après 5 ans, était de 3,8 m. Les taux de croissance pendant les 3 premières années furent de 0,5 m/an en moyenne pour tout le site, ensuite grimpèrent à 1,2 m/an entre 3 et 5 ans. Le contrôle *P. occidentalis*, grandit de 4,2 m (0,8 m/an) en moyenne - plus vite que les deux autres lots de la République Dominicaine (0,6 m/an), bien qu'il n'y ait pas de différence significative à 95% de probabilité.

P. oocarpa 15319 de Zimbabwe était le plus performant, donnant en moyenne 5,9 m. après 5 ans avec un taux d'accroissement de 1,7 m/an pendant la troisième et la quatrième année. Il maintint sa domination pendant toute la période de mensurations. Trois autres lots de semences dépassa un taux de croissance annuel de 1 m; *P. patula* 15275 et *P. taeda* 15169 de Zimbabwe et *P. taeda* 469 de Setropa, une compagnie commerciale de semences établie en Hollande. Ces lots de semences sont supérieurs à ceux de l'espèce locale, *P. occidentalis,* tant pour les taux de croissance que pour la forme.

Le lot de semences qui a manifesté la croissance la plus lente, *P. Caribaea* 15/83 de Marbajitas, Cuba, a donné une moyenne de 1,8 m après 5 années. En général, les lots de semences les moins performants furent représentés par *P. Caribaea caribaea, P. Caribaea hondurensis, Pinus* sp. de Cuba, et *P. radiata*. Ces espèces, généralement adaptées aux conditions de basse altitude, devraient être éliminées comme candidats pour l'agroforesterie ou le reboisement dans des zones de moyenne et de basse altitude en Haiti.

Les lots de *P. taeda* (496, 1003 et 15169) et *P. elliottii* 15441 ont montré une plus grande uniformité de croissance, suivis de *P. oocarpa* 15319. Les taux de croissance les plus variables ont été ceux de *P. radiata, P. oocarpa* 497, *P. caribaea hondurensis* 36/83, 19/85 et 17/85, *P. elliottii* 561. Ces lots de semences sont les mêmes qui se sont montrés les moins adaptés.

Croissance en diamètre

La moyenne de DHP pour tout le site était de 2,0 cm et 6,3 cm à 3 et 5 ans, respectivement. Des différences de classement ont été observées pour la hauteur et le diamètre de tige parmi les lots de semences de pin. Elles reflètent des différences dans la forme de défilement.

Les plus grands diamètres ont été atteints par *P. taeda* 496 (9,1 cm), *P. oocarpa* 15319 (8,8 cm) et *P. caribaea bahamensis* 3/80 (8,8 cm) après 5 ans. Ceci correspond à un accroissement annuel moyen de 1,8 cm,, comparé à 1,1 cm pour le contrôle *P. occidentalis.* Le lot le plus performant pour le diamètre basal, mesuré à hauteur de souche de 0,1 m, était le *P. khasya* 15212 (14,0 cm).

Les chiffres de croissance en diamètre les plus bas ont été accusés par les lots de semences qui ont montré la croissance en hauteur la plus lente. Ces espèces avec les lots de semences au-dessous du taux de croissance annuelle moyenne du contrôle (1,1 cm/an) comprennent: le *Pinus sp.* en provenance de Cuba (0, 6 cm/an), *P. elliottii* 561 (0,8 cm/an), *P. caribaea* 9/76 et 15/83 (0,9 et 0,6 cm/an, respectivement), *P. caribaea hondurensis* 563 et 19/85 (0,7 et 1,0 cm/an, respectivement), *P. occidentalis* 38/77 et 66 (7293) (les deux 1,0 cm/an), *P. oocarpa* 497 (0,8 cm/an), et *P. radiata* 1008 (0,8 cm/an). Le taux de 1,1 cm/an du *P. occidentalis* âgé de 5 ans dans cet essai, devrait augmenter à mesure que les arbres entrent dans le stade de perchis et que l'éclaircie sélective est pratiquée, comme recommandée ci-dessous.

Volume marchand

Les espèces étroitement liées - *P. patula, P. oocarpa,* et *P. tecunumanii* - ont accusé les rendements les plus élevés de volume en bois marchand. Les moins performantes à Kenscoff furent *P. caribaea caribaea*, *P. occidentalis*, *Pinus sp.* de Cuba et *P. elliottii.* La différence entre le lot le plus performant, *P. patula* 15275, et le contrôle *P. occidentalis*, est d'environ 3 fois plus élevée. En plus du *P. patula* 15275, sept lots de semences, représentant 5 espèces, montrèrent un rendement en volume plus élevé que le contrôle, significatif à 95% de niveau de probabilité.

Recommandations

1) Eliminer les lots de semences inférieurs de l'essai de Kenscoff. Eclaircir sélectivement les lots prometteurs, en gardant les meilleurs arbres, sélectionnés pour leur forme et leur dimension, pour une étude à plus long terme. Pratiquer une éclaircie sélective pendant le mois de novembre et au début de décembre quand l'essai est le plus susceptible au vandalisme. Mener la première phase d'études de volume sur les arbres récoltés pour des analyses de régression. Eviter de collecter des semences de l'essai pour propagation, excepté pour la recherche.

2) Etablir et distribuer des lots de semences et provenances d'origine connue sous des conditions de croissance similaires, particulièrement ceux pouvant potentiellement avoir le plus d'impact économique sur les planteurs: *P. patula* 15275, *P. oocarpa* 15319, *P. tecunumanii* 7/77, *P. taeda* 496 et *P. caribaea bahamensis* 3/80. Etablir des peuplements isolés comme source de semences pour tout le pays. Continuer à distribuer un mélange balancé de lots de semences de *P. occidentalis,* récoltés d'arbres sélectionnés pour leur forme et leur vigueur, à partir de populations saines en Haiti.

3) Observer soigneusement toute régénération naturelle dans les essais pour confirmer si les pins importés peuvent se répandre naturellement. Observer tout signe d'hybridation naturelle avec le *P. occidentalis.*

4) Etudier les dimensions sociales de l'essai de Kenscoff, spécialement les problèmes d'incursions et l'utilisation de l'essai par les paysans avoisinants comme source de revenus. Développer des stratégies viables pour augmenter la sécurité de l'essai et établir un contrôle sur l'utilisation de la terre. Ceci a de sérieuses implications concernant la capacité du gouvernement à résoudre des problèmes de gouvernance, et l'encouragement des propriétaires à adopter des stratégies alternatives d'utilisation de la terre, qui conservent les ressources naturelles.

5) Informer le Service des Ressources Forestières (SRF du MARNDR) de l'aspect unique et de l'importance de l'essai de Kenscoff, et investiguer la possibilité pour le SRF de collaborer avec les Wynne dans la gestion et la protection de l'essai pour des études futures. L'essai devrait être étudié pour des observations à long terme sur les pestes et maladies, qualité de bois, régénération naturelle, hybridation naturelle, tolérance aux vents, développement de forme et paramètres quantitatifs de survivance, hauteur et diamètres de tige.

SUMMARY

The *Pinus* genus is one of the most important sources of lumber in the world. It is represented in Haiti by *P. occidentalis*, a species that is endemic to the island of Hispaniola. The increasing demand for wood products, coupled with the deforestation of the pine forests in Haiti for agriculture, have seriously reduced the native populations of *P. occidentalis*. The ever increasing economic needs of peasants merit the testing of improved pine provenances that can offer greater value and be more efficiently managed in the current agroforestry systems of the high-elevation mountains.

In 1989, 29 seed lots, representing 12 species of pine, were established in a species/provenance trial at Viard, near Kenscoff (alt. 1,500 m). A randomized complete block design was used with 3 replications. Survival, height and stem diameter measurements were recorded at 1, 2, 3 and 5 years after trial establishment. Merchantable volume was estimated at 7 years.

Survival

Site survival, including all seed lots, was 80% after 5 years. Following a first year mortality of 10%, each additional year averaged an annual drop of 2.5%. The highest surviving species was *P. taeda* (90.3%), as compared to the lowest survivor, the *P. occidentalis* provenance from Cuba (62.7%). The only statistical difference detected at the species level was at the 3-year stage when *P. taeda* (91.9%) was shown to be superior to the Cuban *P. occidentalis* (67.0%).

A large range of differences were observed among seed lots, though no statistical differences were detected by means comparison tests. The top three surviving seed lots were represented by *P. taeda* (94.7%, 93.3% and 90.7%) compared to the lowest survival, 60.5%, exhibited by a *P. caribaea hondurensis* seed lot acquired from a commercial seed supplier.

Average survival of the control (78.0%) was about the same as the overall site survival (79.6%) and approximately mid-ranked among all accessions tested. The control, a *P. occidentalis* seed lot from Séguin, Haiti, showed virtually no difference in survival from the other two seed lots originating in the Dominican Republic (both 76.7%).

Height Growth

The overall mean height for the site, after 5 years, was 3.8 m. Growth rates during the initial 3 years averaged 0.5 m/yr overall, then jumped to 1.2 m/yr between 3 and 5 years. The *P. occidentalis* control grew an average 4.2 m (0.8 m/yr) – faster than the other two seed lots from the Dominican Republic (0.6 m/yr), though the means were not significantly different at the 95% probability level.

P. oocarpa 15319 from Zimbabwe was the top performer, averaging 5.9 m over 5 years with an increment rate of 1.7 m/yr during the third and fourth year. It maintained its dominance throughout the measurement period. Three other seed lots exceeded an annual height growth rate of 1 m: *P. patula* 15275 and *P. taeda* 15169 from Zimbabwe and *P. taeda* 496 from SETROPA, a commercial seed company in Holland. These seed lots are superior to the local *P. occidentalis* in both growth rates and form.

The slowest seed lot, *P. caribaea caribaea* 15/83 from Marbajitas, Cuba, averaged 1.8 m after 5 years. In general, the poorest performing seed lots were represented by *P. caribaea caribaea*, *P. caribaea hondurensis*, the *P. occidentalis* provenance from Cuba, and *P. radiata*. These species should be eliminated as candidates for agroforestry or reforestation at mid- to upper-elevation areas in Haiti.

The *P. taeda* seed lots (496, 1003 and 15169) and *P. elliottii* 15441 exhibited a high degree of uniform growth, followed by *P. oocarpa* 15319. The most variable growth rates were exhibited by *P. radiata*, *P. oocarpa* 497, *P. caribaea hondurensis* 36/83, 19/85 and 17/85, *P. elliottii* 561. These seed lots are the same as those that showed poor adaptability.

Diameter Growth

The overall site mean for DBH was 2.0 cm and 6.3 cm at 3 and 5 years, respectively. Differences were observed between height and stem diameter rankings among the pine seed lots. These differences reflect differences in taper form.

The largest stem diameters (DBH) were achieved by *P. taeda* 496 (9.1 cm), *P. oocarpa* 15319 (8.8 cm) and *P. caribaea bahamensis* 3/80 (8.8 cm) after 5 years. This corresponds to a mean annual increment of 1.8 cm, as compared to 1.1 cm for the *P. occidentalis* control. The top seed lot for basal diameter, measured at a stump height of 0.1 m, was *P. khasya* 15212 (14.0 cm).

The slowest diameter growths were exhibited by the seed lots that achieved the slowest height growth. Those species with seed lots below the mean annual growth rate of the control (1.1 cm/yr) included the following: the *P. occidentalis* provenance from Cuba (0.6 cm/yr), *P. elliottii* 561 (0.8 cm/yr), *P. caribaea* 9/76 and 15/83 (0.9 and 0.6 cm/yr, respectively), *P. caribaea hondurensis* 563 and 19/85 (0.7 and 1.0 cm/yr, respectively), *P. occidentalis* 38/77 and 66 (7293) (both 1.0 cm/yr), *P. oocarpa* 497 (0.8 cm/yr), and *P. radiata* 1008 (0.8 cm/yr). The 1.1 cm/yr rate of the 5-year old *P. occidentalis* in this trial should increase as the trees enter into the pole stage and selective thinning is conducted as recommended below.

Merchantable Volume

The closely related species – *P. patula*, *P. oocarpa*, and *P. tecunumanii* – exhibited the highest yields of merchantable wood volume. The poorest performers at Kenscoff were *P. caribaea caribaea*, *P. occidentalis*, the *P. occidentalis* provenance from Cuba and *P. elliottii*. The difference between the top seed lot, *P. patula* 15275, and the *P. occidentalis* control is about a 3-fold difference. In addition to *P. patula* 15275, seven seed lots, representing 5 species, showed greater volume yield than the control, significant at the 95% probability level.

Recommendations

1) Eliminate the inferior seed lots from the Kenscoff trial. Selectively thin the promising seed lots, keeping the best trees, selected for form and size, for longer term study. Conduct selective thinning during the month of November and early December when the trial is most vulnerable to vandalism. Conduct the first phase of volume studies on the harvested trees for regression analyses.

2) Establish and distribute seed lots and provenances of known origin under similar growing conditions, particularly those with the greatest potential of making an economic impact among farmers: *P. patula* 15275, *P. oocarpa* 15319, *P. tecunumanii* 7/77, *P. taeda* 496 and *P. caribaea bahamensis* 3/80. Establish isolated stands for an in-country source of seed. Continue to distribute a balanced mix of *P. occidentalis* seed lots, harvested from trees selected for form and vigor from healthy populations in Haiti. Avoid collecting seed from the trial for extension purposes. The genetic quality of the seed harvested from a particular provenance or seed lot cannot be guaranteed because of the possibility of outcrossing.

3) Observe carefully any natural regeneration in the trials to confirm whether the imported pines can spread naturally. Observe any evidence of natural hybridization with *P. occidentalis*.

4) Study the social dimensions of the Kenscoff trial, especially encroachment problems and the use of the trial by neighboring peasants for cash cropping purposes. Develop suitable strategies to increase the security of the trial and establish control of land use. This has serious implications on the ability of government to address governance problems and encourage landowners to invest in alternative land use strategies that conserve natural resources.

5) Inform the Service des Ressources Forestière (MARNDR) of the uniqueness and importance of the Kenscoff trial and investigate the possibility for the SRF to collaborate with the Wynnes in managing and protecting the trial for future studies. The trial should be studied for long-term observations of pest and diseases, wood quality, natural regeneration, hybridization, tolerance to winds, form development and quantitative parameters of survival, height and stem diameters.

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ACKNOWLEDGEMENTS

SECID/AUBURN would like to extend its sincere appreciation to the organizations and individuals who contributed and cooperated in the success of the pine trial at Kenscoff. These include IRG, under whose contract with USAID initiated the trial in 1989; PADF and OFI for providing the seed for testing; USAID who provided financial support under the framework of the AOP, AFII and PLUS projects; the Baptist Mission at Fermathe who kindly propagated the seedlings; and the Wynne family who graciously shared their time and land for experimental purposes. Drs. Frank Brockman, Dennis Shannon and Zach Lea contributed valuable time to review and offer suggestions toward the publication of this report. Our appreciation extends to the SECID administrative staff for providing timely logistical support over a period of 7 years to complete this study.

ACRONYMS

AFII	Agroforestry II (1989–1991)
AOP	Agroforestry (1981–1987)
FAO	Food and Agriculture Organization
AU	Auburn University
IRG	International Resources Group, Ltd.
MBH	Mission Baptiste d'Haïti
OFI	Oxford Forestry Institute
PADF	Pan American Development Foundation
PLUS	Productive Land Use System project (1992–present)
SECID	South East Consortium for International Development
USAID	United States Agency for International Development

INTRODUCTION

Pinus occidentalis, known as Hispaniolan pine, is the only pine species native to Haiti and the island of Hispaniola. It is argued by some botanists to be endemic to the island, since it is very doubtful that the pine described from eastern Cuba as *P. occidentalis* is the same species as that from Hispaniola (Darrow and Zanoni, 1991a). The tree is quite versatile, occurring from nearly sea level to the highest peaks in Haiti (2,674 m) and the Dominican Republic (3,087 m). Hispaniolan pine is the dominant feature of the landscape in 3 regions of Haiti: Massif de la Selle in the southeast, Massif de la Hotte in the southwest, and Montagnes de Nord in the northeast. There has never been a precise inventory of the pine forests in Haiti, though the extent of pine-dominated landscape is certainly less than the estimate of 54 km^2 reported by Holdridge (1942). The largest block of *P. occidentalis* is located in the eastern range of Massif de la Selle, estimated to cover no more than 15 km^2 (T. A. White, pers. comm.).

Past and current exploitation of the species is primarily for lumber and "fat wood," locally known as *bwa gra*, used in the urban areas for lighting charcoal stoves. However, the most serious threat to the species is conversion of the fragile forest ecosystem to agriculture as a result of cultivating relatively lucrative crops of beans and vegetables for the urban market.

Planting pine trees is one of many solutions to the deforestation that is taking place in the high-elevation areas of Haiti. It is essential that the best genetic material be available for such reforestation efforts. The introduction of other *Pinus* species and provenances is necessary to ensure adaptability to changing site conditions (as a result of deforestation and agricultural conversion) and improve the economics of tree planting for Haitians. However, long-term ecological risks should not be overlooked in order to gain short-term economic gain. Close attention should focus on the degree, if any, that introduced species hybridize with *P. occidentalis*, and other negative effects that planting non-native pines may have on the health of local populations. Efforts to test imported *Pinus* species and provenances must be combined with a dual strategy of intensifying the range-wide collection of *P. occidentalis* for tree improvement and conserving the last remaining forests of the native pine species for future generations, both on the island of Hispaniola and abroad.

Review of Pine Trials in Haiti

Research of *Pinus* in Haiti has been all but absent for much of the country's history. Growth trials are very little published and the results, if available, are not readily accessible to the public. FAO established two mid-elevation trials at Furcy in 1976 and two lowland trials at Limbé in 1977 (Mooretel, 1979). Political instability during this period severely hampered trial management and only 1–2 year results were obtained. Three species (*P. caribaea*, *P. occidentalis*, and *P. pinaster*) were tested together at one of the Furcy trials, while the other trial compared *P. halepensis* with *Araucaria cunninghamii* and *Cupressus lusitanica*. All 4 pines species achieved excellent survival after 2 years (92.5–100%). *P. caribaea* and *P. halepensis* exhibited the fastest growth rates, averaging 2 m after 2 years.

Five species were tested (*P. caribaea, P. occidentalis, P. elliottii, P. tropicalis* and *P. patula*) at one of the Limbé trials, while the other trial contained 7 species (*P. caribaea, P. occidentalis, P. khasya, P. elliottii, P. halepensis, P. patula* and *P. canariensis*). In both trials, *P. caribaea* and *P. occidentalis* achieved the fastest growth rates (0.66–0.87 m) and high survival rates (91.1–100%) after the first year. Species that did not perform well were *P. canariensis, P. patula, P. halepensis,* and *P. elliottii.* It was noted that many of the pines were chlorotic, postulated to be a problem associated with a lack of mycorrhizae.

Three of the trials reported by Dupuis (1986) and established by ODH and PADF contained *P. occidentalis* and *P. caribaea* var. *hondurensis*. These trials were located at Cazeau (near Port-au-Prince), Fond-des-Nègres and Mont Puilboreau. At all three sites, pine either failed or was among the poorest performing species. Causes for poor growth were not identified.

In 1989, IRG established a *Pinus* species and provenance trial at Viard, near Kenscoff, containing 29 accessions, representing 12 species. Other smaller trials were established in the southwest (Sudre, Rambo), the Central Plateau (Lapila, Mombin Crochu) and the North (Morne Bois Pin), though these trials were abandoned due to project constraints related to the economic embargo of 1991–1994 and the shift in USAID strategy with the development of the PLUS project in 1992. This report summarizes the 5-year results of the Kenscoff trial for survival, height and diameter growth, plus the 7-year analyses for merchantable volume. The Rambo and Sudre trials were visited in 1995 and a summary of the observations are reported.

OBJECTIVES

1) Identify the best adapted pine species and seed lots for site conditions similar to Kenscoff (el. 1,500 m).

2) Compare the performance of 3 seed lots of *P. occidentalis* with 26 seed lots representing 11 species of *Pinus* originating in Central America, the Caribbean, southeastern USA, and Africa.

3) Select the best performing seed lots and best-formed individuals for reforestation purposes and the possibility of improving the economic value of pine in Haiti under similar site conditions.

METHODS AND MATERIALS

Site Description

The trial was established in 1988 by IRG. It is located an private land owned by the Wynne family at Viard, near Kenscoff, on the road to Godé. *Pinus occidentalis* is the dominant tree species on land adjacent to the trial. A summary of site characteristics is provided in **Table 1**. **Figure 1** shows the location of the trial in Haiti.

Table 1. Site characteristics of the pine trial near Kenscoff.

LATITUDE	18º27'
LONGITUDE	72º17 '
ELEVATION (m)	1565
RAINFALL (mm/an)	1900
RAINY SEASON	April-June, August-November
HOLDRIDGE LIFE ZONE	Montane Humid Forest
SLOPE (%)	40 - 100
SOIL pH	6.6 - 7.5
SOIL TEXTURE (% clay/silt/sand)	15/42/43
SOIL PHOSPHORUS (ppm)	15 - 39
SOIL POTASSIUM (ppm)	66 - 118
ORGANIC MATTER (%)	3.9 - 11.1
PARENT MATERIAL	Limestone

Seedling Propagation

Seed for the trial was acquired from international organizations and commercial seed suppliers: Oxford Forestry Institute (OFI), Zimbabwe Forestry Commission, Lawyer’s Nursery (North Dakota, USA), SETROPA S.A., Seed Export (Alabama, USA), PADF seed bank and the Baptist Mission tree nursery at Fermathe. It was difficult to secure seed source information from most of the suppliers, though this is highly desirable for future acquisitions and continued breeding purposes. Provenance collections from OFI should be distinguished from commercial seed or seed orchard collections, as the genetic quality and procedures for harvesting seed are

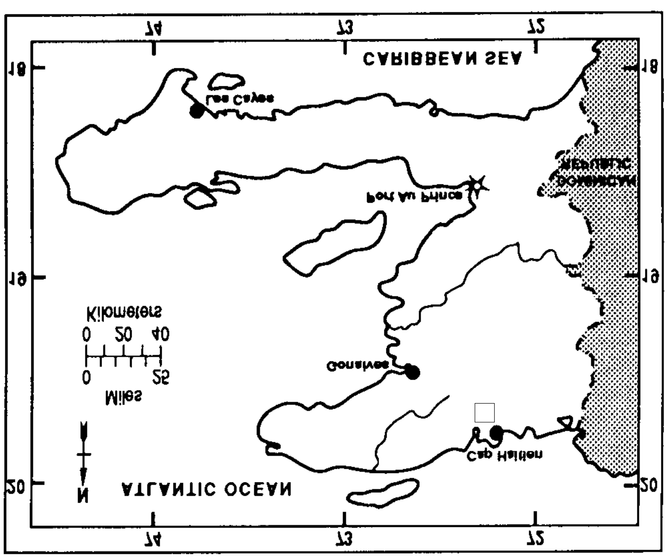

Figure 1. Location of the *Pinus* trial site (•) at Kenscoff, Haiti.

different. In this report, each of the accessions is recognized as a "seed lot." Several seed lots may represent one provenance, though they are analyzed separately. **Table 2** provides a summary of the source information of the pine species, provenances and seed lots used in this study.

Table 2. Provenances and seed lots included in the *Pinus* trial at Kenscoff. Seed Sources: D = DANIDA, O = Oxford Forestry Institute, P = PADF, Z = Zimbabwe Forestry Commission, L=Lawyer's Nursery, F=Baptist Mission, Fermathe.

SPECIES	PROV. NO.	ORIGIN/SOURCE	TEMP.(^{0}C)	ALT. (m)	LATITUDE	LONGITUDE	RAINFALL (mm)
P. caribaea bahamensis	**O**1/79	Little Abaco, Bahamas	24.8	10	26E52'N	77E37' W	1,229
P. caribaea bahamensis	**O**3/80	Byfield, Australia	Orchard seed				
P. caribaea bahamensis	**P**537	Bahamas Island, Bahamas (SETROPA)	Commercial seed				
P. caribaea bahamensis	**O**69(7296)	Andros Island, Bahamas	24.4	3	24E30'N	78E20'W	1,664
P. caribaea caribaea	**O**9/76	Consolacion del Norte, Cuba	24.7	75	22E48'N	82E57'W	1,792
P. caribaea caribaea	**D**51/83	Marbajitas, Cuba	24.7	75	22E48'N	82E57'W	1,792
P. caribaea hondurensis	**P**563	SEED EXPORT, MS, USA	Commercial seed				
P. caribaea hondurensis	**O**17/85	Mountain Pine Ridge, Belize	23.9	400	17E00'N	88E55'W	1,558
P. caribaea hondurensis	**O**19/85	La Mosquitia, Honduras	–	80	15E00'N	84E00'W	–
P. caribaea hondurensis	**O**20/85	Trojes, Honduras	23.0	720	14E03'N	85E58'W	1,649
P. caribaea hondurensis	**O**36/83	Byfield, Australia	Orchard seed				
P. elliotii	**P**561	Harrison, MS, USA	Commercial seed				
P. elliotii	**Z**15441	ZIMBABWE FORESTRY Commission	Orchard seed				
P. khasya	**P**538	Penhalonga, Zimbabwe (SETROPA)	Commercial seed				
P. khasya	**Z**15212	ZIMBABWE FORESTRY Commission	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. Dominicaine					
P. occidentalis	**F**Témoin	Seguin, Haïti	13.6	1680	18^o 19'N	72^o 14'W	1735
P. oocarpa	**P**497	SETROPA, Holland	Commercial seed				
P. oocarpa	**Z**15319	ZIMBABWE FOR. COMM.	Orchard seed				
P. patula	**Z**15275	ZIMBABWE FOR. COMM.	Orchard seed				
P. radiata	**I**1008	LAWYER'S NURS., ND, USA	Commercial seed				
P. taeda	**P**496	SETROPA, Holland	Commercial seed				
P. taeda	**P**562	Lincoln, MS, USA	Commercial seed				
P. taeda	**I**1003	LAWYER'S NURS., ND, USA	Commercial seed				
P. taeda	**Z**15169	ZIMBABWE FOR. COMM.	Orchard seed				
P. tecunumanii	**O**7/77	San Raphael del Norte, Nicaragua	–	1,200	13^{o}14'N	86^{o}08'W	1,362
P. tecunumanii	**O**24/85	Mountain Pine Ridge, Belize	23.9	700	17^{o}00'N	88^{o}55'W	1,558

The pine seedlings were propagated by the nursery at the Baptist Mission of Haiti, situated at Fermathe, from November, 1988 to May, 1989. Seed was sown directly into No. 4 Roottrainers, a plastic container designed to prepared seedling plugs with a well-formed root system that handles and transports safely to site. The potting medium selected for the Roottrainer was Fafard No. 2, a mix of sphagnum moss and vermiculite. Additional fertilizer, fungicides and pine mycorrhizae were added during the propagation period to insure healthy seedlings. The seedlings were hardened off for a period of several weeks prior to outplant.

Experimental Design and Trial Establishment

The trial, established on May 30, 1989 at Viard (near Kenscoff), utilized a randomized complete block design, with 3 blocks. The first level of randomization was by species, followed by a second level of randomization by provenance or seed lot. Each plot consisted of 24 trees, planted in 3 rows of 8 trees. **Table 3** provides of summary of the experiment details.

Table 3. Experimental design of the *Pinus* trial at Kenscoff.

ESTABLISHMENT DATE	May 30, 1989
NO. OF SPECIES†	12
NO. OF PROVENANCES & SEED LOTS	29
BLOCKS	3
TREES/PLOT	24
SPACING (m)	2.0 x 3.0
† The *P. occidentalis* provenance from Cuba and the 3 *P. caribaea* varieties are considered in this report as "species" for statistical purposes.	

Site preparation began in March, 1989. Approximately 4 hectares of land, formerly cropped for vegetables and laid fallow for several years, was prepared by marking contour rows spaced 3 meters apart with string and digging wide shallow holes every 2 m. Care was taken to disturb as little soil as possible due to the steepness of the land and the shallowness of the soil. Rocks were placed along the perimeter of the holes to form water catchments. Moldy pine litter was placed in the holes at a depth of 8 cm to encourage early mycorrhizal infection of planted seedlings. The seedlings were planted after the first series rains under saturated soil conditions. The seedlings were planted with a dibble stick or crowbar and care was taken to insure complete soil compaction around the root plug. The seedlings were initially mulched with decomposing pine litter, which was applied at the base of the seedlings periodically during the first 2 years of the trial.

Measured Variables and Observations

The following variables were measured after trial establishment. All the trees in the plot were measured for statistical analyses.

i) Survival, in %, at 1, 2, 3 and 5 years.

ii) Total tree height, to nearest 0.1 meters, at 1, 2, 3 and 5 years.
iii) Stem diameter at 1.3 m above ground (DBH), to nearest 0.1 cm, at 3 and 5 years.
iv) Basal diameter at 0.1 m above ground, to nearest 0.1 cm, at 5 years.
v) Usable height, to nearest 0.1 m, at 7 years.

The trees selected for usable height were only well-formed dominants, considered for pole or lumber, to a maximum density of 450 trees/ha, or 6 trees per plot. Usable height equaled total height for straight trees. Otherwise, height to the first fork or severe deformity was measured.

Soil samples were taken by randomly selecting 5 locations in each block and sampling at 2 depths: 0–20 cm and 20–50 cm. The samples from each block were bulked and each block was analyzed separately. Soil analyses for texture, pH, organic matter and available nutrients were conducted at the Soil Laboratory of Auburn University using standard procedures for calcareous soils.

The status of each tree was evaluated during each measurement period and given a code. Damages due to natural causes, like chlorosis, wind or insect attacks, were noted. Trees suffering from damages associated with livestock, weeding or vandalism were deleted from the statistical analyses for growth parameters.

Statistical Analyses

Field data was entered into the computer using a Lotus 123 spreadsheet. Merchantable volume was calculated for statistical analyses by multiplying usable height by DBH^2 (Butterfield, 1996). Survival data was transformed to the square root of the arc sine for analysis of variance and mean separation tests, according to procedures outlined in Steele and Torrie (1980). Analysis of variance and means comparison by the Waller-Duncan k-ratio Test were calculated using SAS (SAS, 1988). Analyses were performed at 3 levels: 1) by species, 2) by seed lot within species and 3) by seed lot within site. WordPerfect 6.1 was used for the graphics and word processing.

RESULTS AND DISCUSSION

Survival

The survival statistics for the Kenscoff trial are summarized in **Annex 1**. Site survival, including all seed lots and species, was 80% after 5 years. Following a first year mortality of 10%, each additional year averaged an annual drop of 2.5% (**Figure 2**). The highest surviving species was *P. taeda* (90.3%), as compared to the lowest survivor, the *P. occidentalis* provenance from Cuba (62.7%). The only statistical difference detected at the species level was at the 3-year

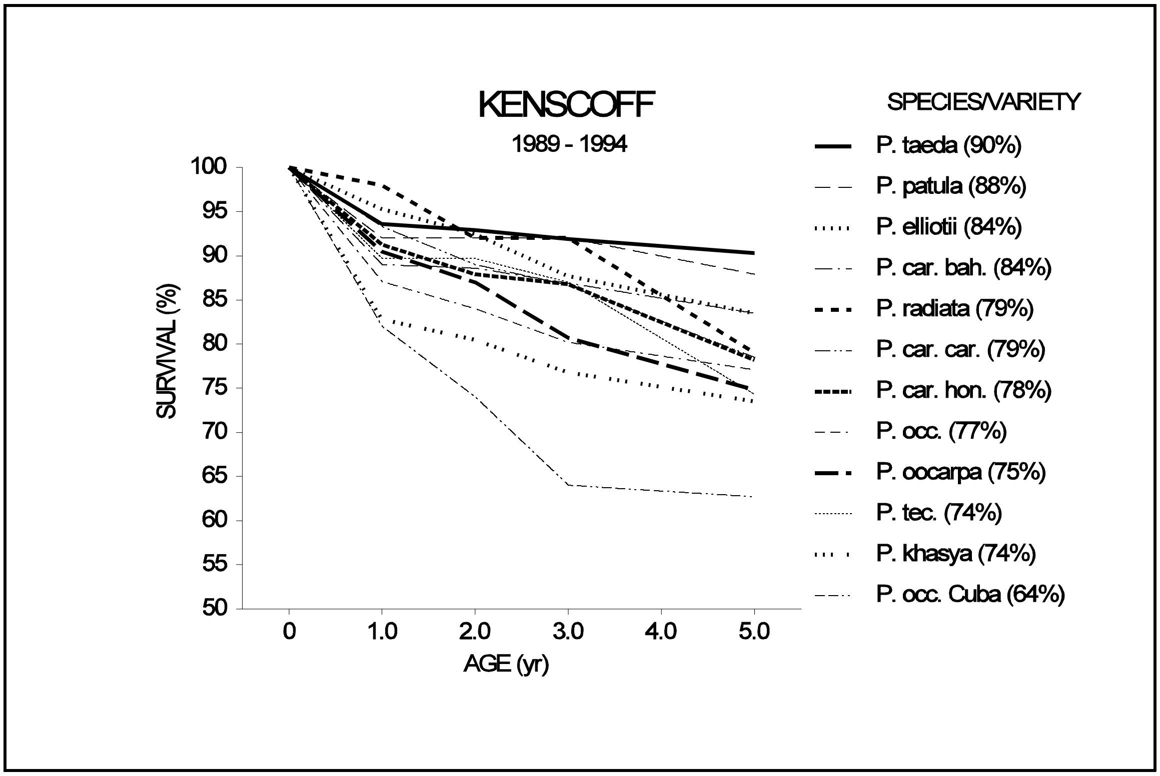

Figure 2. Survival curves of the *Pinus* species after 5 years at Kenscoff.

stage when *P. taeda* (91.9%) was shown to be superior to the Cuban *P. occidentalis* (67.0%).

A large range of differences were observed among seed lots, though no statistical differences were detected by means comparison tests. The top three surviving seed lots were represented by *P. taeda* (94.7%, 93.3% and 90.7%) compared to the lowest survival, 60.5%, exhibited by a *P. caribaea hondurensis* seed lot acquired from a commercial seed company in the USA.

Three groups of species (*P. caribaea caribaea*, *P. caribaea hondurensis* and *P. taeda*) showed differences in survival among seed lots during the measurement periods. The *P. caribaea caribaea* accession from Consolacion del Norte, Cuba, exhibited a 18.4% advantage over another accession from Marbajitas, Cuba, even though the two accessions originate from similar environments according to the information sent with the seed. *P. caribaea hondurensis* 17/85 from Mountain Pine Ridge, Belize showed superior survival (85.7% vs. 60.5) over a commercial seed lot (563), though statistical differences were present only at the 2- and 3-year stages. The *P. taeda* seed lot purchased from SETROPA (Holland) was the best performer overall on site and showed a significant advantage over the *P. taeda* that originated from a seed orchard in Zimbabwe, Africa.

Average survival of the control (78.0%) was about the same as the overall site survival (79.6%) and approximately mid-ranked among all accessions tested. The control, a *P. occidentalis* seed lot from Séguin, Haiti, showed virtually no difference in survival from the other two seed lots originating in the Dominican Republic (both 76.7%).

Height Growth

Height growth is a good indicator of vigor and site adaptability. The rate of height growth is also very important where forests no longer are the main source of trees for wood production. Slow-growing pine trees are at a critical disadvantage where the forest landscape has become dominated by human activities. If the pine tree does not grow quickly, it is more difficult for it to escape the damage caused by livestock (i.e., goats, pigs or cows) or that associated with cropping activities (fires, weeding, staking of livestock, etc.). This is becoming more and more the case in the native range of *P. occidentalis* in Haiti. The land around two-thirds of the trial site is perennially cropped for vegetables (onion, potato, leeks, and cabbage) or used as pasture land for livestock. Natural regeneration of *P. occidentalis* is nearly absent. What pine are left in the overstory are slowly disappearing as site conditions deteriorate under cropping pressure and the mature pines are exploited for a combination of fuelwood, pine straw for mulch, fat wood (*bwa gra*) and lumber.

A summary of the height data during the 5-year period is provided in **Annex 2** and illustrated in **Figure 3**. Note especially the slow growth of the pines during the initial establishment phase of 1–3 years, followed by much faster growth rates between 3 and 5 years. The overall mean height for the site, after 5 years, was 3.8 m. Growth rates during the initial 3 years averaged 0.5 m/yr overall, then jumped to 1.2 m/yr between 3 and 5 years. The *P. occidentalis* control grew an average 4.2 m (0.8 m/yr), faster than the 0.5 m/yr rate reported by Wadsworth (1945) for *P. occidentalis* in the Forêt des Pins at the same elevation (1,500 m). The control grew faster than the other two seed lots from the Dominican Republic (0.6 m/yr), though the statistics were not significantly different at the 95% probability level.

Eleven seed lots grew faster than the *P. occidentalis* control, represented by 7 species. The fastest growing seed lots were those acquired from the orchards of the Zimbabwe Forestry Commission. Four of the top five species were from Zimbabwe – strong evidence that the selection and breeding program of pine in that country can provide improved germplasm material for Haiti.

P. oocarpa 15319 from Zimbabwe was the top performer, averaging 5.9 m over 5 years with an increment rate of 1.7 m/yr during the third and fourth year. It maintained its dominance throughout the measurement period. Three other seed lots exceeded an annual height growth

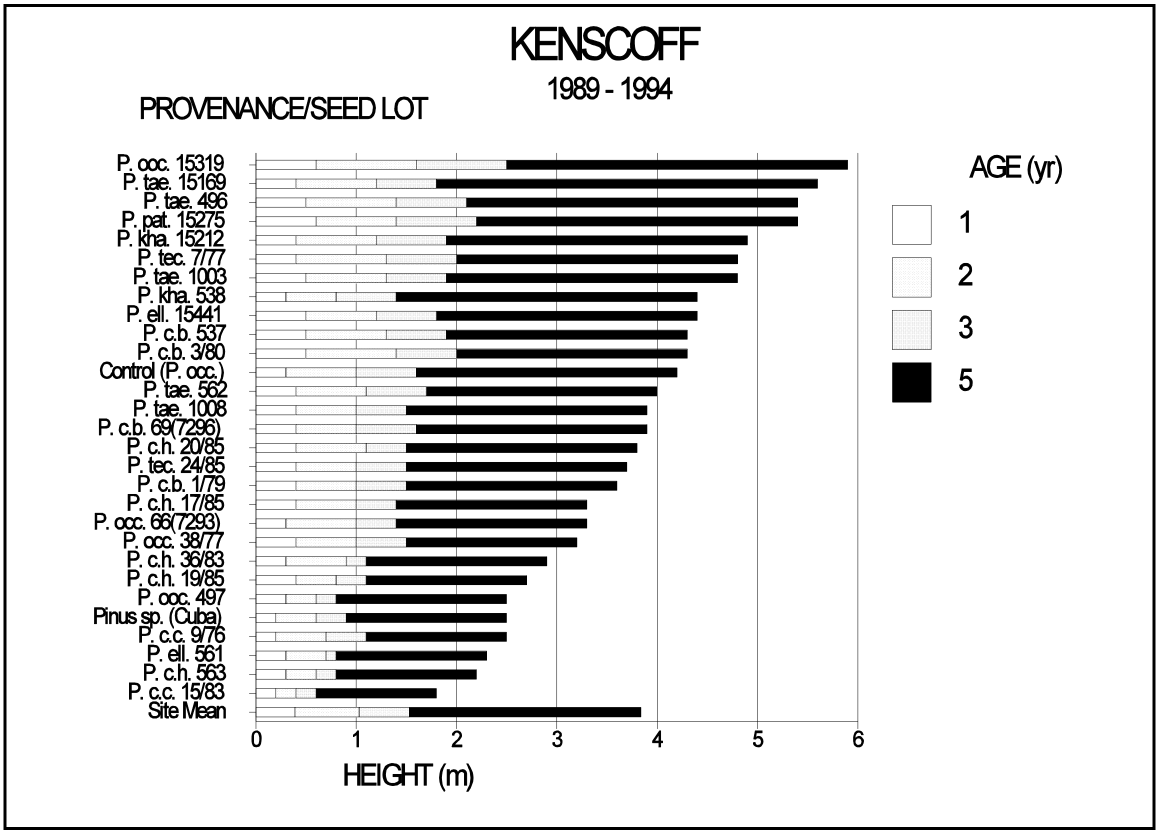

Figure 3. Comparison of height growth of the *Pinus* provenances and seed lots after 1, 2, 3, and 5 years at Kenscoff, Haiti.

rate of 1 m: *P. patula* 15275 and *P. taeda* 15169 from Zimbabwe and *P. taeda* 496 from Setropa, a commercial seed company in Holland. These seed lots are superior to the local *P. occidentalis* in both growth rates and form. Long-term resistance to pests and diseases, or other characteristics that might effect the economic potential of pine over the long-term, are still uncertain and should be a focus of continued research to improve the production of pine as a viable economic and environmental alternative to cash cropping vegetables.

The slowest seed lot, *P. caribaea caribaea* 15/83 from Marbajitas, Cuba, averaged 1.8 m after 5 years. In general, the poorest performing seed lots were represented by *P. caribaea caribaea*, *P. caribaea hondurensis*, the *P. occidentalis* provenance from Cuba, and *P. radiata*. These pine should be eliminated as candidates for agroforestry or reforestation at mid- to upper-elevation areas in Haiti. There were a total of 17 seed lots that grew slower than the control, though only 3 of these were statistically different. These were *P. caribaea caribaea* 15/83, *P. caribaea hondurensis* 563 and *P. elliottii* 561. Relative to the faster growing species, *P. elliottii* and *P. occidentalis* are borderline species – not really contenders in terms of growth rates, but species that may offer other benefits not evaluated in this trial. The variability found in *P. oocarpa* suggests caution when purchasing readily available seed from commercial suppliers.

The commercial seed lot (*P. oocarpa* 497) was purchased by PADF from SETROPA in 1988. It grew less than half the rate of the improved *P. oocarpa* 15319 with form so poor (mostly spiraling, crooked stems) that the entire genetic base in the trial should be eliminated.

One of the criteria used to select a preferred genotype is uniformity – that is, how uniform tree size is when planted on rocky and steep sites with shallow soils. Considering this criteria, the faster-growing seed lots were analyzed in terms of their plot variances. The *P. taeda* seed lots (496, 1003 and 15169) and *P. elliottii* 15441 exhibited a high degree of uniform growth, followed by *P. oocarpa* 15319. The average plot coefficient of variation (CV) for *P. elliottii* 15441 was 20%, while the three *P. taeda* seed lots averaged 21%. That of *P. oocarpa* 15319, the fastest growing seed lot, averaged 26%. For comparative purposes, the control had an average CV of 33%. The most variable growth rates were exhibited by *P. radiata*, *P. oocarpa* 497, *P. caribaea hondurensis* 36/83, 19/85 and 17/85, *P. elliottii* 561. Most of these seed lots are the same as those that showed poor adaptability.

Stem Diameter Growth

Differences in stem diameter growth are important in determining wood volume. The combination of diameter growth and form is analyzed below in terms of merchantable volume. A summary of the stem diameters at 3 and 5 years for the trial is provided in **Annex 3**.

The overall site mean for DBH was 2.0 cm and 6.3 cm at 3 and 5 years, respectively. In general, stem diameter rankings follow a similar pattern to the trends established for height (i.e., the taller seed lots had the larger diameters). However, slight differences were observed between height and stem diameter rankings among the seed lots. These differences are related to differences among species in taper form, which is an important feature of volume tables.

The largest stem diameters at breast height (DBH) were achieved by *P. taeda* 496 (9.1 cm), *P. oocarpa* 15319 (8.8 cm) and *P. caribaea bahamensis* 3/80 (8.8 cm) after 5 years (**Annex 3**). This corresponds to a mean annual increment of 1.8 cm, as compared to 1.1 cm for the *P. occidentalis* control. The top seed lot for basal diameter, measured at a stump height of 0.1 m, was *P. khasya* 15212 (14.0 cm). Both *P. caribaea bahamensis* and *P. khasya* ranked higher in stem diameter than they did for height. This is in favor of increased wood volume, though not necessarily wood that would fetch the highest lumber value. Problems common to both species were badly formed stem bases and low forking.

The slowest diameter growths were exhibited by the seed lots that achieved the slowest height growth. Those species with seed lots below the mean annual growth rate of the control (1.1 cm/yr) included the following: the *P. occidentalis* provenance from Cuba (0.6 cm/yr), *P. elliottii* 561 (0.8 cm/yr), *P. caribaea caribaea* 9/76 and 15/83 (0.9 and 0.6 cm/yr, respectively), *P. caribaea hondurensis* 563 and 19/85 (0.7 and 1.0 cm/yr, respectively), *P. occidentalis* 38/77 and 66 (7293) (both 1.0 cm/yr), *P. oocarpa* 497 (0.8 cm/yr), and *P. radiata* 1008 (0.8 cm/yr).

The control grew twice as fast as the average stem diameter of 10-year-old *P. occidentalis* at Morne des Commisaires (Wadsworth, 1945). He determined, by ring counts, that diameters averaged 5.5 cm, the same average that the control in this study achieved in 5 years. It should be noted that the *P. occidentalis* at Morne de Commisaires was natural regeneration and that growth rates determined by ring counts must be approached cautiously in subtropical environments (Avery, 1983). Darrow and Zanoni (1991b) report a mean annual increment of 0.8 cm for saw log trees over a 40-year period for the same elevations as Kenscoff (1,400–1,500 m). The 1.1 cm/yr rate of the 5-year old *P. occidentalis* in this trial should increase as the trees enter into the pole stage and selective thinning is conducted as recommended below.

Form

A tree's form is a combination of environmental and genetic effects. A good example of genetic differences within species was observed between the two *P. oocarpa* accessions. *P. oocarpa* 15319 was superior to *P. oocarpa* 497 in all qualitative and quantitative parameters: survival, height growth, diameter growth, form and general vigor. The form of *P. oocarpa* 497 was characterized by badly lodged stem bases and twisting stems in wide corkscrew fashion, rendering them useless for anything but fuelwood. Among species with multiple seed lots, *P. taeda* and *P. tecunumanii* were the most consistent in providing the best-formed trees. *P. caribaea bahamensis* was superior to *P. caribaea hondurensis* and *P. caribaea caribaea*, though the *bahamensis* variety seemed to require good soil depth for good form.

Traits that were characteristic of a poorly-formed seed lot included 1) a relatively high proportion of foxtails (i.e., where the terminal leader produces no branches), 2) severe lodging and twisting of the main stem, 3) distorted crown shapes, 4) symptoms of stress (burnt needles, abnormal branching, etc.) and 5) susceptibility to terminal bud damage by winds, insects and other agents. Taking all these traits into account, the following seed lots would be eliminated because of their questionable genetic quality or poor response to the site conditions at Kenscoff: both *P. caribaea caribaea* seed lots; *P. caribaea hondurensis* 563, 19/85 and 36/83; *P. radiata* 1008; *P. oocarpa* 497, the *P. occidentalis* provenance from Cuba, *P. khasya* 538, *P. caribaea bahamensis* 3/80 and 69 (7296), and the Hispaniolan *P. occidentalis.* One must keep in mind that unimproved *P. occidentalis* is being compared to the superior form and growth of other pine species that have benefitted from tree improvement.

Merchantable Volume

An important economic consideration in the choice of pine species and seed lot is merchantable volume yield, on a per hectare basis. This parameter combines survival, wood production, form and stand uniformity. The species and seed lot that best combines these traits has the greatest likelihood of making an economic impact. (Wood quality, resistance to pests and diseases, tolerance to hurricanes, degree of natural hybridization and regeneration are traits that were not evaluated, but should also be assessed over the long term).

It should not be surprising that the seed lots more or less follow the same rankings as for mean height and diameter growth. The closely related species – *P. patula, P. oocarpa,* and *P.*

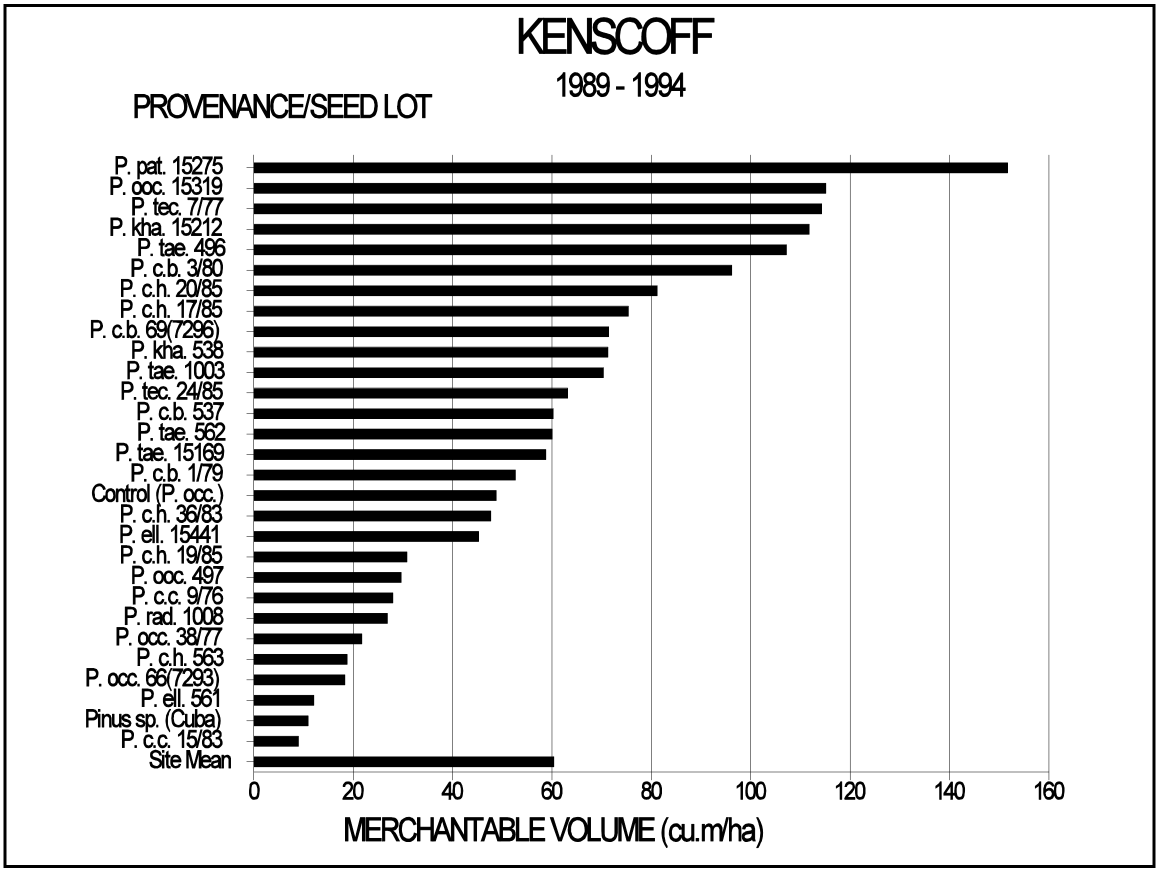

Figure 4. Comparison of merchantable volume among *Pinus* provenances and seed lots after 7 years at Kenscoff, Haiti.

tecunumanii – top the list, as shown in **Annex 4**. The poorest performers are the closely related coastal pines – *P. caribaea caribaea*, *P. elliottii* and the *P. occidentalis* provenance from Cuba. The difference between the top seed lot, *P. patula* 15275, and the *P. occidentalis* control is about a 3-fold difference. In addition to *P. patula* 15275, seven seed lots showed greater volume yield than the control, significant at the 95% probability level. **Figure 4** illustrates the merchantable volume differences exhibited at the Kenscoff trial. It should be noted that the units (m^3/ha) were not derived from actual volume tables (as these were not available), but are estimates calculated for *comparative purposes only*. The volume equations provided in Timyan (1996) were not considered, as they are derived from a sample of *P. occidentalis* timber trees whose stem diameters ranged from 15–50 cm.

A review of **Annex 4** points out several noteworthy observations. Firstly, three of the top seed lots, representing 3 different species, originated from the selection efforts of the Zimbabwe Forestry Commission and is strong evidence supporting the acquisition of tree seed from reputable seed orchards. However, one must know which species to introduce, as shown by the sub-par performance of *P. taeda* 15169, also from Zimbabwe.

Secondly, the risk in purchasing readily available seed from commercial seed companies is shown by the difference in the performance of the *P. oocarpa* and the *P. taeda* accessions. The *P. oocarpa* seed purchased from Setropa, S.A. was one of the poorest survivors of all pine accessions after 5 years (65%) and produced a quarter of the merchantable wood volume as *P. oocarpa* 15319 from Zimbabwe. In contrast, the *P. taeda* seed purchased from Setropa was the best performer for the species at Kenscoff. There is no way to know for certain how well any pine seed will perform in Haiti under a given set of site conditions if experiments such as the Kenscoff trial are not conducted and evaluated. If no such information is available, the only recourse is to minimize long-term risks by utilizing a broad genetic diversity made up of many small seed lots rather than propagating a large number of seedlings from one or a few seed lots. Program efficiencies favor the latter approach which should be avoided to the extent possible, particularly if one is uncertain the adaptability of imported provenances.

Lastly, the pine species vary remarkably in their response to the site conditions at Kenscoff. The wide range in performance of the *P. oocarpa* and *P. caribaea* seed lots are notable examples of the variation found in species whose natural distribution cover a wide range of environmental conditions in Central America and the Caribbean. Even the *P. occidentalis* seed lots showed a range large enough to be of economic significance in extension programs. The control produced twice the volume of wood as either seed lots collected from the Dominican Republic. The control is considered unimproved, since no attempts have been made, to the knowledge of the authors, in selecting *P. occidentalis* for improved traits.

Observations from Other Trials

As mentioned previously, several smaller pine trials were established in other regions of Haiti with a selection of the same provenances and seed lots that were tested at Kenscoff. Two of the sites, Rambo and Sudre, were visited at a trial age of 6 years. Overall, both sites suffered from neglect due to their abandonment by SECID early after trial establishment. Many of the seedlings were either stolen during the first year or vandalized at a later period for poles. It is likely that the trials suffered from inadequate weeding and mycorrhizal development.

The Rambo site is located on the road to Formond at an elevation of 800 m. The best performing provenance was *P. tecunumanii* 7/77 with the highest survival and appreciable growth rates. Also growing well were *P. caribaea hondurensis* 17/85 and 3/80, though average in survival. Mortality of *P. occidentalis* 38/77, *P. caribaea bahamensis* 69(7296), *P. caribaea hondurensis* 20/85 and *P. oocarpa* 4/97 was high, with many seedlings stolen or vandalized.

The Sudre site is located along the road between Cavaillon and Baradères at an elevation of 750 m. The best performing provenance was *P.caribaea hondurensis* 19/75, both in terms of survival and growth rates. *P. oocarpa* 15319 and *P. caribaea bahamensis* 1/79 exhibited average survival for the site with good growth. *P. patula* 15275 survived poorly, but grew well. *P. occidentalis* 66(7293) was the poorest survivor and slowest grower.

CONCLUSIONS

This Kenscoff trial is the first and only one of its kind in Haiti. Other pine trials either failed or were short-lived, never extending beyond 2 years and were of dubious technical value. By far the majority of tree studies in Haiti concern themselves with broad-leaved species adapted to low elevations. Considering the importance of pine to the high-elevation areas of Haiti, the Kenscoff trial has generated a valuable source of information, including the worth of testing alternative pine germplasm to increase productivity and economic value for farmers.

Selected seed lots of several pine species, notably *P. patula, P. oocarpa,* and *P. tecunumanii,* have shown superior yields of merchantable wood volume compared to the local *P. occidentalis*. Yields can be tripled under similar growing conditions by selecting the improved seed lots planted in the Kenscoff trial. If pine trees are to be established by planting, it would be folly not to use the best genetic material available. Species selection is not as important as seed lot or genotype selection for improved performance, particularly for those species that show a high degree of variability and have been selected and bred for production criteria.

Long-term considerations, such as pest and disease resistance, wood quality, natural regeneration and hybridization, have not been considered in this experiment primarily due to the short time scale. These parameters are critically important for sustainability and should be a focus of long-term forestry research. Furthermore, it is expected that a much different suite of provenances would be best under conditions varying significantly from those at Kenscoff.

The pine forests of Haiti are located in the last remaining regions of the country where native ecosystems are relatively intact. Pine is a dominant feature of La Visite and Macaya National Parks. The entire pine ecosystem in Haiti is under severe exploitation pressure and is rapidly being converted to agricultural production. Though site and economic conditions are changing rapidly enough to merit the consideration of new *Pinus* genotypes, there is a critical need to conserve the native populations of *P. occidentalis.* Any attempt to introduce improved *Pinus* species and provenances must be balanced with increased efforts to conserve native biodiversity – by preserving entire tracts of forest (i.e., Forêt des Pins, Parc Nationale de La Visite, Parc Nationale de Macaya) and initiating a genetic conservation effort with important local populations of *P. occidentalis*.

RECOMMENDATIONS

1) Eliminate the inferior seed lots from the Kenscoff trial. Selectively thin the promising seed lots, keeping the best trees, selected for form and size, for longer term study. Conduct selective thinning during the month of November and early December when the trial is most vulnerable to vandalism. Conduct the first phase of volume studies on the harvested trees for regression analyses.

2) Establish and distribute seed lots and provenances of known origin under similar growing conditions, particularly those with the greatest potential of making an economic impact among farmers: *P. patula* 15275, *P. oocarpa* 15319, *P. tecunumanii* 7/77, *P. taeda* 496 and *P. caribaea bahamensis* 3/80. Establish isolated stands for an in-country source of seed. Continue

to distribute a balanced mix of *P. occidentalis* seed lots, harvested from trees selected for form and vigor from healthy populations in Haiti. Avoid collecting seed from the trial for extension purposes. The genetic quality of the seed harvested from a particular provenance or seed lot cannot be guaranteed because of the possibility of outcrossing.

3) Observe carefully any natural regeneration in the trials to confirm whether the imported pines can spread naturally. Observe any evidence of natural hybridization with *P. occidentalis*.

4) Study the social dimensions of the Kenscoff trial, especially encroachment problems and the use of the trial by neighboring peasants for cash cropping purposes. Develop suitable strategies to increase the security of the trial and establish control of land use. This has serious implications on the ability of government to address governance problems and encourage landowners to invest in alternative land use strategies that conserve natural resources.

5) Inform the Service des Ressources Forestière (MARNDR) of the uniqueness and importance of the Kenscoff trial and investigate the possibility for the SRF to collaborate with the Wynnes in managing and protecting the trial for future studies. The trial should be studied for long-term observations of pest and diseases, wood quality, natural regeneration, hybridization, tolerance to winds, form development and quantitative parameters of survival, height and stem diameters.

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Annex 1. Survival means of the *Pinus* species, provenances and seed lots after 1, 2, 3, and 5 years at Kenscoff. Means followed by the same letter are not significantly different according to the Waller-Duncan k-ratio Test, a = 0.05.

			BY SEED LOT				BY SPECIES				BY SEED LOT & SPECIES			
Prov. No.	**Species**	**Origin/Source**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**
			(%)											
1/79	***P. caribaea bahamensis***	**Little Abaco, Bahamas**	90.3 a	90.3 a	86.3 a	78.0 a	89.0 a	88.6 a	86.9 ab	83.5 ab	90.3 a	90.3 a	86.3 a	78.0 a
3/80	***P. caribaea bahamensis***	**Byfield, Australia**	92.0 a	92.0 a	92.0 a	88.7 a					92.0 a	92.0 a	92.0 a	88.7 a
537	***P. caribaea bahamensis***	**Bahamas Island, Bahamas**	85.5 a	85.5 a	85.5 a	83.5 a					85.5 a	85.5 a	85.5 a	83.5 a
69 (7296)	***P. caribaea bahamensis***	**Andros Islands, Bahamas**	83.7 a	82.3 a	80.7 a	80.7 a					83.7 a	82.3 a	80.7 a	80.7 a
9/76	***P. caribaea caribaea***	**Consolacion del Norte, Cuba**	94.7 a	93.3 a	91.7 a	87.7 a	93.3 a	89.0 a	86.7 ab	78.5 a	94.7 a	93.3 a	91.7 a	87.7 a
15/83	***P. caribaea caribaea***	**Marbajitas, Cuba**	92.0 a	84.7 a	81.7 a	69.3 a					92.0 a	84.7 a	81.7 a	69.3 b
563	***P. caribaea hondurensis***	**SEED EXPORT, AL, USA**	81.5 a	73.0 a	73.0 a	60.5 a	91.3 a	87.9 a	86.8 ab	78.2 a	81.5 a	73.0 b	73.0 b	60.5 a
17/85	***P. caribaea hondurensis***	**Mountain Pine Ridge, Belize**	100 a	97.3 a	97.3 a	85.7 a					100 a	97.3 a	97.3 a	85.7 a
19/85	***P. caribaea hondurensis***	**La Mosquitia, Honduras**	94.7 a	90.3 a	90.3 a	86.0 a					94.7 a	90.3 ab	90.3 ab	86.0 a
20/85	***P. caribaea hondurensis***	**Trojes, Honduras**	94.7 a	93.3 a	89.0 a	89.0 a					94.7 a	93.3 ab	89.0 ab	89.0 a
36/83	***P. caribaea hondurensis***	**Byfield, Australia**	83.7 a	81.0 a	81.0 a	64.0 a					83.7 a	81.0 ab	81.0 ab	64.0 a
561	***P. elliottii***	**Harrison, Mississippi, USA**	96.0 a	87.5 a	77.0 a	75.0 a	95.3 a	92.5 a	87.7 ab	83.5 a	96.0 a	87.5 a	77.0 a	75.0 a
15441	***P. elliottii***	**ZIMBABWE FORESTRY COMM.**	94.7 a	94.7 a	93.3 a	87.7 a					94.7 a	94.7 a	93.3 a	87.7 a
538	***P. khasya***	**Penhalonga, Zimbabwe**	78.0 a	78.0 a	72.0 a	68.0 a	82.8 a	80.5 a	76.8 ab	73.5 a	78.0 a	78.0 a	72.0 a	68.0 a
15212	***P. khasya***	**ZIMBABWE FORESTRY COMM.**	87.7 a	83.0 a	81.7 a	79.0 a					87.7 a	83.0 a	81.7 a	79.0 a
4/78	***P. occidentalis***	**Bayoma, Cuba**	82.0 a	74.0 a	67.0 a	64.3 a	82.0 a	74.0 a	67.0 b	64.3 a				
38/77	***P. occidentalis***	**Jumunco, Rep. Dominicana**	90.3 a	86.3 a	82.0 a	76.7 a	87.1 a	84.0 a	80.7 ab	77.1 a	90.3 a	86.3 a	82.0 a	76.7 a
66 (7293)	***P. occidentalis***	**Hondo Valley, Rep. Dominicana**	84.7 a	80.7 a	78.0 a	76.7 a					84.7 a	80.7 a	78.0 a	76.7 a
Control	***P. occidentalis***	**Seguin, Haïti**	86.3 a	85.0 a	82.0 a	78.0 a					86.3 a	85.0 a	82.0 a	78.0 a
497	***P. oocarpa***	**SETROPA, HOLLAND**	89.0 a	86.3 a	76.7 a	65.0 a	90.5 a	87.0 a	80.7 ab	74.8 a	89.0 a	86.3 a	76.7 a	65.0 a
15319	***P. oocarpa***	**ZIMBABWE FORESTRY COMM.**	92.0 a	87.7 a	84.7 a	84.7 a					92.0 a	87.7 a	84.7 a	84.7 a
15275	***P. patula***	**ZIMBABWE FORESTRY COMM.**	92.0 a	92.0 a	92.0 a	87.7 a	92.0 a	92.0 a	92.0 ab	87.9 a				
1008	***P. radiata***	**LAWYER'S NURSERY, ND, USA**	98.0 a	92.0 a	92.0 a	79.0 a	98.0 a	92.0 a	92.0 ab	79.0 a				
496	***P. taeda***	**SETROPA, HOLLAND**	94.7 a	94.7 a	94.7 a	94.7 a	93.6 a	92.9 a	91.9 a	90.3 a	94.7 ab	94.7ab	94.7 a	94.7 a
562	***P. taeda***	**Lincoln, Mississippi, USA**	98.7 a	98.7 a	94.7 a	93.3 a					98.7 a	98.7a	94.7 a	93.3 ab
1003	***P. taeda***	**LAWYER'S NURSERY, ND, USA**	94.7 a	93.3 a	93.3 a	90.7 a					94.7 ab	93.3ab	93.3 a	90.7 ab
15169	***P. taeda***	**ZIMBABWE FORESTRY COMM.**	86.3 a	85.0 a	85.0 a	82.3 a					86.3 b	85.0b	85.0 a	82.3 b
7/77	***P. tecunumanii***	**San Raphael del Norte, Nicaragua**	89.0 a	87.7 a	83.3 a	72.3 a	89.7 a	89.7 a	87.0 ab	74.3 a	89.0 a	87.7a	83.3 a	72.3 a
24/85	***P. tecunumanii***	**Mountain Pine Ridge, Belize**	90.3 a	92.0 a	90.7 a	76.3 a					90.3 a	92.0a	90.7 a	76.3 a
		MEAN	90.24	87.75	85.28	79.70	90.17	87.28	84.47	78.72				
		SE	1.01	1.10	1.37	1.71	1.26	1.38	1.73	2.07				
		Pr>F	0.3967	0.2719	0.3931	0.4775	0.7430	0.3568	0.2174	0.5247				

Annexe 2. Total height means of the *Pinus* species, provenances and seed lots after 1, 2, 3, and 5 years at Kenscoff. Means followed by the same letter are not significantly different according to the Waller-Duncan k-ratio Test, a = 0.05.

		BY SEED LOT				BY SPECIES				BY SPECIES & SEED LOT			
Prov. No.	**Species**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**	**1 YR**	**2 YRS**	**3 YRS**	**5 YRS**
		(m)											
1/79	***P. caribaea bahamensis***	0.4 bcdefg	1.0 abcdef	1.5 abcde	3.6 cdefghi	0.5 ab	1.1 ab	1.8 ab	4.0 ab	0.4 a	1.0 a	1.4 a	3.6 a
3/80	***P. caribaea bahamensis***	0.5 abc	1.4 abc	2.0 ab	4.3 abcdefg					0.5 a	1.4 a	2.0 a	4.3 a
537	***P. caribaea bahamensis***	0.5 abc	1.3 abcd	1.9 abc	4.3 abcdefg					0.5 a	1.3 a	1.9 a	4.3 a
69 (7296)	***P. caribaea bahamensis***	0.4 bcdefg	1.0 abcdef	1.6 abcde	3.9					0.4 a	1.0 a	1.6 a	3.9 a
9/76	***P. caribaea caribaea***	0.2 fgh	0.7 bcdef	1.1 bcde	2.5 ghi	0.2 c	0.5 b	0.8 b	2.2 d	0.2 a	0.7 a	1.1 a	2.5 a
15/83	***P. caribaea caribaea***	0.2 h	0.4 f	0.6 e	1.8 i					0.2 b	0.4 b	0.6 a	1.8 b
563	***P. caribaea hondurensis***	0.3 efgh	0.6 def	0.8 de	2.2 hi	0.4 b	0.9 ab	1.3 ab	3.2 bcd	0.3 b	0.6 b	0.8 b	2.2 b
17/85	***P. caribaea hondurensis***	0.4 bcdef	1.0 abcdef	1.4 abcde	3.3 defghi					0.4 ab	1.0 ab	1.4 ab	3.3 ab
19/85	***P. caribaea hondurensis***	0.4 cdefgh	0.8 bcdef	1.1 bcde	2.7 fghi					0.4 ab	0.8 ab	1.1 ab	2.7 ab
20/85	***P. caribaea hondurensis***	0.4 bcdef	1.1 abcdef	1.5 abcde	3.8 bcdefgh					0.4 a	1.1 a	1.5 a	3.8 a
36/83	***P. caribaea hondurensis***	0.3 cdefgh	0.9 abcdef	1.1 bcde	2.9 efghi					0.3 ab	0.9 ab	1.1 ab	2.9 ab
561	***P. elliottii***	0.3 cdefgh	0.7 cdef	0.8 cde	2.3 hi	0.4 b	1.2 ab	1.5 ab	3.8 abcd	0.3 a	0.7 a	0.8 a	2.3 a
15441	***P. elliottii***	0.5 abcd	1.2 abcde	1.8 abcd	4.4 abcdefg					0.5 a	1.2 a	1.8 a	4.4 a
538	***P. khasya***	0.3 defgh	0.8 abcdef	1.4 abcde	4.4 abcdef	0.2 c	0.9 ab	1.6 ab	4.6 ab	0.3 a	0.8 a	1.4 a	4.4 a
15212	***P. khasya***	0.4 abcde	1.2 abcdef	1.9 abcd	4.9 abcd					0.4 a	1.2 a	1.9 a	4.9 a
4/78	***P. occidentalis (Cuba)***	0.2 gh	0.6 ef	0.9 cde	2.5 fghi	0.3 bc	0.5 b	0.9 b	2.5 cd				
38/77	***P. occidentalis***	0.4 cdefgh	1.0 abcdef	1.5 abcde	3.2 defghi			1.5 ab	3.6 abcd	0.4 a	1.0 a	1.5 a	3.2 a
66 (7293)	***P. occidentalis***	0.3 defgh	1.0 abcdef	1.4 abcde	3.3 defghi					0.3 a	1.0 a	1.4 a	3.3 a
Control	***P. occidentalis***	0.3 defgh	1.0 abcdef	1.6 abcde	4.2 abcdefg					0.3 a	1.0 a	1.6 a	4.2 a
497	***P. oocarpa***	0.3 defgh	0.6 def	0.8 cde	2.5 ghi	0.5 ab	1.2 ab	1.7 ab	4.5 abc	0.3 a	0.6 a	0.8 a	2.5 b
15319	***P. oocarpa***	0.6 a	1.6 a	2.5 a	5.9 a					0.6 a	1.6 a	2.5 a	5.9 a
15275	***P. patula***	0.6 ab	1.4 ab	2.2 ab	5.4 abc	0.6 a	1.4 a	2.2 a	5.4 a				
1008	***P. radiata***	0.4 abcdef	1.0 abcdef	1.5 abcde	3.9	0.4 ab	1.0 ab	1.5 ab	3.9 abcd				
496	***P. taeda***	0.5 abcd	1.4 ab	2.1 ab	5.4 abc	0.5 ab	1.2 ab	1.9 ab	4.9 ab	0.5 a	1.4 a	2.1a	5.4 a
562	***P. taeda***	0.4 bcdef	1.1 abcdef	1.7 abcde	4.0					0.4 a	1.1 a	1.7a	4.0 a
1003	***P. taeda***	0.5 abcd	1.3 abcde	1.9 abc	4.8 abcde					0.5 a	1.3 a	1.9a	4.8 a
15169	***P. taeda***	0.4 abcde	1.2 abcde	1.8 abcd	5.6 ab					0.4 a	1.2 a	1.8a	5.6 a
7/77	***P. tecunumanii***	0.4 abcde	1.3 abcde	2.0 abc	4.8 abcd	0.4 ab	1.2 ab	1.8 ab	4.3 abc	0.4 a	1.3 a	2.0a	4.8 a
24/85	***P. tecunumanii***	0.4 abcdef	1.0 abcdef	1.5 abcde	3.7 cdefghi					0.4 a	1.0 a	1.5a	3.7 a
	MEAN	0.39	1.03	1.53	3.84	0.39	1.00	1.53	3.92				
	SE	0.01	0.04	0.07	0.15								
	Pr > F	0.0003	0.0121	0.0078	0.0002	0.007	0.1371	0.1698	0.0188				
	MSD, a=0.05	0.20	0.74	1.15	1.93	0.15	0.82	1.28	1.98				

Annex 3. Stem diameter (DBH and $D_{0.1}$) means of the *Pinus* species, provenances and seed lots after 1, 2, 3, and 5 years at Kenscoff. Means followed by the same letter are not significantly different according to the Waller-Duncan k-ratio Test, a = 0.05.

Prov. No.	Species	BY SEED LOT DBH 3 Yrs	BY SEED LOT DBH 5 Yrs	BY SEED LOT $D_{0.1}$ 5 Yrs	BY SPECIES DBH 3 Yrs	BY SPECIES DBH 5 Yrs	BY SPECIES $D_{0.1}$ 5 Yrs	BY SPECIES & SEED LOT DBH 3 Yrs	BY SPECIES & SEED LOT DBH 5 Yrs	BY SPECIES & SEED LOT $D_{0.1}$ 5 Yrs
		(cm)								
1/79	***P. caribaea bahamensis***	1.9 abcd	6.7 abcde	10.2 abcdef	2.6 ab	8.1 ab	11.6 ab	1.9 a	6.7 a	10.2 b
3/80	***P. caribaea bahamensis***	3.0 a	8.8 a	12.9 ab				3.0 a	8.8 a	12.9 a
537	***P. caribaea bahamensis***	2.5 abcd	7.9 abc	11.3 abcde				2.5 a	7.9 a	11.3 ab
69 (7296)	***P. caribaea bahamensis***	2.2 abcd	7.7 abc	11.6 abcd				2.2 a	7.7 a	11.6 ab
9/76	***P. caribaea caribaea***	1.1 bcd	4.7 cdef	8.1 bcdef	1.0 bc	4.0 cd	7.3 bcd	1.1 a	4.7 a	8.1 a
15/83	***P. caribaea caribaea***	1.0 cd	3.0 f	6.2 ef				1.0 a	3.0 b	6.2 a
563	***P. caribaea hondurensis***	1.9 abcd	3.6 ef	6.3 ef	2.2 abc	6.1 abcd	9.3 abcd	1.9 a	3.6 c	6.3 b
17/85	***P. caribaea hondurensis***	2.3 abcd	6.4 abcdef	9.6 abcdef				2.3 a	6.4 ab	9.6 ab
19/85	***P. caribaea hondurensis***	1.7 abcd	5.0 bcdef	8.6 bcdef				1.7 a	5.0 bc	8.6 ab
20/85	***P. caribaea hondurensis***	2.0 abcd	7.2 abcde	10.8 abcde				2.0 a	7.2 a	10.8 a
36/83	***P. caribaea hondurensis***	2.0 abcd	6.0 abcdef	8.8 bcdef				2.0 a	6.0 abc	8.8 ab
561	***P. elliottii***	1.1 bcd	3.8 ef	5.3 f	2.1 abc	5.7 abcd	8.3 abcd	1.1 a	3.8 a	5.3 a
15441	***P. elliottii***	2.2 abcd	6.4 abcdef	9.4 abcdef				2.2 a	6.4 a	9.4 a
538	***P. khasya***	1.8 abcd	6.9 abcde	10.9 abcde	2.3 abc	7.6 ab	12.4 a	1.8 a	6.9 a	10.9 a
15212	***P. khasya***	2.7 abc	8.3 abc	14.0 a				2.7 a	8.3 a	14.0 a
4/78	***P. occidentalis (Cuba)***	0.9 d	2.9 f	5.6 f	0.9 c	2.9 d	5.6 d			
38/77	***P. occidentalis***	1.3 abcd	5.0 bcdef	8.1 bcdef	1.4 abc	5.2 abcd	8.4 abcd	1.3 a	5.0 a	8.1 a
66 (7293)	***P. occidentalis***	1.3 abcd	4.8 bcdef	8.4 bcdef				1.3 a	4.8 a	8.4 a
Control	***P. occidentalis***	1.3 abcd	5.5 abcdef	8.2 bcdef				1.3 a	5.5 a	8.2 a
497	***P. oocarpa***	1.0 cd	3.9 def	7.2 cdef	2.4 abc	7.1 abc	10.5 abc	1.0 a	3.9 a	7.2 a
15319	***P. oocarpa***	2.6 abcd	8.8 a	12.8 ab				2.6 a	8.8 a	12.8 a
15275	***P. patula***	2.8 ab	8.3 abc	12.8 ab	2.8 a	8.3 a	12.8 a			
1008	***P. radiata***	2.3 abcd	4.7 cdef	6.5 def	2.3 abc	4.7 bcd	6.5 cd			
496	***P. taeda***	2.5 abcd	9.1 a	12.5 ab	2.3 abc	8.1 ab	11.6 ab	2.5 a	9.1 a	12.5 a
562	***P. taeda***	1.9 abcd	6.5 abcdef	10.1 abcdef				1.9 a	6.5 a	10.1 a
1003	***P. taeda***	2.4 abcd	8.2 abc	11.8 abc				2.4 a	8.2 a	11.8 a
15169	***P. taeda***	2.2 abcd	8.5 ab	12.3 abc				2.2 a	8.5 a	12.3 a
7/77	***P. tecunumanii***	2.5 abcd	7.6 abcd	11.1 abcde	2.2 abc	6.6 abc	10.0 abc	2.5 a	7.6 a	11.1 a
24/85	***P. tecunumanii***	1.8 abcd	5.5 abcdef	8.8 bcdef				1.8 b	5.5 a	8.8 a
	MEAN	1.99	6.32	9.77	2.10	6.20	9.62			
	SE	0.09	0.27	0.36	0.14	0.38	0.53			
	Pr > F	0.0342	0.0010	0.0029	0.1150	0.0209	0.0247			
	MSD, a=0.05	1.74	3.67	5.14	1.62	3.55	4.87			

Annex 4. Comparison of merchantable volume of the *Pinus* provenances and seed lots at Kenscoff after 7 years. The volume estimates are calculated for comparative purposes only. Means followed by the same letter are not significantly different according to the Waller-Duncan k-ratio Test, a = 0.05.

Prov. No.	Species	Dominant Height (m)	Dominant DBH (cm)	Volume per Tree (x 10^{-2} m^3)	Volume per Hectare (m^3)
15275	*P. patula*	10.4 a	17.1 a	36.4 a	151.7 a
15319	*P. oocarpa*	10.4 a	16.2 a	27.6 abc	115.1 ab
7/77	*P. tecunumanii*	8.6 ab	15.9 ab	28.3 ab	114.3 ab
15212	*P. khasya*	9.3 ab	16.7 a	26.8 abc	111.8 ab
496	*P. taeda*	9.3 ab	16.6 a	25.7 abcd	107.2 abc
3/80	*P. caribaea bahamensis*	8.2 abcd	15.9 ab	23.1 abcde	96.2 abcd
20/85	*P. caribaea hondurensis*	8.0 abcd	15.4 abc	20.4 abcdef	81.2 abcde
17/85	*P. caribaea hondurensis*	7.9 abcd	14.4 abcd	18.1 bcdef	75.4 abcde
69(7296)	*P. caribaea bahamensis*	8.0 abcd	14.2 abcd	17.1 bcdef	71.4 bcde
538	*P. khasya*	8.4 ab	13.9 abcd	17.1 bcdef	71.3 bcde
1003	*P. taeda*	8.1 abcd	14.2 abcd	16.9 bcdef	70.4 bcde
24/85	*P. tecunumanii*	7.3 bcdef	13.2 abcdef	15.6 bcdef	63.2 bcde
537	*P. caribaea bahamensis*	8.3 abc	13.9 abcd	15.9 bcdef	60.3 bcde
562	*P. taeda*	7.7 abcd	13.4 abcde	14.4 bcdef	60.1 bcde
15169	*P. taeda*	8.0 abcd	13.4 abcde	14.6 bcdef	58.8 bcde
1/79	*P. caribaea bahamensis*	7.4 bcde	13.4 abcde	13.5 bcdef	52.7 bcde
Témoin	*P. occidentalis*	8.3 abc	11.6 bcdefg	11.7 bcdef	48.8 bcde
36/83	*P. caribaea hondurensis*	7.1 bcdef	12.7 abcdefg	12.2 bcdef	47.7 bcde
15441	*P. elliottii*	8.0 abcd	11.6 bcdefg	10.9 bcdef	45.3 bcde
19/85	*P. caribaea hondurensis*	5.3 defg	11.6 bcdefg	7.8 def	30.9 cde
497	*P. oocarpa*	7.1 bcdef	10.6 defgh	9.6 cdef	29.7 ed
9/76	*P. caribaea caribaea*	4.9 efg	11.4 cdefg	6.7 ef	28.0 de
1008	*P. radiata*	8.5 ab	10.5 defgh	9.6 cdef	26.9 ed
38/77	*P. occidentalis*	5.6 cdefg	11.1 cdefg	7.0 ef	21.8 de
563	*P. caribaea hondurensis*	5.4 defg	9.4 egfh	5.0 ef	18.8 e
66 (7293)	*P. occidentalis*	4.5 fg	10.6 defgh	5.2 ef	18.4 e
561	*P. elliottii*	4.7 efg	8.9 fgh	3.8 f	12.1 e
4/78	*P. occidentalis* (Cuba)	3.1 g	6.4 h	2.9 f	11.0 e
15/83	*P. caribaea caribaea*	3.6 g	8.6 gh	2.9 f	9.0 e
	MEAN	7.31	12.95	15.02	60.36
	Pr>F	0.0001	0.0001	0.0023	0.0019
	MSD, a=0.05	2.81	4.36	18.31	77.07