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AGROFORESTRY RESEARCH IN HAITI

BOOK I

THE FINAL REPORT OF THE UNIVERSITY OF MAINE FOR THE

USAID

AGROFORESTRY OUTREACH PROJECT

VOLUME I
MAIN TEXT

VOLUME II
TECHNICAL AGROFORESTRY STUDIES

March 1987

This report was prepared under USAID Contract No. 521-0122-C-5012.

AGROFORESTRY RESEARCH IN HAITI

BOOK I

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PREFACE

The final report of the University of Maine for the USAID Agroforestry Outreach Project (AOP) is contained in two books. Book I includes both Volume I, the Main Text of the report, and Volume II, the Technical Agroforestry Reports. Book II contains the Economic and Marketing Reports (Volume III), the Anthropological Reports (Volume IV), and the Working Papers (Volume V). The reports in Volumes II through V are The University of Maine's abridged versions of the authors' initial reports. The original documents, however, are available through the University of Maine Agroforestry Outreach Research Project (AFORP).

Volume I contains summaries of all the technical reports and working papers, as well as a general list of recommendations from the project. For specific conclusions and recommendations, the reader is referred to the subsequent volumes. Many of the reports are available in French.

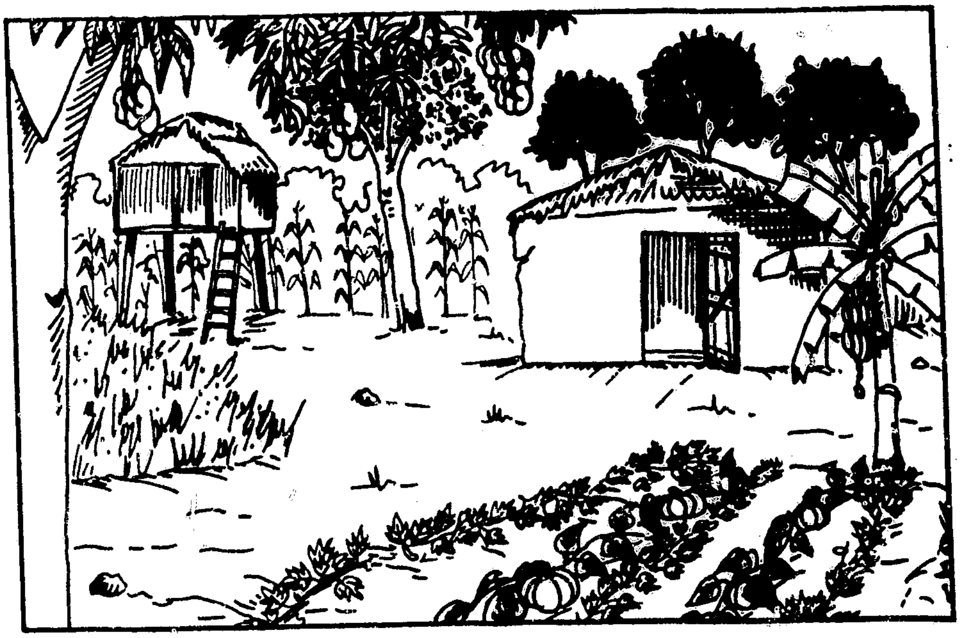
THE FINAL REPORT
OF
THE UNIVERSITY OF MAINE

AGROFORESTRY OUTREACH PROJECT

VOLUME I

MAIN TEXT

by
Marshall D. Ashley, Ph. D
Deborah S. Levine
and
The AFORP Staff



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ACKNOWLEDGEMENTS

The AFORP team recognizes that their work could never have been completed if it were not for the people who helped them in so many ways over the course of this project. The Grantees' offices and field personnel were instrumental in establishing many of our contacts in the farming communities. Their unselfish sharing of their own research results and data added much to our studies and is most appreciated. All three Grantees gave needed logistical support and equipment at times when our own resources were not adequate.

The USAID staff provided significant support and guidance throughout the project. The GSO office was particularly efficient in the handling of our shipped goods. To our Project Manager, Robert Wilson, and AOP Coordinators, Wendy King and Ira Lowenthal, and to the other USAID staff who reviewed our reports, your critiques were most appreciated.

No statement of appreciation would be complete without recognizing the efforts of our Haitian support staff who made our time much more productive.

Finally, we would like to thank the many Haitian farmers who so graciously shared their knowledge with us and allowed us to study their farming systems.

CHAPTER 1

INTRODUCTION

The Agroforestry Outreach Project

The USAID Agroforestry Outreach Project (AOP) began in late 1981. One of its goals was to provide the Haitian farmer with an additional cash crop by encouraging him to grow trees in an agroforestry system. This would simultaneously reduce Haiti's soil losses and other environmental problems.

The AFORP Research Component

One of the original concepts of AOP was to have a research component to support project needs. Although it was presumed that the Grantees (The Pan American Development Foundation °PADF§, Operation Double Harvest °ODH§, and CARE) would undertake their own internal research programs, their planting and outreach programs consumed all of their available time and resources. By the time of the mid AOP review, it had become apparent that an independent contractor was needed to design and implement the necessary research. Thus, the University of Maine (U of M) was selected to conduct studies in the following areas:

Traditional Haitian Agroforestry Systems

Silvicultural Studies

Nursery and Outplanting Techniques

Species Trials

Cost-benefit Analysis of Agroforestry Systems

The purpose of the Traditional Haitian Agroforestry Systems component was to 1) identify major cropping systems by ecological zone, 2) identify the agroforestry practices within these zones by the tree and crop species, spatial patterns, and other recognized technical and socioeconomic classification categories, and 3) use this data to quantitatively and qualitatively characterize Haitian agroforestry systems.

The Silvicultural Studies component was to 1) identify researchable silvicultural treatments in the context of Haitian agroforestry conditions, 2) locate AOP sites and apply these treatments, 3) initiate measurements of these treatments, and 4) document this work laying the framework for follow-up measurements.

The Nursery Outplanting Techniques component was to 1) identify the advantages and disadvantages of various seedling container types and potting mixes, 2) assess their effects on post-planting survival and height growth, 3) define the optimum seedling culture regimes for commonly planted species, 4) assess a variety of outplanting techniques using alternative planting implements and their effects on seedling survival and growth, and 5) prepare a report documenting the results of this work with specific reference to technical and project implications.

The Species Trials component would identify 1) desirable tree species for use in particular environmental conditions, cropping situations commonly associated with small farms, and production of particular wood products, 2) compile and synthesize information on existing species trials in Haiti, and 3) differentiate species performance on the basis of quantitative and qualitative parameters.

The Cost-benefit Analysis component was to 1) review agricultural economic studies, 2) obtain current baseline data on wood pricing, marketing, and consumption patterns, 3) conduct surveys on the decision-making framework of small farmers who have and have not incorporated AOP trees into their farming systems, 4) conduct surveys on the range of consumer preferences for fuelwood, charcoal and lumber, 5) prepare reports from the socioeconomic research, and, 6) produce quantitative and qualitative descriptions of producer preference and price structures, and other aspects of wood markets.

The project included support activities in the areas of Literature and Library services, Translation, and Technical and Administrative Services.

The original U of M research program was scheduled for completion in 18 months. USAID extended the contract to 24 months to allow for more in-depth study of the various components. The project was staffed by a multi-disciplinary team of two full-time researchers and several short-term personnel having assignments ranging from several weeks to 16 months.

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Approach to the Research

The Scope of Work and the U of M proposal were used as a basis to define the objectives of the research studies. The individual researcher detailed his research procedures, including the expected outputs. When necessary, short-term senior level consultants were brought in to strengthen the design. Once completed, the proposed research program was submitted to the entire staff for their review and comments. This enabled staff members to integrate their research. Scheduling was completed after all the revisions were made.

The field data collection procedure was pretested at a site where it would not bias any subsequent work, thus the data collection scheme would gather the desired information in a form which could later be analyzed.

The Final Report

The five volumes of this report represent a synthesis of AFORP research. Volume I includes an introduction to the AFORP research components, a description of the project outputs, and summaries of the Final Technical Reports and Working Papers.

Volumes II through V contain the abridged versions of the Final Technical Reports and Working Papers which were submitted to USAID over the course of the project. Volume II contains the Technical Agroforestry Reports, Volume III contains the Economic and Marketing Final Reports, Volume IV contains the Anthropological Final Reports and Volume V is a collection of the AFORP Working Papers.

The Final Report is being translated into French to best serve the needs of the Haitian development community.

CHAPTER 2

PROJECT OUTPUTS

Introduction

AFORP research has generated various outputs which can be divided into five categories: Progress reports, Technical reports, Working papers, Translations, and Library and Literature search.

Progress Reports

The University of Maine produced various periodic status reports including quarterly reports, semi-annual status reports, and an annual summary. These reports were written for USAID in fulfillment of its contractual agreement.

Technical Reports

The technical reports were divided into three subject areas: technical agroforestry, economics and marketing, and anthropology. Included in each report is a summary of the research methodology and findings, resulting conclusions, and the subsequent recommendations of the author. U of M has made initial contact with publishing houses to investigate the possibilities for mass production and distribution of its reports.

Working Papers

Working papers differ from technical reports in that they merely document research findings. Working papers covered various types of research including price surveys, consumption studies, species trials, and nursery experiments. One of the working papers is the economic analysis performed for the Project Evaluation at USAID's request.

Translations

U of M is translating its documents into French as a service to agricultural programs in Haiti, and French speaking countries.

Library and Literature Search

U of M has established an automated library reference system using USAID's MicroDis system. All documents currently held by U of M, as well as most of those held by the Coordinator's Office, the USAID, UNDP, and FAMV (Faculté d'Agronomie et Médicine Vétérinaire) libraries are on the system. Any new acquisitions can be added. To broaden the base of literature available for the project, U of M has purchased some new publications and subscribed to several technical journals. Also, through the U of M home library system, AOP now has access to all major databases relevant to agroforestry.

CHAPTER 3

SUMMARIES OF FINAL REPORTS AND WORKING PAPERS

TECHNICAL AGROFORESTRY STUDIES

Ashley: A STUDY OF TRADITIONAL AGROFORESTRY SYSTEMS

Introduction

A traditional agroforestry system is defined in this report as a farming system incorporating trees within gardens where the trees originated from other than an AOP type project, such as natural seeding, or transplanting native seedlings from one location to another. Such systems are called non-traditional because there is an implied potential for differences as the result of the outside project's intervening.

Several areas of investigation were undertaken including a survey of crop species, crop calendars, crop/tree competition, the effect of tree shading on crops, fencing and boundary marking, animal grazing and tree use. Data collection was based on sampling within Buffum/Campbell Environmental Zones, which are defined by elevation, rainfall, and parent soil-type differences.

The study surveyed more than 40 agroforestry systems over 15 B/C zones, representing more than 60% of Haiti's land mass. Approximately 140 other farms were studied to obtain a subset of tree information. This data was used to verify the representativeness of the survey. The combined surveys represented nearly 88% of Haiti's environmental zones, as defined in the Buffum/Campbell classified system.

The observed traditional systems were usually agri-silvo-pastoral. Such systems grow food crops, tree crops, and provide grazing for livestock, all over the same period between consecutive planting of food crops.

Farmers with traditional systems often had trees for boundary plantings, employed cut and carry feeding of grasses, or other vegetation for feeding livestock, and had several uses for their trees growing within the system's gardens. AOP plantings should be able to meet and even expand upon tree use for all of these purposes.

Conclusions

There will be little difficulty in getting farmers to plant AOP trees in the regular patterns envisioned to maximize wood production and soil conservation because farmers have *traditionally* been practicing these methods. Some exceptions exist, such as getting farmers to plant more than the average number of trees found at present on their farms, or when the species being distributed are perceived by the farmers as being weedlike, prolific seeders like leucaena, or an excessive user of soil moisture such as eucalyptus.

Recommendations

More fieldwork is needed to complete the study of crop associations in those B/C zones that have not been studied.

New research is needed on tree mortality within gardens, particularly on AOP planted seedlings. This study would include the off seasons.

Further studies on shade, crop species and associations, and calendar surveys for some zones should also be performed.

An economic analysis should be performed to find the marginal value of growing various densities of tree and crop combinations, as short term production of their other crops may be decreased because of shading.

Further research should be undertaken on the technical outputs and methods for increasing farmer motivation in using AOP trees for boundary marking.

Begin nursery production one to two months earlier to assure acceptable seedlings when the seasonal rains come.

Where farmers want to continue growing their shade intolerant crop associations: 1) AOP trees should be widely spaced within the gardens, 2) they should be pruned to reduce shade, 3) the trees should be planted on garden borders or as living contours, and 4) they should consist of species which do not give excessive shade, except when shade from the trees will conserve moisture needed by the shaded crop species.

Cut and carry feeding should be practiced where appropriate AOP tree species can be used for livestock, resulting in better animal nutrition and higher tree survival rates.

The CARE and PADF outreach programs should be expanded to include explanations and demonstrations for controlled grazing, as well as cut and carry, including trimmings from hedgerows or living contour plantings.

PADF should adopt a more complete presentation of utilization methods for exotic species in their outreach programs. The Forestry Support Program and USAID's Science and Technology staff should be requested to provide a summary of these uses in a non-technical format. This would eliminate the farmer's hit and miss utilization trials which could potentially lead to his rejection of the project.

Ashley: AGROFORESTRY IN HAITI
Illustrations of Gardens and Land Use Representing Agroforestry Systems in Haiti

Introduction

This booklet illustrates Haitian agroforestry systems; it is intended as a companion volume to "A Study of Traditional Agroforestry Systems" (Ashley, 1986). The report detailed the crop and tree species within major cropping systems, the crop-tree geometrical arrangements and the biological interrelationships between these crops and trees, agri-silvo-pastoral needs and potential grazing problems, and the uses and products of Haitian trees grown in agroforestry systems.

Three different schemes are used to illustrate the agroforestry systems commonly found in Haiti. All three are partially based on land use. The first system shown is a generalized one developed by the Centre de Madian-Salignac, and will provide a foundation for the farm settings in which the other two more detailed classifications will be used. The latter two were developed by ICRAF and are universally accepted by those portraying agroforestry systems.

Two special interest sections are included in the booklet: one on wood products, and the other on living fences. The booklet does not represent all tree and crop combinations found within Haitian agroforestry systems, as there are possibly thousands of these combinations. Farmers often diversify the species and their proportions to minimize their loss if a given crop species fails, to ease their needs for labor by spreading out the planting and harvesting times, and to meet a variety of marketing and personal food demands. Such diverse farm management practices will render varied appearances within similar agroforestry classifications.

Ashley and Grosenick: ENVIRONMENTAL ZONES AND ERODIBILITY OF TERRAIN IN HAITI WORKING PAPER #3

Introduction

Several USAID/Haiti projects are concerned with the amelioration of environmental and agricultural problems in Haiti. This working paper describes how summary tables for Buffum/Campbell environmental zones and erodibility classes have been obtained both for Haiti in its entirety and select political subdivisions. These summaries are reported by parent soil group, elevation, rainfall, erosion, erosion potential, and erosion risk classes.

Examples are given of some of the ways in which agricultural and environmental policy planners may gather needed information from these summaries. Each sample includes a numerical solution as a model to follow. One can obtain information such as the area of a given soil group for a given range of slope which can have its risk of erosion reduced by improving its vegetative cover or land use. Measures of the data shown in this report could be used in the management of specific areas such as a given watershed. However, the measures of parent soil group, rainfall, vegetative cover, and land use must be obtained from actual field sampling by experienced personnel.

The purpose of this paper is to explain in detail the basis of the Buffum/Campbell zone and DATPE (Direction de l'Aménagement du Territoire et Protection de l'Environnement) systems, to summarize by political subdivision and for Haiti in total, the extent of environmental conditions by each of these systems singularly and in combination, and to give a description of how environmental planners might use this data. A general discussion of the implications of the data in these summaries for policy planners in the agricultural sector is presented with suggestions of how these systems may be used for management decision-making.

This report can provide a basis for those interested in agricultural development and environmental concerns in Haiti to infer relationships between parent soil types and erodibility over specified slope, vegetation, rainfall, and elevation conditions. The authors contend that this same type of information could be of use in recommending future management of specific areas (such as watersheds), however, field studies at the site of interest will be required. The maps and data cited or given in this report are broad averages for political divisions and management of specific areas requires actual field verification since any given sub-area may vary greatly from the average political unit enclosing that area.

Field personnel with appropriate experience should be used to map out whatever units of parent soil type, slope, precipitation class, and vegetative cover class exist over the area of interest. Elevation and slope classes could be measured from existing topographic maps or directly in the field.

Dupuis: TWO CONTAINER/MIX TRIALS IN HAITI

Introduction

One of the reasons why the Agroforestry Outreach Project has been successful is the use of small containerized seedlings with an imported growing medium, which has greatly aided the distribution of seedlings. It has not only enabled farmers to easily transport more trees to their farms, but has enabled more farmers to receive trees and thus participate in the project.

Although this usage is widely practiced in North America, it is not the case with most reforestation projects in developing countries where black plastic bags and native soil are almost always used.

Three container types and two soil mix types were being used in AOP when the Ganthier trial was planted in October 1983. At that time, it seemed necessary to investigate not only the influence of these container and soil mix types on the seedlings, but also to test two additional container types. Therefore, a container/mix trial was established which tested effects of five containers and two soil mixes on five AOP and two naturalized tree species.

Another container/mix trial was planted in October, 1985. The selection of containers and mixes were based on the Ganthier trial results, and the present use (1985) of containers and mixes by the AOP grantees. Thus, the container/mix trial, which was located in Bon Repos, tested the effects of four containers and four mixes on two AOP and one naturalized tree species.

The research performed in these studies attempts to focus and explore two important technical issues within AOP, namely the selection of containers and soil mixes. The objectives of this research were to select and evaluate the effects of containers and mixes on the growth of AOP and naturalized tree species.

Conclusions

The results of the Ganthier trial indicated that leucaena survival is not significantly influenced by containers or mixes, though its survival would possibly be influenced by smaller containers and poorer quality mixes than those used in the trial. However, containers and mixes did have a significant influence on height.

Both Prosopis height and survival were affected by container volume. Prosopis grown in Pro-mix reach consistently taller heights than those grown in Haiti mix.

Parkinsonia survival is not significantly influenced by containers and mixes, but its height is.

Azadirachta is significantly influenced by containers, and its height affected by both containers and mixes.

n general, the survival rates of leucaena and prosopis at Bon Repos were a function of container volume, in that the greater the container volume, the better the survival.

Mix influence on survival and height growth is not significant after outplanting.

Recommendations

AOP trees should be required to use inoculant, especially leucaena and prosopis.

Leucaena should be grown in rootrainers, preferably the "sixes", and a mix which contains some native soil.

Prosopis should be the preferred species in low rainfall areas because of its hardiness and good growth performance. It should be grown in the plantband, winstrip, or "sixes" rootrainer and in Pro-mix.

Parkinsonia should not be planted in AOP because prosopis has better growth performance for the same environmental conditions and is more widely accepted.

Azadirachta should be planted in a plantband or "sixes" rootrainer as the "fives" rootrainer gives low survival.

Dupuis: AN EVALUATION OF CURRENT AOP, FAO, AND WORLD BANK SPECIES TRIALS IN HAITI

Introduction

The purpose of this report is to summarize available data for survival and growth rate by ecological zone from existing species trials. Secondly, to use this information to make conclusions and recommendations about current species selection in Haiti, the establishment of new species trials, and the selection of new species to be used in Haiti.

The process for selecting appropriate species is made through the use of the species trials. This report is based on the measurement of 36 species trials (21 AOP, nine FAO, and six World Bank) throughout Haiti. The trials are classified according to the Holdridge Biological and Buffum/Campbell zones. Species trials, when properly established and maintained, allow reliable growth and survival comparisons between various species. Despite the lack of uniform establishment and maintenance procedures, these trials revealed that the initial five tree species selected for AOP (*Azadirachta indica, Cassia siamea, Casuarina equisetifolia, Eucalyptus camaldulensis,* and *Leucaena leucocephala*) are good performers. Leucaena was the best performer in every lowland species trial where it was present.

Appropriate selection will ensure that with the proper weeding and protection, the trees will exhibit maximum growth and survival, thus motivating Haitian peasants to plant and maintain the trees. This report addresses the field performance of project trees under varying ecological conditions.

Conclusions

Many of the AOP species trials were set up using inappropriate research methodologies which influenced the ability to statistically analyze and compare the height growth and survival of the species being tested.

Further, species trial information such as seed sources, nursery management techniques, outplanting procedures, maintenance procedures and schedules, measurement schedules and data collection were often poorly recorded, and in some cases were not recorded at all.

Recommendations

Standard research methods should be set for all AOP species trials.

Literature searches should be conducted on leucaena provenances and their specific uses.

Seed provenances and seed dealer information should be requested for leucaena, neem, casuarina, eucalyptus, and cassia species.

New seed sources of the above species should be tested against Haitian seed.

Extension agent training programs should stress special care during the first year while the species are developing their root systems.

Dupuis: THREE DIRECT SEEDING TRIALS IN HAITI

Introduction

Direct seeding is an ancient technique which along with cuttings and clones is the only way in which mankind grows plant materials. Agriculture is almost entirely based on direct seeding. In forestry, however, seedling production is the mainstay of the reforestation effort in the world today. Technically, one could say that the seedlings were originally direct seeded into the containers, but this does not appropriately represent the material being outplanted. In recent years, there has been a growing interest in the aerial seeding of forest tree species, which is nothing more than direct seeding with a high technology delivery system. Aerial (direct) seeding of a variety of forest tree species has proven successful in many countries under varied conditions.

Several factors are essential if direct seeding is to be successful in Haiti: 1) the desire for more trees, 2) available land, 3) the ability to collect large quantities of appropriate seeds, and 4) AOP's ability to store and distribute seed so that farmers can plant them well before the rainy season.

The purpose of this report is to summarize the results of the direct seeding trials and to determine if AOP should implement this technique.

Conclusions

The study found that direct seeding technology if applied and managed correctly, can successfully provide trees for Haitian farmers, though it is limited in its application to areas with greater than 800mm average rainfall, and that are frequently weeded.

Secondly, direct seeding requires the selection of medium to large seeded tree species that exhibit rapid germination and seedling growth.

Thirdly, direct seeding requires continuous weeding throughout the first year to allow the seedlings to grow and establish themselves.

Finally, direct seeding requires that the seed be planted at the appropriate depth in relation to seed size.

Recommendations

Future research should place an emphasis on improving the scarification methods and cultural practices, and broadening the selection of species to be direct seeded.

Small direct seeding demonstrations should be established near or adjacent to nurseries. These should clearly demonstrate to the farmers who come to the nursery to get their seedlings the effects of weeding and water catchment on germination and growth of direct seeded and container grown seedlings.

Dupuis: THE EFFECTS OF TOP-PRUNING OUTPLANTED SEEDLINGS IN HAITI

Introduction

The purpose of this study was to examine the effects of top-pruning on survival and height growth and to determine whether this technique should be applied in AOP.

Survival rates are influenced by environmental, technological and sociological factors. One of the most important technological factors influencing survival is the degree to which the seedling is hardened-off at the time of planting. Seedlings that are more hardened-off generally have greater survival. Top pruning, by removal of the upper portion of the seedling at least two weeks before outplanting, may increase seedling survival by reducing transpiration losses. This is especially true for seedlings that are tall and have large shoot/root ratios.

Conclusion

Top-pruning does not appear to increase survival or height growth after planting, in fact, the height growth of cassia and neem are negatively affected by top-pruning. Though there were no significant survival differences found, the unpruned seedlings generally had better survival than the pruned seedlings. In several cases, the difference in survival rates was as much as 15 percent.

Recommendation

Discontinue top-pruning seedlings before planting except where the seedlings are tall and have large height shoot/root ratios.

Dupuis: THE EFFECTS OF EXTENDING THE NURSERY GROWTH PERIOD FOR OUTPLANTED SEEDLINGS IN HAITI

Introduction

This paper deals with improving the survival rate of AOP seedlings. Approximately 25 million seedlings have been planted over the last five years with a survival rate of about 45 percent. This rate is not satisfactory and could be increased according to the mid project evaluation.

Two approaches can be taken in dealing with the issue of increasing survival: the technological approach, which emphasizes better nursery management practices, and the sociological approach, which emphasizes training farmers in outplanting and maintenance techniques.

The purpose of this study was to examine the survival and height effects of seedlings grown with both a standard period, and a 25% extension of that period. Due to uncontrollable circumstances, the seedlings were held in the nursery for a period of time beyond that experimentally designed. This resulted from a lack of rain. Therefore, the actual growth periods were never attained. Nursery periods referred to as standard and extended were actually extended and over-extended, respectively.

Conclusions

Although the results of this study are inconclusive for the planned experiment because a standard growth period was not tested against an extended growth period, the results are valid for two different extended growth periods called in this report extended and over-extended. The former produces significantly taller seedlings than the latter.

Prosopis juliflora is an excellent species to plant in dry lowland areas because it survives well, grows the fastest over a three to four year period, and is the most adapted species to those sites. There are thornless varieties of prosopis available and these should be tested for farmer acceptance.

Recommendations

Further research is necessary and should include nursery and field trials.

Seedlings that are held in the nursery for an extended period of time should be root pruned before they are planted so that the lateral roots will be stimulated to egress through the sidewalls of the plug.

Ehrlich, Schmitt, and Di Mavindi: COPPICING TRIALS INVOLVING *LEUCAENA LEUCOCEPHALA* AND *CASSIA SIAMEA* NEAR PERDI MIDI AND MIREBALAIS

Introduction

This report details the interim results of a coppicing trial established in September, 1985 involving *Leucaena leucocephala* and *Cassia siamea* near Perdi Midi, and the establishment of a new trial in October, 1986 involving *Leucaena leucocephala* near Mirebalais.

The objectives of these trials are to:

1) Assess the productivity of coppice growth relative to tree growth in an untreated stand of trees

2) Assess the relative productivity of different coppicing treatments

3) Assess the effect of coppicing on the tree's overall performance as a producer of fuelwood over one or possibly several coppicing cycles

These coppicing trials are expected to provide essential information on the appropriate coppicing treatment to apply to tree plantations of *Leucaena leucocephala* and *Cassia siamea*.

The experiments will provide valuable information on the productivity of coppicing for fuel or polewood production. Appropriate analysis of the results will establish whether or not coppicing increases yields of a stand of trees managed for a specific purpose, such as fuelwood. This information will enable the elaboration of fuelwood and polewood yield tables for coppices of these two species.

Recommendations

The length of the coppice cycle should be reduced or increased as a function of the specific production objectives.

Soil samples should be taken from each experimental plot at the Perdi Midi site. The pH and nutrient composition should be determined in order to examine the role of microsite differences in the results obtained up to this point.

Careful adherence to the measurement schedule will allow for easy comparison of the data collected from the two sites.

The treatments on the Mirebalais site must be as identical as possible with those already applied at the Perdi Midi site.

Similar coppicing experiments should be set up for other tree species commonly used in Haiti, such as neem.

Ehrlich, Schmitt, and Di Mavindi: FORAGE QUALITY AND BIOMASS PRODUCTIVITY OF *LEUCAENA LEUCOCEPHALA* CONTOUR HEDGEROWS

Introduction

AOP has recognized the potential of *Leucaena leucocephala* hedgerows for soil conservation and stabilization. Both CARE and PADF have established numerous contour hedgerows in various areas of the country. Procedures for the establishment and harvesting of hedgerows are still experimental and vary as a function of the intended use (soil conservation, green manure, or animal fodder). In Haiti, the use of leucaena hedgerows planted along contour lines offers great possibilities as a biological measure to control erosion, sustain and eventually increase agricultural productivity, and provide a source of animal fodder when grown on many low to medium altitude hillsides across the country.

Leucaena is an excellent soil improver and stabilizer. Its fast growing root system breaks up compacted soil layers, thereby improving moisture penetration, decreasing run-off and reducing the chances of soil slippage. It increases soil fertility by means of its nitrogen fixing bacteria and by its nitrogen rich leaf litter which often rivals animal manure for nitrogen content. It is also a favored browse for both cattle and goats due to its high protein content.

All of the above considerations combined with its ability to thrive on the steep slopes and alkaline soils common in Haiti make leucaena hedgerows an attractive possibility for use in agroforestry systems. This report summarizes the results of the first phase of the research.

Conclusions

Soil analysis by itself does not appear to explain the differences of biomass production encountered in the field, but some variation among sites in the percentage of soil nutrients can however be noticed.

On the whole, the chemical composition of forage falls within the norms established by NFTA. Phosphorus, magnesium, sodium, and fiber were the exceptions. There is also some variation between sites in the ranking of mineral elements in the forage. Most sites produced forage of good nutritive value, adequate for beef and dairy production.

During this phase of the research, only a limited number of samples could be collected and analyzed. Given leucaena's growth variability especially at a young age and the variability of site characteristics in Haiti, it is difficult to draw any definite conclusions on growth patterns. A limited interpretation of field data shows a positive correlation between hedgerow height and total biomass productivity, fuelwood productivity, and forage production. Though measured, spacing of the contour hedgerows did not affect biomass production significantly.

Recommendations

Future data collection should be expanded both to cover a wider range of sites and to build up the total sample size.

Research should be designed to determine the most appropriate harvesting cycles for leucaena hedgerows in order to maximize forage and fuelwood productivity.

Data on the nutritive value of leucaena hedgerows should be collected and analyzed as an ongoing and parallel research activity.

Experiments should be established to test the productivity and usefulness in contour hedgerows of other tree species.

A study should be established to determine the effect of seed inoculation with mycorrhizae and *Rhizobium* on hedgerow growth and productivity.

Ehrlich: FUELWOOD AND BIOMASS YIELD TABLES FOR *LEUCAENA LEUCOCEPHALA, CASSIA SIAMEA, AZADIRACHTA INDICA, COLUBRINA ARBORESCENS, EUCALYPTUS CAMADULENSIS, AND PROSOPIS JULIFLORA*

Introduction

This report presents the result of five months of silvicultural research designed to study the fuelwood, biomass, and polewood production potential of six tree species. The tree studies included four exotic species (leucaena, cassia, neem, and eucalyptus), and two indigenous species (*Colubrina aborescens* and *Prosopis juliflora*).

Each species was studied on one or more sites, reflecting some of the environmental conditions within which the species would commonly be found in the Haitian countryside. The study involved the cutting of a sample of trees at different diameters, the weighing of the entire tree by sections, and the sampling of the tree sections for laboratory analysis and determination of moisture content and specific gravity.

A comparative analysis of fuelwood production for the six exotic species studied shows that leucaena at the ages found in AOP is by far the better producer of fuelwood, as a function of Dbh, at least in the earlier stages of growth. Leucaena branches out considerably and has a voluminous crown from which fuelwood can be produced, whereas eucalyptus grows primarily along one axis.

Cassia produces the greatest polewood volume when compared to eucalyptus and neem.

Conclusions

Yield tables for leucaena, neem, cassia, eucalyptus, and prosopis represent a significant first step in assessing lumber and fuelwood production potential. The production tables for *Colubrina arborescens* both contributes new knowledge relative to a tree species, and are of value for agroforestry applications in most humid tropical areas.

Recommendations

Further research should be conducted on both indigenous and exotic species capable of producing polewood and fuelwood, and their agroforestry applications.

Additional sampling and laboratory testing is needed for eucalyptus, as it has displayed unusual variability in moisture content and specific gravity. Leucaena requires additional sampling to account for site variability, and its variance in growth parameters.

Introduction

This report presents the results of three months of silvicultural research conducted to study the fuelwood, biomass, and polewood production potential of two tree species in Haiti: *Catalpa longissima (chêne)* and *Casuarina equisetifolia*. This report compliments the Yield Tables report prepared by Ehrlich (1985) which covers six tree species, specifically: *Leucaena leucocephala, Cassia siamea, Azadirachta indica, Colubrina arborescens, Eucalyptus camaldulensis,* and *Prosopis juliflora*.

Chêne is one of the most commonly used native trees in traditional agroforestry practices in Haiti. It is planted on moist terrain that is low to medium in altitude, and not too steep. It withstands seasonal flooding, grows well on flood plains and rice fields, and is tolerant of pruning, though traditionally it has been pruned excessively. The quality of the wood is generally excellent for lumber and furniture manufacturing, and is well regarded by peasants and craftsmen.

Casuarina has been extensively distributed to peasants participating in AOP. Due to lower than expected survival rates in those initial plantings, this species is presently planted with greater care to site and climatic considerations. Casuarina holds great promise as an agroforestry tree in Haiti as it is appreciated for its fuelwood and polewood quality.

The tree species were studied on sites that reflect the environmental conditions within which these species are commonly planted in Haiti. The study of the tree species involved the cutting of a sample of trees of varying diameter classes, the weighing of the entire tree by sections, the sampling of the portions for laboratory analysis, and the determination of moisture content and specific gravity.

One section of the report is dedicated to the productive potential of each species studied, and to its significance for agroforestry applications in Haiti. These results are presented in graphic form to enable a simple and clear interpretation of research findings.

Conclusions

Catalpa longissima has great potential for agroforestry applications in Haiti. Although quite demanding in terms of rainfall, it adapts well to poor and alkaline soils, even on steep slopes, and is tolerant of seasonal flooding.

Casuarina equisetifolia is undoubtedly adaptable to the diverse environments of Haiti. It is appreciated for its polewood production and for its adaptability to different edaphic and climatic conditions.

The yield tables for casuarina and *chene* represent a significant first step in assessing the fuelwood and polewood production potential of these species. Their practical value in terms of predicting specific yields on similar site conditions could prove extremely useful in the planning and design of agroforestry applications along the Haitian countryside and elsewhere.

Recommendations

Future research efforts should focus on improving the growth performance of *Casuarina equisetifolia* on sites which are edaphically poor, climatically extreme, or both, by carefully selecting seed sources, and improving nursery techniques and outplanting methods. The effect of nitrogen-fixing bacteria on tree survival and growth in the fields should be given top research priority.

Research should also assess the potential of *Casuarina equisetifolia* in contour hedgerows for soil conservation stabilization purposes and as a potential source of forage.

Biomass and yield table studies are recommended for other tree species with unquestionable agroforestry potential such as: *Simaruba glauca (frene), Swietenia mahoganii (acajou), Swietenia macrophylla,* and *Cedrella odorata (cedre)*.

Fournier: EXPLORATORY STUDY OF SHOOT/ROOT RATIOS AND GROWTH CURVES FOR CONTAINERIZED SEEDLINGS *CASSIA SIAMEA*, *AZADIRACHTA INDICA*, AND *LEUCAENA LEUCOCEPHALA*

Introduction

This paper discusses a method of establishing shoot/root ratios and growth curves for three species of containerized seedlings. Height is the most practical measure for the statistical evaluation of seedling crop size. It can be measured easily without damaging the seedlings.

The ability to predict seedling growth is essential for production planning, both in the nursery, and in field planting. Standard growth curves were prepared for different species and conditions. Graphs were drawn for height, and dry weight shoot/root ratios of *Cassia siamea, Azadirachta indica*, and *Leucaena leucocephala*.

Historically, failure to meet specifications generally means that the grower is faced with the dilemma of what to do with a substandard seedling crop. An undersized crop may either be held for a second growing season or planted. It has been observed that attempting to grow large seedlings in small containers will result in quality reduction and possibly unfavorable shoot/root ratios at the time of planting. It is useful, therefore, to develop standard curves for each nursery, species, and cropping method used.

Recommendations

Using the methodology developed, further derivation of shoot/root ratios and growth curves for different seasons of nursery production is needed. This information should be used to develop a specific monitoring system for the grantee nurseries.

An appropriate monitoring system is required which would allow adequate time under proper hardening conditions.

Survival data following field planting of seedlings is needed to substantiate findings of any shoot/root ratio determinations.

Monitoring of seedling growth on the basis of standard growth curves is highly recommended.

Gill: HARVESTING TIME ESTIMATES FOR *LEUCAENA LEUCOCEPHALA* ON A FUELWOOD PLANTATION IN THE CUL-DE-SAC REGION OF HAITI WORKING PAPER #4

Introduction

One objective of AOP is to provide fast growing trees for fuelwood; leucaena is one of the more widely used trees for this purpose. Leucaena may well play an important role in meeting Haiti's future fuelwood requirements. Firewood is a primary energy source for many distilleries. bakeries, and dry cleaners as well as for private consumption.

The purpose of this paper is to analyze the time required to harvest leucaena for firewood on a fuelwood plantation and provide information of labor inputs for fuelwood production. Firewood, as designated for this study, is any piece of cut wood measuring approximately one meter in length and having a minimum end diameter of two centimeters. These are the minimum size requirements generally accepted by the local commercial market.

Conclusions

Statistical analysis of the felling operation revealed a positive relationship between stump diameter and felling time. There was no apparent relationship between stump diameter and felling time.

The time required to produce fuelwood from standing trees is necessary to accurately assess the value of AOP trees.

Recommendations

Additional research is warranted to refine the time estimates and to determine if slope and stocking density affect the firewood production time estimates.

ECONOMICS AND MARKETING STUDIES

Grosenick: AN ECONOMIC ANALYSIS OF AGROFORESTRY SYSTEMS IN HAITI

Introduction

The objective of this study was to determine whether agroforestry is feasible in Haiti. Two broad categories of agroforestry systems were examined: systems established by farmers with AOP seedlings and with the help of AOP extension agents, and secondly, those systems traditionally established and maintained by Haitian farmers.

A survey of AOP participants was used to describe the twenty typical or representative cropping systems found in a random sample. Each of these systems was analyzed to determine whether the addition of a tree component was financially beneficial to the farmer. Regional variations in input and output prices were included to reflect local conditions.

All crop budgets, with regional variations in labor and other physical inputs, prices of outputs, and costs of inputs were placed on computer spreadsheets. These spreadsheets automatically re-calculate the net present value and the internal rate of return for each of the regional agroforestry systems, based on input quantities and prices.

Several agroforestry systems traditionally used in Haiti were analyzed in the second part of this study. These systems included systems based on coffee, cocoa, mangoes, citrus, and coconuts. Each is discussed giving the geographic distribution of the system, its relative importance, and estimates of production and productivity. The net present value and the internal rate of return of establishing these tree crops on agricultural land is calculated using the establishment and maintenance costs and the production estimates for the tree component and the costs and returns of the agricultural component.

Conclusions

If the farmer is assumed to maximize his monetary returns per hectare, 85% of all agroforestry systems established under the guidance of AOP have positive net present values. If non-monetary benefits were included, the returns would be even

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higher. Non-monetary benefits discussed include ecological benefits, increased opportunity to save and invest, risk reduction through crop diversification, and labor savings or redistribution.

One could use an alternative decision criterion: the maximization of returns to labor. The discussion points out some of the instances in which farmers will use this criterion and why it will be to their advantage. This discussion explains why some farmers who are seemingly less well off for having planted AOP trees are really satisfied with their decision.

Recommendations

Future AOP policy statements should specifically recognize the value of non-monetary benefits to tree planting. Although cash-cropping of trees is a valid objective, AOP should also encourage farmers to consider the non-cash benefits as well. Future economic analyses should attempt to more fully describe and quantify these benefits.

Studies and recommendations should be farmer specific as well as area specific because labor availability, the desire to reduce risk, and access to credit vary significantly from farmer to farmer. Therefore, CARE and PADF extension materials should emphasize that what may be good for one farmer may not be good for another.

A series of extension materials treating farm management decisions should be developed for use by extension agents in group or individual discussions with prospective planters. Group discussions may provide for a greater degree of farmer participation and feedback, thus allowing for more effective program improvement.

Grosenick: CONSUMER PREFERENCE TEST FOR CHARCOALS MADE FROM EIGHT EXOTIC SPECIES

Introduction

Haitian women were asked to use a series of charcoals, and express a preference for one or the other of each pair of charcoals tested. This study tested the preferences for charcoal made from eight species: *Acacia auriculiformis, Albizia lebbek, Azadirachta indica, Cassia siamea, Casuarina equisetifolia, Eucalyptus camaldulensis, Leucaena leucocephala,* and *Prosopis juliflora*.

The existence of a preference does not imply that a charcoal will sell more readily or at a higher price than other charcoals. In Haiti, charcoal is sold in mixed lots and most people do not know what type of charcoal they are using.

Conclusion

Haitian women show definite preferences for certain charcoals. The eight charcoals can be divided into four groups:

Group 1. Casuarina

Group 2. Prosopis and Acacia

Group 3. Eucalyptus, Abrizia, and Neem

Group 4. Leucaena and Cassia

Operation Double Harvest has been selling limited quantities of leucaena charcoal at approximate market prices for two years. Since all other charcoals are at least as good as leucaena, they should be marketed as well.

AOP can continue to recommend all of the tested species to those prospective AOP participants who wish to produce charcoal. Those AOP participants who have already planted these species can be assured that these species will make charcoals acceptable to consumers in Port-au-Prince.

Recommendations

Casuarina should be tested against charcoal made from *gaiac (Guaiacum officinale)*, a high quality charcoal which sells at a premium, to determine if casuarina can be marketed as a substitute for *gaiac*.

Grosenick: ANALYSIS OF PRICE TRENDS FOR CHARCOAL AND FIREWOOD IN HAITI

WORKING PAPER #10

Introduction

The Agroforestry Outreach Project is based on the important assumption that agroforestry is economically feasible in Haiti. The University of Maine research team is analyzing the benefits and costs of agroforestry to test this assumption. Since wood products are important outputs of the project, any change in their real market prices must be considered.

For several practical reasons, economists prefer to evaluate projects using real prices rather than nominal prices. Using real prices normally permits one to eliminate all price changes from an analysis, because most costs and prices increase at about the same rate. However, in analyzing some projects, a product may stand out. Its price will rise or fall relative to other products. If this product is a significant input or output of the project, this real price change must be considered.

The purpose of this paper is to establish current estimates of the changes in the real price of charcoal and firewood. All available information on wood product pricing has been assembled to serve as baseline data for future analysis.

Conclusions

The prices of charcoal and firewood have risen significantly faster than the cost-of-living in Port-au-Prince. The prices of these two products have also risen faster than major agricultural crops. The trend of increasing charcoal prices is not unique to Port-au-Prince, but reflects other urban markets.

Given current levels of consumption and production, wood will become increasingly scarce during the coming years, thus the real price increases are expected to continue at the current rate.

There will be a tendency for farmers to shift from the production of food crops to the production of tree crops, as more input should be devoted to trees because of relative price changes. AOP's success suggests that this is already happening.

Grosenick: A REVIEW OF LITERATURE DOCUMENTING CONSUMPTION OF WOOD PRODUCTS IN HAITI WORKING PAPER #8

Introduction

In order to make economic projections, it is necessary to have estimates of the past and future trends of wood product consumption. The quantities of various wood products being consumed today may be compared with the estimated production of raw material. A difference would be the amount of production shortfall which one might want to satisfy through additional programs.

Consumption projections, both by product and by region, can give program planners necessary information for their extension programs, for example, whether or not it will be better to encourage farmers in a certain region to produce long rotation lumber rather than short rotation poles or fuelwood. The species one recommends and produces in the nursery should be related to the end use of the wood. Farmers are encouraged to use multiple use trees to expand their harvesting options. In some cases, however, specific species can be aimed at certain markets.

This paper reviews the various estimates of wood product consumption in order to establish a reasonable range of values which can be used by policy makers. The wood products are discussed within three major groups: fuelwood in the form of charcoal and firewood; poles, posts, and wattle; and finally, sawnwood in the form of lumber, railroad ties, and wood for crafts.

Grosenick: AN ECONOMIC EVALUATION OF THE AGROFORESTRY OUTREACH PROJECT WORKING PAPER #6

Introduction

The objective of this study was to determine the economic feasibility of the Agroforestry Outreach Project. The report was written to be included in the evaluation of AOP in early 1986. The analysis was done in two parts. The first was an analysis of agroforestry plantations on small peasant farms. The second was an analysis on industrial plantations on relatively large tracts of privately owned land.

For the analysis of small farm plots, costs and benefits of the different types of AOP participants were estimated. After determining the 16-year stream net benefits to individual agroforestry systems established as a result of the AOP, the net benefits to each participant were totaled over all those who planted seedlings in a given year to obtain the total net benefits for all participants for that year.

The total net benefits to AOP participants were then compared with the costs of the project to USAID and other donors who made contributions to the grantees administering the program. In essence, each year a certain expenditure brought forth a stream of benefits over the next 16 years. The net present value and the internal rate of return were calculated.

The analysis of industrial plantations began by dividing the ten tree farms into four classes bases on subjective evaluations of site quality. The plantation which was established on the best site was the oldest plantation and had the most information. The costs of establishment and maintenance were compared with actual and expected returns. The net present value was calculated.

Conclusions

The analysis of small farm agroforestry showed that the internal rate of return on donor investment was 15.6% and that the benefits of the project exceeded the costs by a factor of 1.54 to 1 when at ten percent. When each of the two grants were analyzed separately, only slight deviations from the average are observed. Both grantees managed their components in a manner as to have higher than expected internal rates of return and lower than expected costs per seedling produced and cost per tree established.

The evaluation of industrial plantations showed that the net present value of costs exceeded the net present value of the benefits for all discount rates tested. Only one plantation was analyzed since the cost of producing wood on the plantation with lower site quality were higher than those on the plantation studied while production was lower.

The results of the evaluation do not condemn industrial tree plantations in Haiti. They only indicate that the management regime tested is not feasible on the particular sites chosen.

Recommendations

The small farmer agroforestry program is successful and performed better than expected, thus funding for this program should continue.

Future studies should analyze more fully the importance of non-monetary benefits to the AOP participant.

Program policy should change to reflect less bias toward cash-cropping. Raising trees for other reasons can be beneficial to the farmer and can help achieve the goals of the project.

Decisions which may seem to be technical in nature still have economic costs. Decisions for technical improvement of the program should not be made without considering the costs of those changes.

Large scale tree farming has not been shown to be feasible under the management system tested. Further funding should be delayed until management strategies can be independently reassessed.

Grosenick and McGowan: DETERMINING THE CONSUMPTION OF WOOD PRODUCTS IN PORT-AU-PRINCE USING SUPPLY SURVEYS

WORKING PAPER #7

Introduction

During the past year, the University of Maine conducted three week-long surveys of all domestically produced wood-based products entering Port-au-Prince. These products fall into four categories (charcoal, firewood, poles, and lumber), each of which are discussed separately. The purpose of these surveys was:

1) to assess total demand for the different wood-based products used within the metropolitan area

2) to determine the origin of these products

3) to estimate the transportation costs for these products

4) to describe the participants in the marketing of these wood products

Despite the potentiality for error, the surveys allowed a reasonably accurate depiction of the quantities of wood based products consumed in Port-au-Prince, the origin of these products, and the cost and method of transportation.

The study describes the types of people who bring these products to the city, and some of the relationships they have with others in the marketing chain.

McGowan: POTENTIAL MARKETABILITY OF WOOD PRODUCTS, RURAL CHARCOAL CONSUMPTION, PEASANT RISK AVERSION STRATEGIES, AND THE HARVEST OF AOP TREES

Introduction

The purpose of the wood marketing research sub-component of AFORP was to determine if there will be a market for AOP wood products.

The determinants of farm gate prices for poles, planks, and charcoal are discussed in this report. Price determinants common to all three of these wood products are quality, local supply and demand levels, distance of the producer from the market, bargaining skills, personal relationships, specific uses, and market structures.

The price for poles varies according to whether they are sold in an urban or rural market, or whether they are sold for construction materials. The species of wood determines the price for planks. Farm gate prices for charcoal vary greatly between regions due to the structure of the market. This hurts the poorer and more isolated charcoal producer.

Taxes on wood products in some areas are collected in an inconsistent and illegal manner. This not only harms the producers and merchants of wood products, but also destabilizes the market in areas where it is prevalent by introducing an independent risk variable.

The author's studies on harvest practices have shown that cutting trees for charcoal is done in response to an immediate need. Trees have become a financial safety net because they are easily transposed into a marketable product. Trees harvested into poles are used for auto-consumption purposes.

Conclusions

AOP participants will have a wide-open market for selling their charcoal. AOP planters could meet three percent of Haiti's charcoal needs in 1986, rising to 16% in 1995.

Charcoal production is used as a risk aversion strategy factor; charcoal is sold when cash is needed, as opposed to the planned, systematic harvesting practices of poles and planks.

Recommendation

Further research is needed on planters' harvesting practices and charcoal consumption. The consumption studies would include the areas of individual consumption, specific towns consumption levels, and supply surveys.

ANTHROPOLOGICAL STUDIES

Conway: THE DECISION-MAKING FRAMEWORK FOR TREE PLANTING IN THE AGROFORESTRY OUTREACH PROJECT

Introduction

This study describes and analyzes factors in the decision-making framework of AOP participants. The report is based on field research on 60 farms at seven PADF and CARE subproject sites.

Most of the planters were not cultivating their trees for one specific use. Rather, they viewed their trees as a reserve which could be used in a number of ways to meet cash needs. Many planters intended some of their trees for auto consumption rather than cash cropping.

Most project seedlings are planted in gardens, which reduces labor in weeding the seedlings and protects against animal damage. Planters leave wide spacing of trees in their gardens to reduce competition with other crops, leave room for animals, and protect trees when crop residues are burned.

At the beginning of the project, some planters placed their seedlings, especially leucaena, too closely for other crops to grow. These planters tended to keep their leucaena, at least temporarily, because it had a greater chance of providing income during a cycle of drought. While pruning is common in Haitian gardens, thinning is rare. Some planters have used their project trees for coffee groves, while others use them to establish agri-silvo-pastoral systems.

Soil conditions were a major concern, as many farmers planted trees both to improve the condition of the soil and protect against erosion.

Planters are putting their seedlings on land which they feel secure about, regardless of its land tenure category. The sample planters did not appear to be afraid that they would be unable to protect their project trees from kin. When they were planting on unsecured land, they were often using the seedlings as part of a strategy to acquire that land. On several of the sites interviewees said that they had been reluctant to participate in the project because of fears that they would lose their land to an outside agency. However, this situation has been resolved, as agencies have not made any claims to the land throughout the first four years of the project.

Conclusions

Planters are incorporating their project trees into a variety of farming systems depending on ecological conditions and the particular combination of resources available to the planter.

Planters are more interested in the long-term benefits of their trees than may have been previously assumed.

Land tenure is somewhat less of a problem in decisions about tree planting than had been expected, and new tree tenure arrangements can be expected to emerge on their own, without direct project intervention.

Recommendations

Extension agents should discuss planting options with farmers so that planting strategies are coordinated with end use.

Peasants with small landholdings should be a special target group, as they are highly motivated to increase the long-term value of their land with intensive agroforestry systems.

Women should also be a special focus of extension messages; one way to accomplish better communication with women would be to increase the number of female extension agents.

Extension messages should also encourage peasants to find and plant their own seeds, seedlings, and cuttings.

Transferring management and harvesting techniques should be emphasized, especially where traditional practices are deficient as in thinning.

Further research is needed to find the best technical packages for improving soil conditions through controlling erosion and adding nutrients.

Agricultural windbreaks should be instigated, as peasants have expressed a need for protection against wind damage.

Further research is needed on the economic and technical causes of mortality in project seedlings.

Conway: SYNTHESIS OF SOCIOECONOMIC FINDINGS ABOUT PARTICIPANTS IN THE USAID/HAITI AGROFORESTRY OUTREACH PROJECT

Introduction

This report summarizes socioeconomic findings about participants in the USAID/HAITI Agroforestry Outreach Project (AOP) and synthesizes data from five surveys of tree-planters and non-planters. AOP research has been designed to assess the effectiveness of the project, including the validity of the assumptions on which it is based. This research has been conducted both by the grantees, CARE and PADF, and by AFORP of the University of Maine (U of M).

The design of the CARE and PADF components of the project was based upon a number of assumptions derived from the research:

agroforestry associations can be economically viable at the small farm level in Haiti

peasants will be motivated to plant and maintain trees if they perceive their economic benefits, especially in terms of cash income

peasants will not be motivated to plant seedlings unless they have assurance that the trees and their products will belong to them and that participation in the project will not endanger their landholdings

Conclusions

Labor is a constraint for most of the farmers interviewed. Some absentee landowners displaced sharecroppers to plant trees; however, this is not expected to be a general problem in the project.

Trees are also planted for reasons other than a direct increase in income. Their potential for reducing uncertainty has been an attraction, since they resist drought and can be harvested at any time once they are mature.

An economic analysis of twenty tree-crop associations indicated that 85% of AOP plantings would have a higher net present value than cropping without trees over a sixteen year cycle.

Recommendations

Micro-level analysis of agroforestry management on a small sample of farms should be emphasized.

Future research should focus upon non-participants and unregistered planters, and their impact on AOP.

Livestock should be included in future cost/benefit analyses.

Balzano: SOCIOECONOMIC ASPECTS OF AGROFORESTRY IN RURAL HAITI

Introduction

This study describes the diverse economic components of Fond-des-Blancs and Beaumont in terms of their ecological and agricultural setting. Secondly, this study discusses the role played by the sub-grantees, who stand between PADF and the planter. The differing institutional structures of the sub-grantee at each site has affected the rate of registered and unregistered planters. At Beaumont, the manner of tree distribution has resulted in a higher percentage of Baptist registered planters and Catholic unregistered planters than are represented in the general population.

Tree planting on private holdings began in both areas in the spring of 1982. In Fond-des-Blancs, AOP provides funds and technical assistance through PADF's *Projé Pyebwa* to a local private voluntary organization, CODEPLA. In Beaumont, PADF provides direct assistance to a local community group called *Tet Ansanm*.

Research began with surveys aimed at gathering data on a broad range of socioeconomic variables. Investigations were then conducted on planting decisions, the local agricultural economy, and traditional agroforestry as a way to contextualize these quantitative data.

Conclusions

Distribution of AOP project trees is unequal, which places the poorer peasants at a disadvantage.

Several other land classifications besides gardens were found in Fond-des-Blancs, which form the basis of traditional agroforestry systems. These classifications hold significant potential for future agroforestry development.

Most AOP tree planting decisions were made within the context of traditional agroforestry strategies. Some AOP plantings constitute innovative behavior with regard to the role of tree crops in the household economy.

Planters already having significant indigenous wood resources are not as concerned with seedling survival as those who have little or no indigenous wood resources.

Recommendations

Further research is needed on balancing the benefits gained from tree planting and the loss of land for food production.

LITERATURE AND LIBRARY SYSTEMS

Kooi: LITERATURE SEARCH AND DOCUMENT RETRIEVAL SYSTEM FOR THE UNIVERSITY OF MAINE AGROFORESTRY OUTREACH PROJECT

Introduction

The literature search and document retrieval system was created to assist the research efforts of the Agroforestry Outreach Project. The documents deal both with agroforestry in general and specific areas of interest to the project.

All documents available in Haiti and other relevant material are catalogued in the computer program MicroDis. A user can inquire into MicroDis and subsequently receive a list of documents. The user must obtain the document from its holder; if the holder is not in Haiti, the document may be obtained from the Folger Library at the University of Maine. U of M may be approached directly by telephone for information retrievals; they will forward the information by Federal Express.

Conclusions and Recommendations

The literature Search and Document Retrieval System can presently be used to produce citation lists satisfying the criteria formulated by the user. It is important that the system be used and maintained regularly, following these specific recommendations:

New documents in the U of M offices in Port-au-Prince be entered into MicroDis on a monthly basis.

Other Haitian document holders be reviewed on a six-month basis and their new documents entered into MicroDis.

Citation searches be made at least several times per month, resulting in suggestions for improvement.

A brochure should be prepared and circulated to all concerned individuals in Haiti, describing the system, inviting them to use it, and contribute appropriate bibliographies.

The descriptor/identifiers of new citations be chosen by reading the document if possible, or at least by reading the abstract.

One of the writers of the MicroDis program from LTS Corporation be invited to Haiti to review the operation and upgrade the system.

CHAPTER 4

RECOMMENDATIONS FROM AFORP RESEARCH

Recommendations on Outreach

Where farmers want to continue growing their shade intolerant crop associations: 1) AOP trees should be widely spaced within the gardens, 2) they should be pruned to reduce shade, 3) the trees should be planted on garden borders or as living contours, and 4) they should consist of species which do not give excessive shade, except when shade from the trees will conserve moisture needed by the shaded crop species. (Ashley)

Cut and carry feeding should be encouraged where AOP trees are used for livestock, resulting in better animal nutrition and higher tree survival rates. (Ashley)

The CARE and PADF outreach programs should be expanded to include explanations and demonstrations for controlled grazing, as well as cut and carry, including trimmings from hedgerows and living contour plantings. (Ashley)

PADF should adopt a more complete presentation of utilization methods for exotic species in their outreach programs. The Forestry Support Program and USAID's Science and Technology staff should be requested to provide a summary of these uses in a non-technical format. This would eliminate the farmer's hit and miss utilization trials which may lead to his rejection of the project. (Ashley)

Extension agents should discuss planting options with farmers so that planting strategies are coordinated with end use. (Conway)

Extension messages should also encourage peasants to find and plant their own seeds, seedlings, and cuttings. (Conway)

Transferring management and harvesting techniques should be emphasized, especially where traditional practices are deficient as in thinning. (Conway)

The use of project trees to form windbreaks should be investigated, as peasants have expressed a need for protection against wind damage. (Conway)

Extension agent training programs should stress special care during the first year while the species are developing their root systems. (Dupuis)

Recommendations should be both area specific and farmer specific, as criteria such as labor availability, the desire to reduce risk, and access to credit vary significantly. (Grosenick)

A series of extension materials should be developed for use by the extension agents in group or individual discussions with prospective planters. (Grosenick)

Recommendations should be made based on volumetric growth of the species, the possibility that it can yield products other than charcoal, and the ease of harvest. (Grosenick)

Small direct seeding demonstrations should be established near or adjacent to nurseries. These should clearly demonstrate to the farmers who come to the nursery to get their seedlings the effects of weeding and water catchment on germination and growth of direct seeded and container grown seedlings. (Dupuis)

Recommendations on Seedling Production

Nursery production should begin one to two months earlier to assure properly hardened off seedlings in those years when the seasonal rains come early. (Ashley)

The length of the coppice cycle (24 months) should be reduced or increased as a function of specific production objectives (fuelwood, poles, or lumber). (Ehrlich)

Seedlings that are held in the nursery for an extended period of time should be root pruned before they are planted so that the lateral roots will be stimulated to egress through the sidewalls of the plug. (Dupuis)

AOP trees should be required to use inoculant, especially leucaena and prosopis. (Dupuis)

Leucaena should be grown in rootrainers, preferably the "sixes", and a mix which contains some native soil. (Dupuis)

Prosopis should be the preferred species in low rainfall areas because of its hardiness and good growth performance. It should be grown in the plantband, winstrip or "sixes" rootrainer and in Promix. (Dupuis)

Azadirachta should be planted in a plantband or "sixes" rootrainer, as the "fives" rootrainer gives low survival. (Dupuis)

Monitoring of seedling growth on the basis of standard growth curves is highly recommended. (Fournier)

Discontinue top-pruning seedlings before planting except when the seedlings are tall and have large height shoot/root ratios. (Dupuis)

Seed provenances and seed dealer information should be requested for leucaena, neem, casuarina, eucalyptus, and cassia species. New seed sources should be tested against Haitian seed. (Dupuis)

Recommendations on Policy Changes

Peasants with small landholdings should be a special target group, as they are highly motivated to increase the long-term value of their land with intensive agroforestry systems. (Conway)

Women should also be a focus of extension messages; one way to accomplish better communication with women would be to increase the number of female extension agents. (Conway)

Standard research methods should be set for all AOP species trials. (Dupuis)

Parkinsonia should not be planted in AOP because prosopis has better growth performance for the same environmental conditions and is more widely accepted. (Dupuis)

CARE and PADF should experiment with group discussions in order to provide an outlet for farmer input and feedback. (Grosenick)

Recommendations for Future Research

Each of the technical report summaries has given the recommendations for future research as identified by the individual AFORP researchers. A review of these recommendations shows that there are five areas which will have maximum impact on AOP these are:

Nursery Studies

Silviculture and Site Relationships

On-farm Tests of Agroforestry Systems

Economic Studies Involving Marketing and New Products

Increasing the Effectiveness of AOP Extension Activities

The following research topics will have the greatest benefit to AOP and its farmers:

Nursery Studies

- Container/mix trials
- Nursery management improvement
  - Extended growth periods
  - Shoot/root ratios

Silviculture and Site Relationships

- Coppicing
- Pruning and thinning trials
- Detailed soils studies of long-term experimental plots
  - Species Trials

On-farm Tests of Agroforestry Systems

- Food crop versus tree production trade-off studies for various systems
- Completion of the study of crop associations
- The causes and magnitude of tree mortality in gardens
- Development of systems to improve soil conditions
- Economic analysis of differing agroforestry systems
- The returns to labor (non-monetary benefits)

Economic Studies Involving Marketing and New Products

- Continued effort on national surveys of wood products supply and prices
- Consumption surveys for select towns as an indicator of national and regional trends

Investigation on the possibility of increasing or diversifying AOP species' outputs, such as forage, green manuring higher value wood products, and fruit

Increasing the Effectiveness of AOP Extension Activities

Demonstration of alternative agroforestry systems
Explanation of uses and limitations of products from introduced exotic species
Development of more extensive extension materials

THE FINAL REPORT
OF
THE UNIVERSITY OF MAINE

AGROFORESTRY OUTREACH PROJECT

VOLUME II

TECHNICAL AGROFORESTRY STUDIES

by
The AFORP Staff

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A STUDY OF TRADITIONAL AGROFORESTRY SYSTEMS IN HAITI

AND

IMPLICATIONS FOR THE USAID/HAITI

AGROFORESTRY OUTREACH PROJECT

By

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Dr. Ashley is Team Leader and the Agroforestry Systems Researcher for the Agroforestry Outreach Research Project. This research is reported under USAID Project No. 521-0122.
May 7, 1986

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ACKNOWLEDGEMENTS

Credit and heartfelt thanks are given here for all those who helped organize and gather data for this study. CARE and PADF personnel willingly reviewed our work plans and gave us much needed data that they had collected. Their staffs also took time from their busy schedules and were very helpful in arranging my initial visits with many farmers that I interviewed. Special mention is given to Fred Conway of our staff for his help in designing questionnaires and checking for the proper Créole language translation, for the recording of several data sets on tree and wood uses, and for his review of this text. Thanks also to Anthony Balzano, Gerold Grosenick and Lisa McGowan of our staff for their contributions to the study on tree uses and their critical review of this report.

Lastly, I must recognize those whose lives are central to this report and for whom this work is supposed to benefit--the Haitian farmer. Coming from a rural background, I greatly appreciated their many kindnesses and candor in our interviews.

EXECUTIVE SUMMARY

This report presents the results of research done by the University of Maine Agroforestry Outreach Research Project (AFORP) on traditional agroforestry systems in Haiti. A traditional agroforestry system is defined in this report as any farming system incorporating trees within gardens, where the trees originated from other than an AOP type project (e.g., natural seeding or transplanting of native seedlings from one location to another). Farmer practices and garden productivity within gardens may or may not differ after the farmer becomes an AOP participant and his gardens are no longer traditional in the sense of the definition above. However, the system is called non-traditional because there is an implied potential for differences as the result of an outside project intervening in the farm's management.

In this report, as in most studies, the agroforestry systems are characterized using biological/physical/environmental and social/economic/management characteristics of farmers' lands. Examples of these characteristics are:

<u>biological</u>-planting times or tree species
<u>physical</u>-elevation or parent soil type
<u>environmental</u>-rainfall
<u>social</u>-land tenure or type of labor used for cultivation
<u>economic</u>-average price per sack of charcoal sold or average farm income
<u>management</u>-planting pattern or presence/absence of grazing animals within gardens

As per the U of M contract, this report also discusses the technical and policy implications of this work for the overall USAID Agroforestry Outreach Research Project (AOP). These implications are formulated into recommendations which should improve the performance of AOP in the future.

The work reported here is the result of data collection by AFORP staff and the AOP Grantees, CARE and the Pan American Foundation (PADF). Some data was also obtained from the study of farms which AOP trees had been planted. This was needed to provide linkages for the policy implications.

Several areas of investigation were undertaken including a survey of crop species, crop calendars, crop/tree competition, the effect of tree shading on crops, fencing and boundary marking, animal grazing, and tree use. The collection of the data was based on sampling within Buffum/Campbell Environmental Zones. These zones are defined by elevation, rainfall, and parent soil-type differences.

In this study, some forty agroforestry systems on different farm plots were intensively surveyed over 15 Buffum/Campbell zones representing more than 60% of Haiti's land area. Some 120 other farms were studied to obtain a subset of crop and tree information. The data from these farms was used to verify the representativeness of the intensive surveys and to expand the tree information. The data from these farms was used to expand the tree and crop data base to some zones not picked up in the intensive surveys. Combining these survey types, there were some 180 farms studied for crop and tree data over 21 Buffum/Campbell zones representing nearly 88% of Haiti.

These systems were usually agri-silvo-pastoral. Such systems grow food crops and tree crops, and provide grazing for livestock, all over the same time cycle between consecutive plantings of food crops.

More than 80 crop associations were observed on the areas studied. These generally consisted of shade intolerant (sun loving) species planted in an interspaced pattern. However, only minor problems are envisioned in the conversion of traditional gardens into those with AOP trees.

Also, tree shade was sometimes found beneficial for increasing moisture availability for food crops. An economic analysis is suggested to find the negative impact, if any, of lost food crop production from excessive shading due to high density AOP tree plantings within the garden, versus the positive influence of increased moisture. This analysis would advise farmers of the potential impact of growing AOP trees.

Farmers with traditional systems often had trees for boundary plantings, employed cut and carry feeding of grasses or other vegetation for livestock feed, and had several uses for their trees growing within the system's gardens which ranged from lumber to voodoo drum production. AOP plantings should be able to meet and even expand upon tree use. However, if maximum benefits are to be gained from them, the AOP participants will need a thorough explanation of the AOP trees' potential products and uses, as well as their limitations.

The following definitive recommendations for AOP are made as a result of this study on traditional systems:

1. Where farmers want to continue growing their present shade intolerant species, AOP trees should be planted at wide spacing within gardens, pruned to reduce shade, planted on garden borders or as living contours, and consist of species which do not give excessive shade, except where moisture conservation is a primary concern.

2. The number of trees distributed to individual farmers should be flexible within some maximum and minimum limits. To minimize logistical problems a slightly modified distribution system is suggested.

3. An economic analysis should be done to find if growing tree crops is more profitable than raising other crops. If so, it is recommended that CARE and PADF develop materials and demonstrations on maximizing wood production for various species under a range of spacing, thinning, and pruning regimes.

4. Nursery production should begin one or two months earlier to assure acceptable seedlings when the seasonal rains come.

5. Explanations and demonstrations of the use of AOP trees for cut and carry and controlled grazing, which includes the trimmings from hedges grown for boundary or living contour plantings, should be put into the CARE and PADF outreach programs.

6. Forestry Support Program and USAID Science and Technology Staff should be requested to provide a summary of potential uses, including utilization methods, for the exotic species being introduced by the AOP and that this be put in as non-technical form as possible so that CARE and PADF can adopt it in their outreach programs.

Some need for further research on traditional systems and on AOP project farms has been identified. New research is needed on the causes of the mortality of trees planted in gardens, particularly those planted within the AOP project. More work on the shade is also recommended. Furthermore, the crop species, associations, and calendar surveys should be completed for some zones.

CHAPTER 1

INTRODUCTION

The USAID Agroforestry Outreach Project (AOP) began in late 1981. One of its goals has been to provide the Haitian farmer with an additional cash crop by growing trees in an agroforestry context, which will simultaneously reduce Haiti's soil losses and other environmental problems. This project was well received by peasants, and by the end of 1985 more than 19 million trees had been distributed for planting.

The project is an unqualified success, however, USAID and others feel that many technical and policy questions remain unanswered. For example, more information is needed on the best ways to plant trees in order that they will fit within the farmers' existing cropping systems and management objectives while also satisfying AOP objectives. The need to answer these questions initiated the USAID/HAITI Agroforestry Outreach Research Project (AFORP) in March, 1985.

The purpose of this AFORP research is to study traditional agroforestry systems in order to obtain a better comprehension of systems outside the sphere of AOP type projects, and through this insight to better understand why AOP is so successful and how it may be improved even further. A traditional system is defined as any farm system which has not had trees introduced into it by some governmental agency, Private Voluntary Organization (PVO), or other donor. Such systems may have land dedicated to cropping, grazing, lying fallow, or growing of forest products. For a given piece of land, these uses often change over time.

This report presents the results of U of M's work on traditional systems and discusses the implications for the overall AOP. Specifically, the objectives of the research discusses are to study traditional agroforestry systems in Haiti by:

1. Identifying major cropping systems in Haiti by ecological zones based upon soils and climate

2. Identifying by field survey, the types of agroforestry practices being used within the cropping systems identified above. These agroforestry practices are to be classified by tree and crop specie used, spatial patterns, and intercropping practices

3. Analyzing the data collected above to quantitatively and qualitatively characterize various agroforestry systems in Haiti. Particular attention is to be given to economic, social, and environmental factors

4. Preparing report summarizing the above analytical work with specific reference to technical and policy implications for AOP

In the following chapters, a brief description of Haiti's peasant agricultural setting is given, followed by a presentation of how one describes agroforestry systems. The remainder of this report then discusses the character of Haiti's agroforestry systems and the results of their study with reference to the above objectives.

The Country of Haiti

Haiti has a land area of 27,750 km^2 and is a mountainous, highly populated, but rural agricultural country (Werleigh, 1983). In 1980, more than three quarters of the population was rural and there were more than 180 people per square kilometer. Less than one third of the country was rated suitable for agriculture, yet the percent area under cultivation was much higher. Haiti fits Eckholm's (1976) description of a developing country having great problems. Such countries have "rapid deterioration which form a vicious cycle." As further testament to her problems, more than 50% of the country is now highly eroded or has the risk of becoming so (Ashley and Grosenick, 1985; BDPA, 1983). This problem is exacerbated by the high percentage of people involved in agrarian related work and by the small average farm size. Nearly 60% of all farms are less than 1.5 hectares (ha) in size and one third are less than 0.78 in area (Werleigh, 1983).

The Haitian Farm

The small average size farm was cited above. A farmer often owns three or more geographically different garden plots (Balzano, 1986). A garden is defined as any piece of land cultivated by the same person using the same crop species. These can be characterized in any number of ways, but one of the best found is described in a report by the Centre de Madian-Salagnac in cooperation with the Faculté d'Agronomie et de Médecine Vétérinaire at Damien and the Haitian Agricultural Research Service (Madian-Salagnac, 1978). The gardens are described in terms of their location relative to the farmer's home, the species and system of cultivation, and the relative ability of the land to grow crops. Essentially, the types are 1) those gardens next to the home, 2) gardens near the home, 3) gardens further away which are open fields with little shade, 4) grazing land of very poor quality for growing crops, and 5) bottom or wet lands in gullies,etc. In general, the first two types have the better soils, contain most of the crops grown for self-consumption, and are the most intensively tended by the farmer. The first two are also the gardens to which farmers make an effort to build up organic matter to maintain or increase fertility. The latter are net exporters of organic matter. All these types may not be present on a given farmer's lands; this varies by ecological zones.

CHAPTER 2

AGROFORESTRY CLASSIFICATION

This report centers around agroforestry and its practice. By one definition, agroforestry is "land use practices and systems where woody perennials are used in the same land management unit as agricultural crops and/or animals, either in the same form of spatial arrangement or in temporal sequence" (Lundgren, 1985). Many authors have expanded upon this broad definition and suggest describing agroforestry systems in terms of their biological/physical/environmental and social/economic/management characteristics. Such systems may be compared between different regions or countries. This study has attempted to follow his advice. Much of the work already done to classify agroforestry practices has been done by CATIE (Turrialba, Costa Rica) and ICRAF (Nairobi, Kenya). Several case studies have been published by these organizations and their descriptions generally combine the environmental and social traits described in the citations above to explain the workings of the systems they have studied (Torres et al, 1984; Hoekstra et al, 1984; Rocheleau and Hoek,1984).

Agroforestry System Descriptions in General

Agroforestry systems are usually defined in four broad categories, as presented by Nair (1980):

> Agrosilviculture, where on a given piece of land there is concurrent production of agricultural (including woody species) and forest crops
>
> Silvopastoral systems, where there is an integration of animal production through grazing within forest covered lands
>
> Agri-silvo-pastoral systems, where a combination of the above two systems exists on the same piece of land
>
> Multipurpose forest tree production systems, where trees are grown to produce useful wood, leaves, and/or fruit that are suitable for food and/or fodder

Beyond this, agroforestry systems are often characterized by the geometrical arrangement, cropping sequences, and species of crops and trees found within the system. Figure 1 is a schematic representation of some of the common arrangements described in the literature. To illustrate a few of these, in Haiti *Candélabre (Euphorbia spp.)* often grow as a "border planting" around gardens, or *frêne (Simaruba glauca)* and various fruit trees often grow in an "interspersed" pattern with other crops.

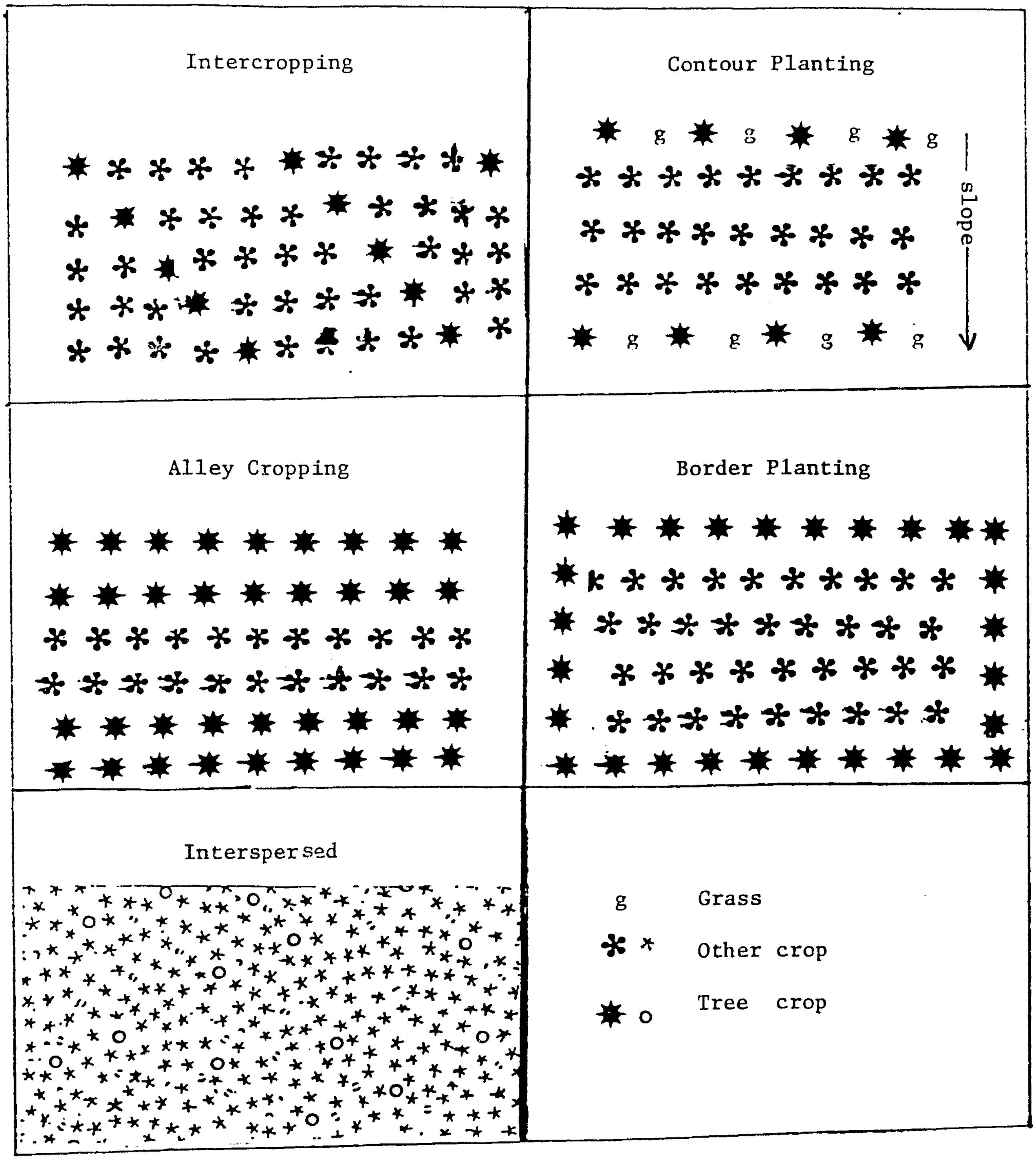
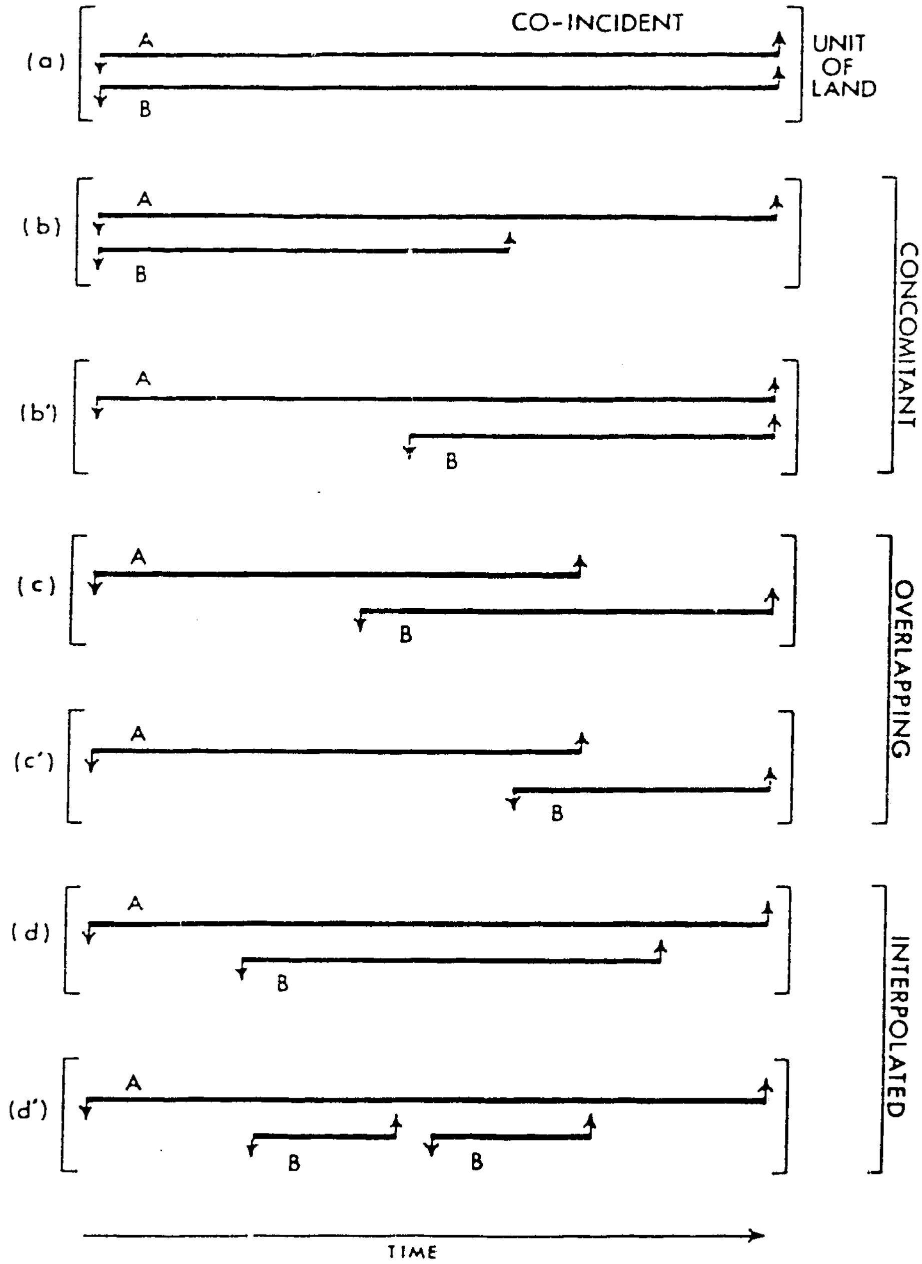


Figure 1. A schematic example of some of the possible gemometric arrangements of crops and trees used in describing agroforestry systems. This is synthesized from a diagram shown in the ICRAF crop sheets manual. (Nair, 1980).

The cropping sequence refers to the time of planting and harvesting of each species on the same piece of land where their growing periods overlap at least in some part. Figure 2 is a reproduction of how ICRAF and many others define several possible sequences (Huxley, 1984). Crop calendar and crop association data can be used to derive these sequences. Crop associations are the combinations of crops found growing in the same garden. For example, an overlapping sequence occurs when maize *(Zea mays)* is planted in April, and harvested in July and *pitimi* *(Sorghum bicolor)* is planted in the same garden in May of that year and harvested in January.

Lastly, a listing of crop and tree species is often used to characterize an agroforestry system. Such listings can be done for all of these species present or for only those of economic importance. One of the more commonly found species groups in Haiti included maize, sorghum, and congo beans.

These descriptions define agroforestry systems through the use of biological/physical/environmental and social/economic/ management characteristics. Rainfall, soils, topography, elevation, and land tenure information are also often used to portray agroforestry systems.



<u>Fig. 2.</u> Cropping sequences: (a) co-incident; (b) and (b'), forms of concomitant sequences; (c) and (c'), forms of over-lapping sequences and (d) and (d'), forms of interpolated sequences. For more than two component systems the individual species making up pairs of crops relate to one another in the same way. ↓ = sowing/planting. ↑ = harvesting/clearing. (Copied from Nair, 1984, ICRAF Reprint No. 9)

CHAPTER 3

THE INFORMATION COLLECTED IN THIS STUDY

The agroforestry systems information collected in this study parallel that of the studies cited in Chapter 2. This included the collection of biological, physical, environmental, and farm management data on farms and garden plots within these farms. Economic and sociological data related to traditional agroforestry systems was also obtained in other parts of the overall AFORP program and will be reported upon separately by other authors.

General agroforestry systems surveys were made country-wide with more detailed data collected on gardens within select environmental zones. The more detailed, intensive studies were done on both traditional and AOP gardens. The AOP sites were visited to provide the necessary base-line data for comparison with the traditional-systems data. AFORP staff and those of AOP Grantees (CARE and PADF) also provided information on AOP farms from their fieldwork.

Data Forms

For the intensive garden study, seven forms and questionnaires were designed and pretested with instruction manuals written in English and French. These forms had the following uses:

FORM 1 Farm plan/Map

This form was a planimetric sketch map of the farm under study.

FORM 2 Vertical Crop and Tree Profiles

The average height for each species of the crops and trees in the garden was sketched on vertical axis.

FORM 3 General Farm Description

This form recorded various physical, environmental, crop, tree, and livestock management data.

FORM 4 Crop Calendars

The planting and harvesting cycles for crops on the farms were shown.

FORM 5 Competitive Indices - Trees

The form tallied the competition between a given tree species and other trees or crops at select points on the farm.

FORM 6 Competitive Indices - Crops

This served the same purpose as Form 5, except that the competition between a given crop species and other crops or trees was recorded.

FORM 7 Survey of Tree Use

On this form, the uses by species were compared with the 19 potential uses for each specie found in or near the garden. The generalized potential use categories ranged from firewood to medicinal purposes. Special uses were also noted, e.g., honey production.

Environmental Data

The environmental data concerned rainfall and the Buffum/Campbell (B/C) environmental zones. Early in AOP, Bill Buffum of PADF and Paul Campbell of CARE realized that a system was necessary to determine the environmental and physical factors that indicated the suitability of sites for growing different tree species; for example it is important to know where the various species being outplanted in AOP could be expected to grow best (Buffum, 1984). Their classification was based upon rainfall, elevation, and parent soil types as shown in Table 1. This system is similar to the often-used Holdridge Biological Zones and, in fact, is based in part upon recommendations by Holdridge for Haiti (Sedwitz and Grant, 1972). Table 2 compares the standard Holdridge zones with those of Buffum/Campbell.

For this project, the variables effecting each potential site were measured in the following ways. Rainfall for a given site was obtained from rain gauge records, if a rain gauge was located near the area being studied, or from extrapolation of rainfall isolines that were produced from data collected by the Haitian Meteorological Service.

The elevation of study areas was determined by using an altimeter accurate to within 10 meters. Topographic maps having 100 m contour intervals were also used for general orientation.

The seven parent soil type groups (3 limestone, 3 igneous, 1 fluvial) were determined by field examination using the soil type description in the 1972 OAS report, "Haiti, Mission d'Assistance Technique Intégrée" (Sedwitz and Grant, 1972). Table 3 lists those individual parent soil types which were included in each group by zone. In essence, each soil type was put in a given group based upon its origin (sedimentary, igneous, water borne), relative weathering ability of the parent rock type, and relative water-bearing capability.

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Table 1. The Buffum/Campbell Environmental Zones.

Parent Soil Group	Elevation	<400 m			400-800 m			>800 m		
	Rainfall (MAP)	<1000mm	1000-1500mm	>1500mm	<1000mm	1000-1500mm	>1500mm	<1000mm	1000-1500mm	>1500 mm
	Limestone 1 (1)	11	21	31	41	51	61	71	81	91
	Limestone 2 (2)	12	22	32	42	52	62	72	82	92
	Limestone 3 (3)	13	23	33	43	53	63	73	83	93
	Basalt (4)	14	24	34	44	54	64	74	84	94
	Andecites And Dacites (5)	15	25	35	45	55	65	75	85	95
	Quartz Diorites (6)	16	26	36	46	56	66	76	86	96
	Alluvium (7)	17	27	37	47	57	67	77	87	97

Source: Memo by Bill Buffum, Pan American Development Foundation, Port-au-Prince, Haiti. December 1984.

Table 2. The Relationship Between Buffum/Campbell Environmental Zones and Holdridge Biological Zones

Elevation (ASL)	<400 m			400-800 m			>800m		
Rainfall (MAP)	<1000 mm	1000 - 1500 mm	>1500mm	<1000mm	1000 - 1500 mm	>1500mm	<1000mm	1000 - 1500 mm	>1500mm
Buffum/Campbell Zone	11-17	21-27	31-37	41-47	51-57	61-67	71-77	81-87	91-97
Holdridge Biological Zones	Subtropical Thorn Forest (<500 mm) ------------ Subtropical Dry Forest (500 - 1000mm)	Subtropical Moist Forest (1000 - 2000mm)	Subtropical Moist Forest ------------ Subtropical Wet Forest (2000 - 4000mm)	Subtropical Dry Forest (500 - 1000 mm) usually found below 600 m	Subtropical Moist Forest (1000-2000 mm)	Subtropical Moist Forest ------------ Subtropical Wet Forest (2000-4000mm) ------------ Subtropical Rain Forest (4000-8000mm)	Negligable Amount of this Zone Lower Mountaine Dry Forest	Lower Montaine Moist Forest (1000 - 2000mm) ------------ Montaine Wet Forest (1000 - 2000mm) (>2000 m elevation)	Lower Montaine Moist Forest ------------ Lower Montaine Wet Forest (2000-4000mm) (800 - 2000 m) elevation) ------------ Lower Montaine Rain Forest (4000-8000mm) ------------ Montaine Wet Forest (1000-2000mm) (>2000 m elevation)

Parent Soil Type Group		Specific Parent Soil Type
Group No.	Group Name	
1	Limestone 1	EPC, Ksce, K-Mc, Mmi, Oc, Omc
2	Limestone 2	Mca
3	Limestone 3	Qc
4	Basalt	Eba, Eomb, Kb, Qbn
5	Andecites and Dacites	Ea,,Eta, Ka
6	Quartz Diorites	Kdq
7	Alluvium	Qual

Table 3. The specific parent soil types within each of the Buffum/ Campbell parent soil groups.

The zones served as guides in the sampling done for the study of agroforestry systems. This allocation was based by zones on a combination of the following: a percentage area of the country, the ability of the zone to support tree growth, and the possibility of there being AOP plantings in that zone. A map of the B/C zones was produced early in the project by superimposing the three base entities. Area statistics were then obtained from a dot grid tally of the B/C classes shown on the maps (Ashley and Grosenick, 1985). As a matter of interest, area summaries of erodibility were also made by parent soil type, slope and land use by using maps produced for the Haitian Government (BDPA, 1983). This erodibility study was outside the scope of the work that will be discussed here, but it is worth noting because it will certainly be of use in future AOP project work and to others outside AOP interested in agricultural development and watershed management.

Physical Data

The physical variables recorded in this study related to the soil and landscape. The elevation and parent soil parameters within the B/C zones discussed above are physical variables. The percentage of slope and aspects of the soil's surface character were also recorded along with the cultivator's impression as to whether the soil on his farm had greater than average, average, or less than average moisture retaining ability and fertility.

Farm Management Data

Farm management data was biological and farm practice information related to the crops, trees, and animals in the garden or agroforestry system being studied. Cropping data was collected on the species planted, the arrangement of planting, the percentage of ground covered, the crop calendar, and the competitive indices. The competitive indices were a series of fractions which represent the percentage of ground cover at 25 systematically located points over the garden. For example, for a given garden, if 8 points had maize growing over common beans, the competitive index was 8/25; or for another garden, if 17 points had some crop over them, the fractional crop cover or competitive index for crops was 17/25. This would be equivalent to a 68% cover. Tree-related information included the species and age of trees planted, the spatial arrangement, the percent in shade, the number of trees of that species present, the product (pole, post, lumber) potential of those trees, and the competitive indices where trees were dominant. Finally, the presence of grazing animals was noted by species along with whether they were tethered or not.

Fencing surveys recorded whether fences were living, non-living, or a combination of the two, and what species or kinds of materials were used to make the fences. Living fences in Haiti have been cited as potential sources of erosion control, herbs, fiver (sisal), and other products of value to farmers (Mintz 1962).

CHAPTER 4

CHARACTERISTICS OF HAITIAN AGROFORESTRY SYSTEMS AND IMPLICATIONS FOR AOP

From the data collected one can characterize the traditional agroforestry systems studied according to crop and tree species composition, crop-tree geometrical arrangements, agri-silvo-pastoral uses, and tree uses and products. As stated previously, these characterizations are comparable to other agroforestry system studies throughout the world. Each of these will now be considered.

Crop and Tree Species Within The Major Cropping Systems of Haiti

What was Studied

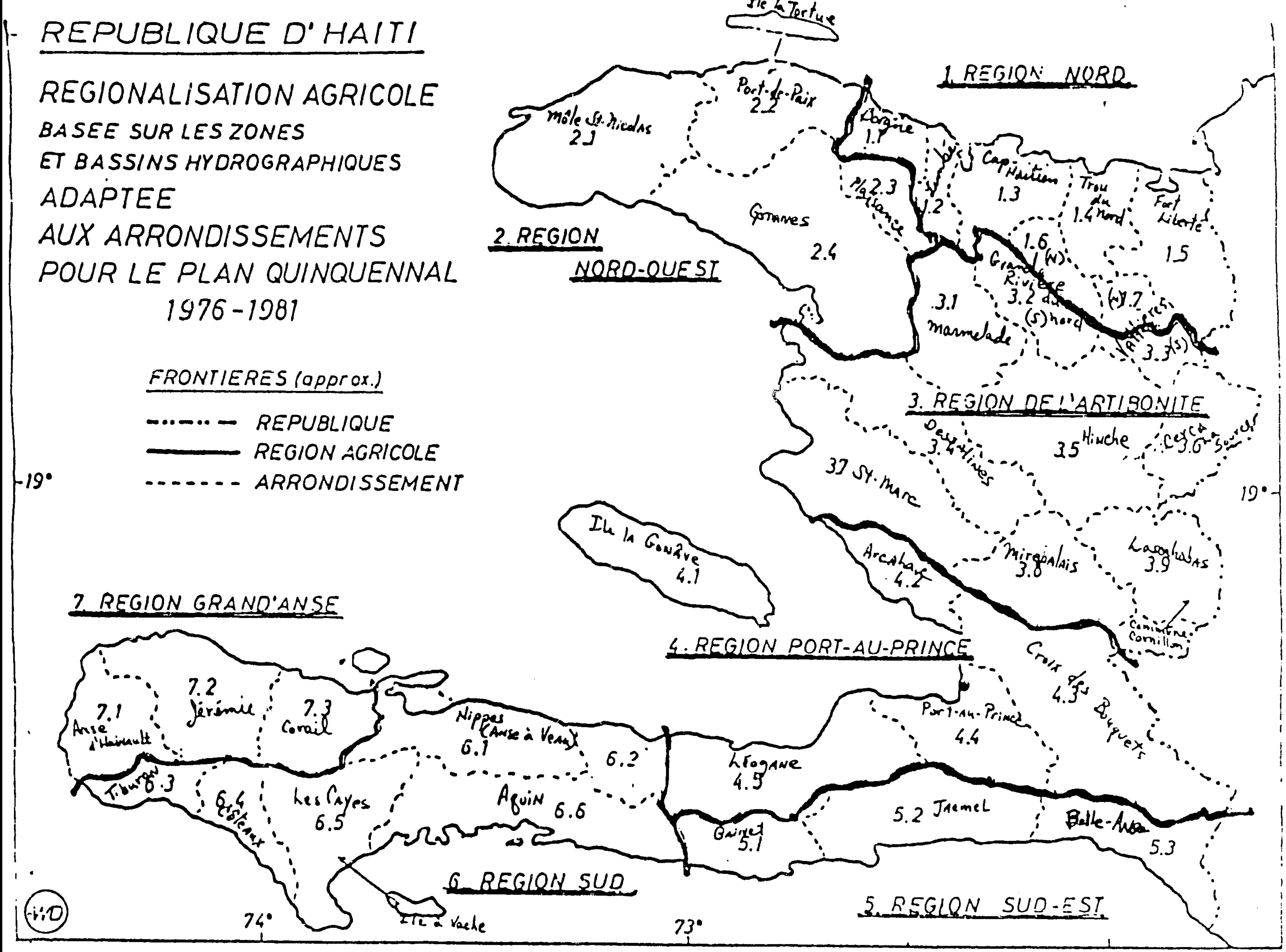
The major cropping systems of Haiti were surveyed in terms of the crops and tree species occurring on farms. Crop calendars were also derived for the major species planted throughout the country. Much of this data had been collated by zone or singularly by elevation. This data was summarized by the agricultural regions used by the Ministry of Agriculture and Natural Resources and by the Political Departments used by the Haitian Government. Figure 3 shows the agricultural regions and Figure 4 the political departments. Although they overlap, both are presented since potential users of this report may find one system desirable over the other.

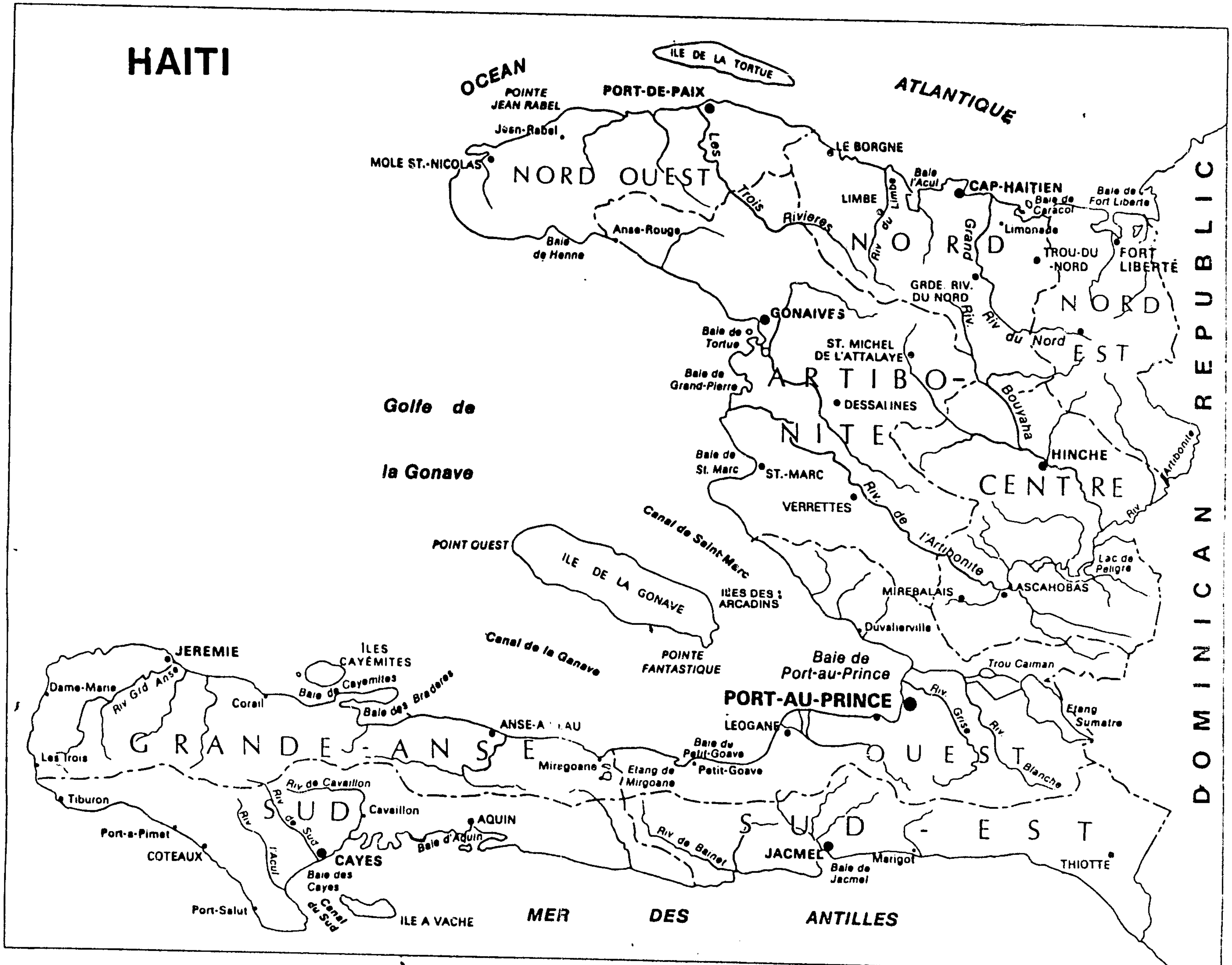
Synopsis of Results

Buffum/Campbell zones which represent 87.6% of Haiti, were sampled, while 86.6% was surveyed for crop associations. The sample of crops, trees, and crop associations on farms was not taken within many of the B/C zones, but these account for less than 14% of the country's area. On average, three gardens were intensively studied and six gardens generally surveyed per B/C zone studied.

Haiti has a semi-tropical climate. The crop and tree species found in Haiti reflect this, however, some crops such as the potato (*Solanum tuberosum*), are often thought of as a temperate species. Haiti's mountainous, upland terrain has a temperate character and permits cultivation of these more cold-loving species. ICRAF has published some material illustrating the adaptability of several of the species found in Haiti to varying altitude, temperature, and moisture regime. Figure 5 is a reproduction of one of these figures (ICRAF, 1980).

Figure 3. The Agricultural Regions of Haiti





PREPARED BY WILCOX ASSOCIATES

Figure 4. The Administrative Departments of Haiti.

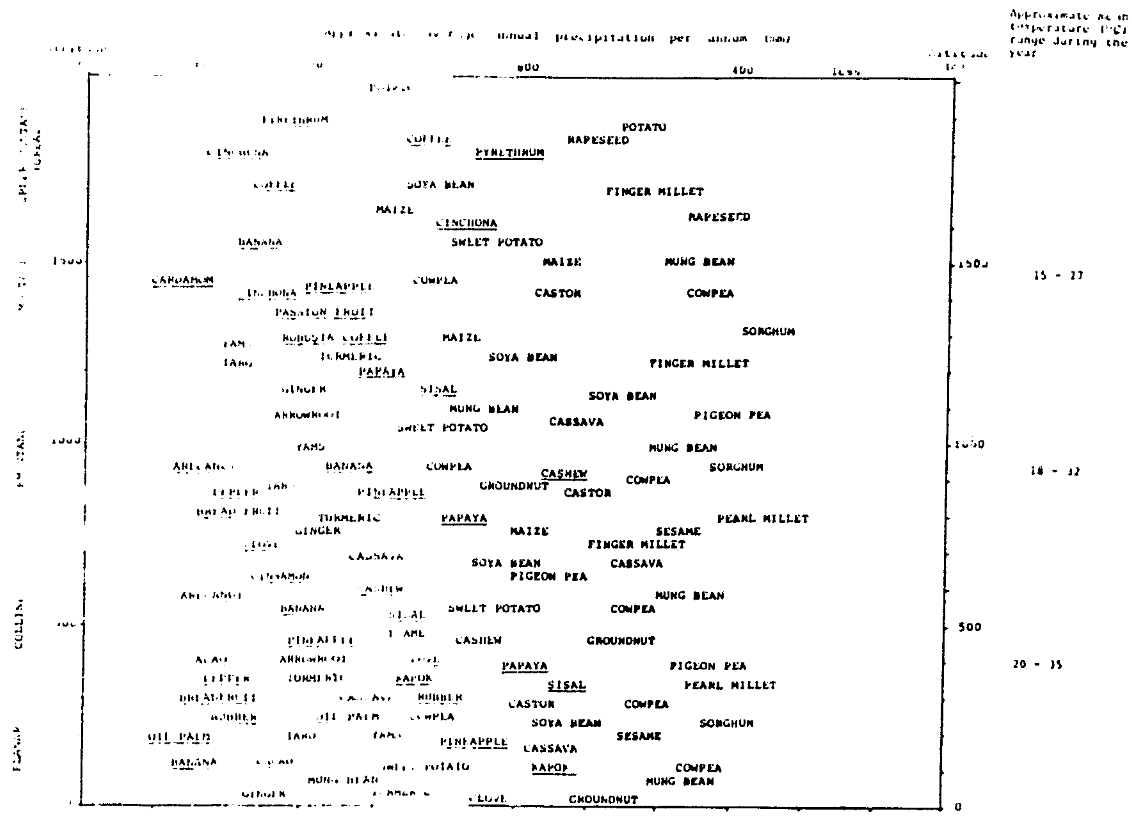


Figure 5. Ecological adaptability of the selected species. Perennials are underlined; species having wider adaptability are mentioned more frequently. (Figure is as copied from ICRAF publication, Agroforestry Species, a crop sheets manual, P. K. Nair, 1980. pp. 44)

Some anomalies are also obvious, such as the relatively high moisture-requiring species of rice, yams, and banana growing in a B/C zone with less than 1000mm MAP (mean annual precipitation). Such anomalies occur because of man-induced or natural modification of the planting site, although the site itself was correctly put within the proper B/C zone. In the above examples, the rice, yams, and banana were growing in areas that were irrigated or were near springs or streams. In fact, some of Haiti's most agriculturally productive land, such as in the Artibonite Valley, has relatively low rainfall. However, through irrigation the fluvial soils there support crops exceedingly well.

Haitian farmers often plant several species within a single garden; he does this to diversify his market opportunities, to ensure variety in his own food supply, and to spread his labor over a longer period time span in order not to plant or harvest all his crops simultaneously. Of these 82 species associations, 24 were probably unique to only a limited number of B/C zones, and 32 were not likely to be in AOP planting areas, which leaves 26 that are found within AOP gardens. Examples of the unique associations found within a few zones include banana, manioc, and sweet potato; cow peas and watermelon; or yam and congo bean. Those commonly observed in AOP planting areas were primarily the high value (e.g., carrots, beets, parsley; potato and cabbage; or leek and cabbage) market vegetables grown at upper elevation.

The 26 associations seen frequently in surveys of areas having AOP outplantings are shown in Table 4. Of these 26, only four associations contain species that will grow reasonably well with partial shade (those with some combination of yam, sweet potato, and manioc) and four others will have reduced but acceptable yields, (those with some combination of yam, sweet potato, manioc, and congo bean). None of the associations grow well in full shade. Grosenick (1986) found several other associations in his summary of farm studies by CARE and PADF and none of these associations grow in complete shade.

The crop calendars of the nine major species found in the surveys are typical of those reported in the literature (ICRAF, 1980). These species are the cereals (maize, sorghum) tubers (sweet potato, manioc, yam) and pulses (common beans, congo bean, cow pea, and lima bean). The seasonality of the rains in Haiti and their differences by region are apparent when comparing planting times for a given crop. In all but a few arid areas, there are two planting seasons per year, spring and fall. The spring season is from February to May and the fall from August to December. The planting schedule for individual farmers for a given crop was found to vary because of differences in the timing of the rains in a given area and because of his labor constraints in tending his other garden plots or because of other demands on his time (selling his labor, etc.). Also, as a generality only partly evident from the table, a given crop species takes longer to mature in areas of lower rainfall or higher altitude.

ASSOCIATION	
Beans (black, red, white)	Maize, sorghum, manioc
Congo bean	Maize, sorghum, sweet potato
Congo bean, sweet potato	Maize, sorghum, congo bns, swt potato
Castor bean, sweet potato	Maize, sorghum, manioc, sweet potato
Congo bean, manioc, sweet potato	Maize, sorghum, bns, sweet potato
Maize	Manioc
Maize, banan	Manioc, beans (black, red, white)
Maize, beans	Manioc, peanuts
Maize, congo bean	Manioc, sweet potato
Maize, sorghum	Seasame, peanut
Maize, sweet potato	Sorghum
Maize, manioc, sweet potato	Sweet potato
Maize, sorghum, congo bean	Yam, manioc

Table 4. Crop Species Associations Found Frequently in Areas where AOP trees are being planted.

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AOP Implications

If farmers want to continue growing their shade intolerant associations, tree shading must be controlled at an acceptably low level through planting at wide spacing in the garden, by pruning tree crowns, by planting species that give little shade, by planting trees on the garden boundaries where the effect will be minimized, or by planting living contours within the garden where the importance of soil conservation outweighs the short-term impact of reduced crop yields from land taken by the contour.

There are some exceptions to this in that farmers may purposefully choose to grow trees on a given garden site at the expense of their crops, if the trees will give them more income per unit area than their other crops and they have enough income from their other sources (e.g., crops or trees from other gardens) to meet their basic needs. Conway (1986) and Grosenick (1986) also have found that farmers often plant blocks of trees to improve their fallow land. In these cases the tree spacing may be much closer and the degree of pruning less than in gardens where there is to be a continuing cropping of non-tree species. These species must not give excessive shade, except where moisture conservation is of primary concern where farmers want to continue growing their present, shade intolerant crop associations. The AFORP cost/benefit analysis by Grosenick (1986) gives some insight into this. However, the farmer's use and sale of trees will ultimately determine if an increased level of planting is warranted at the expense of other crop yields. If this is shown to be a possibility by the cost/benefit analysis studies, it is recommended that CARE and PADF set-up demonstrations of plantations having spacing, thinning, and pruning regimes designed to produce maximum wood production.

The crop calendars also permit some inferences of importance to the AOP. The farmers interviewed often indicated a range in months over which they do their planting. This reflects the variability in the timing of the rainy seasons from year to year. Consideration should be given to starting nursery production one or two months earlier than is done now. Acceptable nursery stock would then be available for outplanting if the rains came earlier than expected. This assumes that the present AFORP research on extended growth schedules, through extending the hardening-off period, will show no adverse effects upon survival. At the least, this will assure an acceptable seedling for early rains and should provide a more hardy seedling for rains on schedule or late. The rains in the fall of 1985 in many parts of the country came about one month early, and some seedlings were planted out undersized and without sufficient hardening-off. Their survival will likely be lower than average.

This proposal is not without its problems. There would be an increased cost per seedling because the trees will be in the nursery longer. However, this should be negligible as little watering or fertilization needs to be done over the extended growth period. Another cost addition would potentially result from having to expand the size of nurseries, because for some species there would not be time to reuse seedling containers from the spring outplanting in preparation for the fall. Ninety-three percent of the sample points and some kind of cover other than base soil. Nearly 60% of the farms surveyed had greater than 75% crop cover. More than 75% of these same farms had greater than 60% ground cover. Even though the grid was purposefully shifted to the area of greatest tree outplanting. For these species the nursery would have to be expanded so that an overlapping nursery production could be accommodated. An economic analysis is suggested to find the marginal value of increased tree survival versus the increased nursery costs.

Crop-Tree Geometrical Arrangements and Biological Interrelationships Between Crops and Trees

The Haitian farmer often has an interspaced pattern in the planting of his crops. The trees found growing within gardens also follow this pattern. The major exceptions to this were found in alluvial lowlands, steep hillsides, and in the upper mountains, regardless of slope. In these locations crops were planted in well defined rows. High-value commodity crops were grown in the lowlands and mountains, and contour planting in rows was often observed on steep slopes, regardless of elevation. Of the gardens intensively surveyed, 53% had an interspersed pattern of planting, 24% had a mixture of interspersed with row planted crops, and 23% had all the crops in the garden planted in rows.

Farmers using native tree species that were planted from local seed, natural seedlings, or cuttings did not plant them in regular patterns, other than banana or plantains. However, this is not to say that farmers will not plant trees in regular patterns. A one-percent random sample of AOP planters stratified by regions, as well as studies of project farms, indicated that project trees are usually planted in some set pattern.

Interrelated with the planting patterns is the effect of the various crop and tree species through their competition for sunlight, moisture, and nutrients. To quantify this biological interaction between species, particularly the effect of trees on other crops,a survey of crop and tree occupation of the garden was undertaken.

The Sample Studied

A 25-point sample of vegetative cover was taken on each intensively surveyed farm. This grid of two meters by two meters spaced points was purposefully located in the portion of the garden having the heaviest tree cover. The overall percent of shade from tree cover in the entire garden was also recorded. The competitive index system was designed as a sampling scheme to indicate which crops and trees grew in association with each other and under what conditions of shade.

Synopsis of Results

The amount of crop cover was generally quite high. More than 93% of the sample points had some kind of cover other than base soil. Nearly 60% of the farms surveyed had greater than 75% crop cover. On more than 75% of these, the grid was purposefully shifted to the area of greatest tree cover. There was less than one-third tree cover on 74% of same farms which had greater than 60% ground cover. Observations on several AOP gardens gave similar results. From Table 5 it can be seen that three-quarters of AOP trees are being planted within garden borders; the gardens visited were managed such that the trees gave less than 40% tree crown cover or shade. Although more study should be done on this, it appears that this shade is controlled by the farmer's spacing and pruning of branches as the trees mature. Mortality of the introduced trees also is a big factor in shade reduction.

Even though the amount of tree cover was generally low, several tree species were found growing over various crop species. By far, sweet potato, manioc, and yam were the species found most often growing in the shade of trees. Occasionally, congo bean plants were found growing in the shade.

This data again confirms that farmers are generally growing sun-loving crops, and although they do incorporate trees in their gardens (nearly all farmers surveyed had some trees growing on them), the farmer will want to control the effects of tree shading so that it will not significantly reduce crop yield.

There is one notable exception where the effect of tree shade is not always considered bad. This is the use of tree shade to increase the moisture available to crops. Some farmers in northwest Haiti claim that tree shade from *Leucaena leucocephala* lessens moisture stress on dry sites for crops such as sweet potatos and cow peas. Conway (1986) and Balzano (1986) have found that trees, in general, are often used to increase moisture on the garden plot. This positive influence was also cited in interviews with Conway's farmers in the North, West, and Southeast and Balzano's in the South and Grand'Anse Regions. Observations by Conway, and Balzano, and Ashley of leaf turgor, an indicator of moisture stress, on species growing within and outside of shade on the same site confirms their statements.

AOP Implications

Generally the same conclusion is reached here as with the survey of crop associations. Farmers control tree shade so that it does not adversely effect the crops they are growing. Because of this it is additionally recommended that the number of trees distributed to each farmer be flexible and that CARE and PADF outreach program continue to contain messages on how to properly space and prune trees to meet the farmer's objectives. It is likely that each farmer will put more effort into caring for the number he feels appropriate for his land; he will probably request fewer trees to limit his shading problems.

TABLE 5. Methods of Planting Trees on AOP Farms. 1/

Type of Planting	Border	Border and Rows	Border and Intercropping	Border and Soil conservation	Border, Rows and Intercropping	Border, Rows and Soil conservation	Border, Intercropping and Soil conservation	Rows and Soil conservation	Rows	Intercropping	Soil Conservation
Percent of Farms	24.8	23.9	2.7	3.5	0.9	1.8	1.8	1.7	12.4	25.6	0.9

Border planting, singularly or in combination (59.4%) with other plantings within the farm.

Plantings within the farm, assuming Soil Conservation plantings are within. (75.2%)

1/ Data from Care and PADF surveys using a geographic stratified random sample of 117 farms planted under their projects within the USAID Agroforestry Outreach Project in Haiti.

The grantees have already reduced substantially the number of trees given to each farmer since AOP's beginning. In many cases this is now down to 150 trees. However, it is recommended that the minimum limit be at 50 and the upper limit be the largest amount of seedlings that can be packed in one box for distribution from the nursery. No more than this should be given any one farmer as the benefits of the project should spread over several farmers' lands.

If AOP is to maintain or increase its level of planting, this proposal could pose a severe logistical problem, since fewer trees would be requested per farmer and several more farmers would have to be contacted each season to maintain or increase planting numbers. To alleviate this potential problem, the same or larger numbers of trees should be distributed to selected farmers as they are now by the CARE and PADF staff. These farmers would then redistribute smaller lots to other nearby farmers. In essence, he would become a sub-animator. Studies by CARE, PADF, and AFORP staff have shown that this is already happening on an informal basis. The selected farmer's incentive to do this could perhaps be the offer of some improved fruit tree stock.

Live Fencing, Boundary Marking and Haitian Agroforestry Systems

Until now, only plantings within the gardens have been considered in characterizing the systems. However, trees were found growing around the borders of about 50% of the farms surveyed and their role in Haitian agroforestry systems will be discussed now.

The Sample

Trees and other plants are often used by peasants as living fences and boundary markers. Fencing is used to define structures and to restrict the passage of animals, including humans. Boundary markers are plants planted along a property division to establish that line or along foot or animal paths and roadways to define these routes. The frequency of fencing was noted from an intensive farm survey of 35 farms. A general study of fencing materials was made on another 231 farms located throughout the country.

A specific study of trees used as boundary indicators was not undertaken. However, some general observations can be made from the farm maps sketched in the intensive garden surveys. Table 5 also gives an estimate of the role of AOP trees in boundary plantings, since it is likely that nearly all those listed as border plantings were on boundaries.

TABLE 6. Fencing for Surveyed Gardens from Intensive Farm Surveys. 1/

Species or Materials	Candélabre	Sisal, Medcinier	Sisal, Benzolive	Sisal	Sisal, Shrubs	Bayonette, Brésillet	Bayonette, Penguin	Bayonette, Shrubs	Candélabre, Bayonette Brésillet	Bayonette, Shrubs Leucaena	Sisal, Medcinier Mango	Rocks	Prosopis / Piled Prosopis Brush	Candélabre, Brush / Piled Brush	Euc., Coave, Vetiver / Rocks	None
Percent of Total Gardens	5.3	2.6	2.6	2.7	5.3	2.6	2.7	2.6	2.6	2.6	2.6	2.6	2.7	2.6	2.6	55.3
Fencing Used	Live only (34.2%)											Non live only (2.6%)	Combination Live and Other Materials (7.9%)			No Fencing (55.3%)

1/ All elevations and rainfalls within the Buffum/Campbell Zones are represented over the 38 farms surveyed. Of the seven group types, only parent soil group 5 isn't represented.

TABLE 7. A General Summary of Fencing Types for Haiti. 1/

Species or Materials	Euphorbia (Candélabre)	Euphorbia (pencil bush)	Sisal	Bayonette	Penguin	Médcinier	Shrubs	Bayonette, brésillet	Candélabre, sisal, Médcinier	Candélabre, Médcinier, Other shrubs	Picket, traverse	Picket, barbed wire	Cement post, barbed wire	Brésillet, traverse	Médcinier, traverse	Candélabre, barbed wire	Médcinier, Barbed wire	
Percent of Class (no./%)	163/80.7	2/1.0	17/8.3	2/1.0	6/3.0	5/2.5	1/0.5	1/0.5	2/1.0	3/1.5	4/50.0	3/37.5	1/12.5	6/31.6	7/36.8	3/15.8	3/15.8	
Fencing (no./%) Used	Live only (202/88.2%)										Non Live Only (8/3.5%)			Combination Live and Other Materials (19/8.3%)				229/100%

1/ The "no." given in the table entries is the number of fences observed in the survey of 229 total fences.

Synopsis of Results

Not all gardens had fencing or boundary markers, live or otherwise. As can be seen in Table 6, slightly less than half of those in the intensive survey had fencing. However, most gardens near houses did have fencing. The fencing served the purpose of restricting access of animals and people to the house and to the crops grown around it. The frequency of animals grazing in any given area seemed to determine whether fencing was used in gardens away from the house.

In the general survey of gardens having fencing, most fences were made up of living materials. Table 7 gives a summary of results from this survey. Nearly 85% of the fences surveyed were made of living plants eight percent had some living plants and only four percent were made completely from non-living materials. *Candélabre (Euphorbia spp.)* made up 84% of the live fencing, nine percent was sisal (*Agave sisalana)*, and the remaining seven percent was a variety of shrubs.

The boundary plantings consisted of several tree and other plant species. These ranged from coconut (*Cocos nucifera)* to mahogany (*Swietenia mahogani)* trees to pinguin (*Bromelia pinguin)* and vetiver (*Antherum zizanoides)* plants.

AOP Implications

There have been two recent consultant reports to AOP which have recommended that the project increase its emphasis on the use of project trees for live fencing or boundary plantings (Salizar, 1985; Buffum and King, 1986). Judging by the high percentage of gardens found not fenced and boundaries only minimally located using trees, this seems a logical recommendation; there probably is an opportunity to expand the planting of trees for these purposes.

However, interviews with farmers raised several issues which would argue against increased tree use for fencing. The trees now being outplanted would generally be unsatisfactory for live fences in themselves. They could not be planted close enough together to provide a satisfactory animal barrier. There is some use of cut poles now as traverses or posts in non-live fencing, but farmers say that this wood is sometimes stolen for fuelwood or other uses.

On the positive side, there could be an increased use of trees such as *lilas étranger (Gliracidia sepium)* to provide live posts on which wood traverses or barbed wire could be fastened. Such trees could also be pollarded to control shade and to provide fuelwood, poles and stakes. However, such fences would require a higher capital investment than a fully live fence put in by the farmer. This increase would be from having to purchase barbed wire, nails, etc., and could be a deterrent to those farmers having little available cash. Further, Conway reports that some farmers say that the government is against the use of species such as pinguin and sisal along pathways because their sharp, pointed leaves can injure animals and people. Farmers also say that rats and mongoose live in the present live fences. Possibly a change to trees in these fences would make a less suitable habit for these pests. Lastly, Conway found that the farmers raise many of herbs that are used for cooking and medicinal purposes in their live fence systems. Any attempt to replace existing live fencing with predominantly tree species will need to consider what will happen to these herbs. Even with these positive points, only the possibility of a moderate increase in tree use is seen because the cost of nails and barbed wire for partial live fencing will be beyond the financial resources of most farmers.

While there is limited opportunity for the expanded use of trees for live or partially live fencing, there is a great potential for their use in marking boundary lines. Some negative aspects of this were found in the farmer interviews. Potential problems were envisioned where the adjoining land owner might claim damages because the trees would shade his crops. Also, if the trees were planted directly on the border, the adjoining landowner might claim half the trees were his. However, all of these arguments can be overcome. For the latter problem, the farmer planting the trees could possibly reach some kind of sharecropping agreement with 50% or every other tree being planted for the neighbor. Another alternative used now by some farmers is to plant the trees one to two meters from the actual boundary, thus avoiding the dispute of whose land the trees are on. If shade from the boundary planting is a major problem, then trees could be either coppiced or pollarded regularly to prevent the crown from developing excessive shade on the other property. The cuttings could be used to provide such products as fuelwood, poles, crop stakes, animal fodder, or green manure. If the trees are going to be coppiced or pollarded, the plantings could be made as living hedges and serve a valuable soil conservation purpose on hillside farms. Table 5 indicates that about two percent of the AOP plantings are presently of this type. There is also great potential for using AOP trees for shelter, for windbreaks to improve household comfort, and to reduce evapotranspiration and soil drying. Conway (1986) cites the benefits farmers recognized from the shelter and shade of trees growing around homes. Research done by the Haitian Ministry of Agriculture has also shown that yields of some crops can be increased significantly through using shelterbelts. However, some demonstration of this influence on crop yields needs to be done under peasant farm conditions before this potential will be realized.

Trees could also serve a much greater role in marking pathways, both for shading, and the benefits of periodic cutting of these trees. However, in erosion prone areas, the present *Euphorbia spp.*, and *Agave sisalana*, etc. now found planted along paths serve as a superior soil conservation species and should continue to be used until some substitute for them, such as grasses can be found.

It is recommended that CARE and PADF incorporate explanations and demonstrations of all these uses into their outreach programs. The demonstrations would be needed for uses such as living hedges and shelterbelts. Presently, neither are used commonly by the Haitian peasant farmer.

Agri-silvo-pastoral Needs and Potential Grazing Problems

Livestock are often an important source of farm income and are an integral component in the farmer's management plans for his land. In Haiti, farmers having traditional systems often pasture their animals on fallow lands, on scrub lands never used for cultivation, and in their gardens after crop harvest. Conway found that farmers graze animals in gardens for several reasons, among which are to convert crop residue into fertilizer and to build soil organic matter through the animals' walking on plant stubble. Balzano also observed that coffee cultivators often allow pigs in their coffee groves to scavenge food and provide fertilizer through their defecation.

However, grazing animals can present problems to projects such as AOP, and many agroforestry projects throughout the world have been plagued by the predation of browsing animals on young trees. Haiti, however, has some laws which could minimize this problem. There is a national law which in essence says that animals are to be tethered so that the crops of another can not be damaged, and if they are, the animal owner must compensate the crop owner.

The Sample Studied

In the farm studies made by the author, the presence of browsers on farms was surveyed, along with the presence of those near, but not in the gardens. Any farm management practices concerning the animals which might involve the positive use of AOP trees was also noted. Additional data gathered from the one percent random sample of AOP planters CARE and PADF was also tabulated on the ownership of grazing animals. Although this data is not necessarily representative of farmers outside the project, it does indicate the relative magnitude of potential grazing problems and pastoral needs.

Synopsis of Results

Grazing animals are frequently owned by AOP farmer participants. The CARE and PADF random sample gave the following ownership claims:

Seventy percent had goats or sheep
Fifty percent had cattle
Forty-eight percent had horses or burros
Three percent had pigs
Eighty-seven percent had at least one of the above animals

This indicates a large pastoral need by farmers and a large potential for grazing within gardens. However, surveys made during the crop growing season showed few animals within gardens, even though there was a high presence of potential grazers in the vicinity. Browsers were found on only three percent of the farm plots and none of these were untethered, which 46% of these same gardens had animals nearby. Those animals outside the garden were usually either tethered or excluded from the garden by fencing. However, some of the interviewed farmers said they let their animals in the garden to feed on the crop residues after harvest.

The tethered animals were often tied to trees, the tree serving as an attachment point for the tether rope and to give shade needed by the animal. The area around these trees was often heavily grazed and the tree itself was sometimes damaged from chafing by the tether rope or by the animal. Browsing by the animal also sometimes damaged these trees.

The use of tree foliage and small branches by farmers as a controlled feed source was not observed, but several farmers told Conway that they used trees as fodder (Conway, 1986). However, cutting and carrying of grasses and farm crop residues to tethered or fenced-in animals was seen quite often. Interviews with AOP farmers indicate that many of the species AOP's outplanting are highly palatable to all livestock and even to chickens and turkeys.

AOP Implications

There is an excellent opportunity to expand the use of project trees for fodder in a cut and carry context. This method of feeding is already accepted practice by farmers and an increase in its use would likely lead to fewer roaming animals, which in turn should result in increased tree survival. Other studies have also shown that the foliage of many of the species used in this project have a much higher protein content than that of the forage Haitian animals are eating now.

It is proposed that CARE and PADF prepare explanations and demonstrations of the use of the project trees for the cut and carry feeding of select animals. This should be incorporated in their outreach programs. Some of this work has already been stated by the Grantees, but it needs to be given more emphasis. It is further suggested that the demonstrations use trimmings from hedges grown for boundary plantings or living contours and that the manure from the feedlots be put back on gardens for fertilizer.

The Uses and Products From Haitian Trees Grown In Agroforestry Systems

An understanding of the uses Haitian farmers have for trees in their agroforestry systems is necessary to assure that the proper species are being used in the AOP program. The acceptance of AOP in the long run will depend upon the farmers' ability to fill some of their perceived needs for tree products, e.g., fuelwood, lumber, honey production, medicinals, etc., from AOP trees.

The Sample Studied

Seventy native species not commonly planted in AOP were identified and their uses determined. These uses ranged from fuelwood to voodoo drums. It is apparent that the farmers' knowledge of uses and products from native trees is extensive and complex. It is also obvious that there is no species or plan which does not have multiple uses. Many of which, if not available from trees, e.g., production of medicinals, would cost the farmer dearly from his disposable income to buy an alternative from the market.

Furthermore, the interviews showed that the farmers did not realize some of the potential uses and limitations of the exotics being introduced by the AOP. For example, that leucaena can be used for posts, but should be treated to prevent attack by insects such as termites.

AOP Implications

Haitian peasants have a history and acceptance of growing trees within their traditional agroforestry systems for a number of uses and products. This may be one of the leading reasons why trees have been so readily accepted and are continually in demand.

However, the farmers should be given complete information on the potential uses and products, including production techniques for the exotic species being introduced through AOP. CARE, PADF, and the AOP Forestry Advisor are disseminating some of this, but more information is needed. It is recommended that this be requested from Forestry Support Program and USAID Science and Technology staff and used by CARE and PADF in their Outreach programs.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This report describes AFORP research on traditional Haitian Agroforestry systems and discusses the technical and policy implications for AOP. This discussion should provide insight into how this project may be made even more effective. Agroforestry systems in Haiti were characterized using biological/ physical/environmental and social/economic/management attributes. Generally, these systems serve agronomic, silvicultural, and pastoral purposes over a given cropping cycle. Trees and other crops were often found planted in an interspersed pattern with several different species associations of mostly shade intolerant plants. More than twenty products and uses were found for native trees ranging from house construction to voodoo drums.

There were 82 species associations observed during this study, and there are likely several more. The exact combinations are determined by, among other things, biological/environmental constraints and farm management factors, such as the availability of labor for planting, tending, and harvesting the crops.

There should be little difficulty in getting farmers to plant AOP trees in the regular patterns envisioned to maximize wood production and soil conservation. Even though trees were generally found growing in an interspersed pattern, farmers will probably be willing to plant trees in regular patterns, e.g., intercropped rows, alley cropping, contour planting, because many of their other crops are planted in at least one of their gardens in one of these regular designs. This will serve as a model to follow if AOP extension agents suggest planting in these patterns. In fact, this is a historical fact as a summary of AOP grantee data implies that most AOP trees are now planted in regular patterns.

With few exceptions, all of the AOP species now being outplanted could be introduced into the existing traditional systems without adverse effect. The exceptions to this involve situations where the planting of more trees than normal in the traditional system is desired, because more shade is needed for the optimal growth of other crop species. Also, leucaena, neem, and eucalyptus can give the farmer further problems. Leucaena and neem have been cited by some farmers as being too weedy to control on some of their better sites, and eucalyptus in some areas is seen as a tree which dries the soil and tends to make it more difficult to work.

An economic analysis is needed to find the marginal value of growing various densities of trees with crop combinations. This is desirable so that AOP personnel can better explain to farmers what their expected benefits will be from growing trees. In some instances this will mean decreasing the short term production of other crops because of shading.

This study, and those done by other AFORP researchers, found that the trees within traditional systems were used for garden improvement. Farmers often used tree leaves as a mulch to increase soil organic matter. Shade from trees was also often seen as a beneficial for increasing soil moisture and reducing crop stress from excessive evapotranspiration.

A better extension package is also needed to explain the potential product uses and limitations of AOP plant species. This should not be left to the farmers' hit or miss trials. The failure of a tree to meet his needs may result in his rejection of the project.

Most fencing in Haiti does not involve trees, and there does not appear to be an opportunity to expand this, as it would involve a substantial capital investment for the peasant, e.g., barbed wire and staples. However, boundary marking often involves tree use, and there should be an opportunity to greatly increase the use of AOP trees for this purpose. As pointed out in the text, there are several sociological considerations in doing this, primarily related to interpersonal relationships with neighbors, but these are seen as resolvable.

The following definitive recommendations are made as a result of this study:

1. AOP trees should be planted at wide spacing within gardens, pruned to reduce shade, planted on garden borders or as living contours, and consist of species which do not give excessive shade except where moisture conservation is of primary concern where farmers want to continue growing their present, shade intolerant crop associations.

2. The number of trees distributed to individual farmers should be flexible within some maximum and minimum limits.

3. An economic analysis should be done to find if growing tree crops is more profitable than raising other crops. If so, it is recommended that CARE and PADF develop materials and demonstrations on maximizing wood production for various species under a range of spacing, thinning, and pruning regimes.

4. Nursery production should begin one or two months earlier than done now to assure acceptable seedlings when the seasonal rains come.

5. Explanations and demonstration of the use of AOP trees for cut and carry, controlled grazing, and growing from living contour trimmings should be put into the CARE and PADF programs.

6. Forestry Support Program and USAID Science and Technology Staff should be requested to provide a summary of potential uses, including utilization methods, for the exotic species being introduced by AOP, and this should be put in as non-technical format as possible in order that CARE and PADF can adopt it into their outreach programs.

From these recommendations it can be seen that the research reported here on traditional agroforestry systems has led to several findings which should have a direct impact upon AOP. However, some of the subject areas need to have more data collected to complete their study, and some needs for new research have become apparent. More fieldwork is needed to complete the investigation of crop associations over those Buffum/Campbell Zones which have not been studied. New research is recommended into the causes of mortality of trees within gardens, both for gardens with and without AOP trees. This should include a study of grazing in the off seasons when crops are not growing in the garden.

The proposed extension of AFORP could be used to continue this component. Of particular importance is the initiation of a study into the causes of mortality of AOP outplanted seedlings.

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TWO CONTAINER/MIX TRIALS

IN HAITI

By

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This study was done with the assistance of many of the good people in the AOP. ODH personnel, in particular, Ron Smith, Joel Timyan and Peter Welle were instrumental in locating and making available the trial sites in this study. I am especially grateful to Marshall Ashley, thesis advisor and Thomas Greathouse, Senior Forestry Advisor - USAID/Haiti, who gave me much needed encouragement when the going was rough in the Fall of 1983. I am also thankful to Dieubon Devilas who was my assistant in the field, as well as my constant companion and teacher of Haitian culture and Creole.

EXECUTIVE SUMMARY

The use of small containerized seedlings and an imported growing medium, which greatly facilitate the distribution of seedlings to rural farmers, are two of the reasons why the AOP has been successful. To better understand the effects of containers and mixes on seedling survival and height growth after outplanting, a container/mix trial was conducted in October 1983, which tested five containers and two mixes.

The results showed that Pro-mix grew a significantly taller seedling at outplanting than did the locally produced Haiti mix. However, the influence of mix on survival and height growth after outplanting was not significant. The results indicated that containers do have an influence on survival and height growth after outplanting. Specifically, the plantband gave significantly better survival than the other containers. Also, Rootrainers appeared to enhance height growth to a greater extent than the other containers, though not significantly so. In addition, the fives rootrainer gave the lowest survival for all tree species, though it was not significant.

From these results, a second container/mix trial was conducted in October 1985, which tested four containers and mixes. The results showed that mix did not significantly influence survival and height growth after outplanting. In addition, Terrasorb did not appear to influence survival or height. Containers were found to have an influence on survival and height growth after outplanting. The plantband had significantly better survival and height growth than the other containers, though in the wetter clay areas, the plantband had the poorest height growth. This shows that if moisture is available, containers which allow rapid lateral root egress will most likely produce the best height growth. The fives rootrainer again had the lowest survival for all tree species, though it was not significant.

CHAPTER 1

INTRODUCTION

The use of small containerized seedlings, especially in plug type containers and a peat-based growing medium are widely practiced in North America (Tinus and McDonald, 1979). This however is not the case with most reforestation projects in developing countries where black plastic bags and native soil are nearly always used. Two of the reasons why the Agroforestry Outreach Project (AOP) has been successful is the use of small containerized seedlings, which has greatly facilitated the distribution of seedlings and the use of Pro-mix, which is a lightweight Canadian growing medium containing sphagnum peat moss, vermiculite, perlite and micronutrients, which produces higher quality seedlings in less time than seedlings grown in native soil. This system has enabled farmers to easily transport more quality seedlings to their farms and has allowed more farmers to receive seedlings and thus participate in the project than would have been possible using the traditional bag system.

Three container types (Fives Rootrainer, Winstrip and Todd planter # 150-50) and two soil mix types (Pro-mix and Haiti mix) were being used in the AOP in 1983. At that time, it seemed desirable to investigate not only the influence of these container and soil mix types on the seedlings, but also to test two additional container types (Hillson Rootrainer and Plantband). Therefore, a container/mix trial was established in Ganthier in October, 1983 which tested effects of five containers and two soil mixes on five AOP and two naturalized tree species.

In 1985, the Ganthier 17 month results showed that seedlings grown in the Plantband had better survival than other containers and that height growth was generally better in the Rootrainers. There appeared to be little height difference between mixes after outplanting, though mix significantly influenced seedling height in the nursery.

Another container/mix trial was established in October 1985. The selection of containers and mixes were based on the Ganthier trial results and on the types of containers and mixes by the AOP grantees at that time. Thus, the container/mix trial, which was located in Bon Repos, tested the effects of four containers (Plantband, Winstrip, Sixes and Fives Rootrainers) and four mixes (Pro-mix/50% peat, Pro-mix/50% peat with Terrasorb, Haiti mix/50% peat and Haiti mix/50% peat with Terrasorb) on two AOP and one naturalized tree species.

The research performed in these studies attempts to focus and explore two important technical issues within the AOP, namely the selection of containers and soil mixes. The objectives of this research were to select and evaluate the effects of containers and mixes on the growth and survival of AOP and naturalized tree species.

CHAPTER 2

METHODS AND MATERIALS

Ganthier

The study site was located approximately 30 km east of Port-au-Prince in the Cul-de-Sac Plain (Lat. 18° 40'N, Long. 72° 10'W). The topography of the site is generally flat and the altitude is 90 meters above mean sea level.

The site selection criteria were based on the availability of land, the ability to protect the site from animals, the proximity of the site to Port-au-Prince, and the semi-arid (720 mm) site conditions.

Three sites were selected in Ganthier on which to perform the container/mix trial. Site selection criteria for each site in Ganthier were based on the homogeneity of vegetative cover and visible plant/water relationships during the dry season. The objective was to select the most uniform area for each site in terms of environmental factors affecting plant growth. Thus, variability within each site was kept to a minimum.

According to the Holdridge Life Zone System, the area is classified as sub-tropical dry forest (Ewel and Whitmore, 1973). Presently, the site is degraded thorny secondary savanna with small areas under cultivation by the local population. Little of the original forest cover remains, thus the floral diversity is low. *Prosopis juliflora* and *Acacia* species constitute about 75% of the trees and the remainder is composed of other members of the Caesalpiniaceae and Mimosaceae subfamilies (Beard, 1949).

The climatic conditions exhibit only minor fluctuations throughout the year. The mean monthly temperatures range from 24° C in January to 28° C in July (OAS, 1972). Annual rainfall is about 720 mm which falls in two distinct rainy seasons; a very brief April/May season and a longer season from August through October.

During the Quaternary Period, the alluvial soils were derived from the limestone parent material (Woodring, 1924). These soils are high in base saturation, pH and organic matter and are characterized by thick poorly defined surface horizons. The soil texture generally ranges from clay to silty clays.

A composite soil sample was taken in early October with a pick and shovel at a depth of 50-60 centimeters. Six locations within the site were sampled. The soil samples for this trial and the other two were analyzed by Agricultural Services Inc. of Bon

Repos, Haiti. The results for this trial showed that the conductivity was 0.92 mmhos/cm, pH was 6.8, phosphorus was 14 ppm and potassium was 50 ppm.

The site was prepared in June 1983 with a 50 cm disk pulled by a John Deere 6040 tractor. One pass was made on the site which chopped and uprooted much of the vegetation and disked the soil to a depth of 25 centimeters. During the drier months of June and July, the local population collected many of the bigger pieces of wood and brush that had not been broken up in the disking operation for fuelwood. In addition, many of these people cleared the land entirely of brush to make their gardens. In August 1983, the site was again prepared in one pass by a bedder pulled by the same John Deere tractor. The bedder prepared the soil so that a 25 cm bund of soil was formed at three meter intervals and a 20 cm deep furrow was formed in between these bunds.

Seven tree species planted in the AOP were selected for planting in this trial. These species were *Leucaena leucocephala, Azadirachta indica, Parkinsonia aculeata, Prosopis juliflora, Eucalyptus camaldulensis, Casuarina equisetifolia* and *Cassia siamea*.

All the seed was obtained from Operation Double Harvest (ODH) in June 1983 except Azadirachta which was collected in early July 1983 along the South National Highway in Petit Goâve Haiti (Lat. 18° 26'N, Long. 72° 52'W).

Two soil mix types were tested in the trial, Pro-mix which is a Canadian growing medium containing sphagnum peat moss, vermiculite, perlite and micronutrients; and Haiti mix produced locally by ODH which contained 70% decomposed sugar cane bagasse, 15% rice hulls and 15% soil. The mix was analyzed by Agricultural Services Inc. and found to have a conductivity reading of 0.74 mmhos/cm, a pH of 8.4, 61 ppm of phosphorus and 140 ppm of potassium.

Five container types were also tested in the trial. These were the Plantband, Hillson Rootrainer, ODH Winstrip, Fives Rootrainer and the Todd Planter # 150-50.

Containers

Plantbands

This container was supplied and manufactured by Monarch Manufacturing Company of Salida, Colorado. The Plantband is a plug type container made of biodegradable cardboard which is coated with 0.05 mm of plastic. The container has a depth of 12.7 cm, a top and bottom diameter of 3.81 cm, a soil capacity of 187.4 cc, and a density of 579 cavities/square meter.

Hillson Rootrainer

This molded plastic container, which has vertical grooves that guide roots to the bottom opening, was supplied and manufactured by Spencer-Lemaire Company of Edmonton, Alberta, Canada. The container, which resembles an open book when unassembled, is formed by bringing the two pages together, thus resembling a closed book. The container has a top diameter of 3.81 cm, a depth of 12.7 cm, a soil capacity of 177 cc, and a density of 455 cavities/square meter.

Winstrips

The Winstrips were supplied by ODH of Port-au-Prince, Haiti. The hard plastic honey comb container has a soil capacity of 98 cc, a depth of 16.4 cm, a top and bottom diameter of 2.54 cm, and a density of 592 cavities/square meter.

Fives Rootrainer

This container has the same design and was supplied and manufactured by the same company as the Hillson rootrainer. The container has a depth of 10.8 cm, a top diameter of 2.54 cm, a soil capacity of 62.3 cc, and a density of 568 cavities/square meter.

Todd Planter # 150-50

These styrofoam block containers were supplied by ODH and are manufactured by Speedling, Inc. of Sun City, Florida, USA. The container is pyramid shaped and has a soil capacity of 52.4 cc, a top diameter of 3.81 cm, a depth of 12.7 cm, and a density of 554 cavities/square meter. The container measurements are summarized in Table 1.

Table 1. Ganthier Container Dimensions and Volumes.

Container	Top Dimensions	Depth	Volume *
Plantband	3.81 cm x 3.81 cm	x 12.70 cm	184.4 cc
Hillson Rootrainer	3.81 cm x 3.81 cm	x 12.70 cm	177.0
Winstrip	2.54 cm x 2.54 cm	x 15.24 cm	98.3
Fives Rootrainer	2.54 cm x 2.54 cm	x 10.80 cm	62.3
Todd Planter # 150-50	3.81 cm x 3.81 cm	x 12.70 cm	52.4

* The container volume is less than the product of the top dimensions and depths because of the taper of the container.

Three 0.7 hectare blocks (replications), each located within one kilometer of each other, were selected in the Wa plantation in Ganthier. Each block measured 60 m x 150 m and each corner was marked with a painted wooden stake. Because each block represented a replication of the trial, each block contained all possible combinations of species, soil mix, and container. Plots had 20 trees each and all seedlings were planted at a 2.5 m x 3 m spacing. Within each block, a specific species/mix combination such as Leucaena in Haiti mix was planted across the short axis of the block. Represented at random within this strip of Leucaena in Haiti mix were the five container types. Specific species were always grouped in adjacent plot rows which represented all possible combinations of container and mix types for one species. The plots for the remaining six species were laid out in a similar fashion.

The seedlings were grown in the MCH/U of M nursery in Vialet. The species/container/mix combinations were grown in their respective replications in the shadehouse. Insect problems, in particular crickets and caterpillars were experienced on the Casuarina and the Eucalyptus.

The seedlings were grown between nine and thirteen weeks in the containers and mixes. Specifically, Leucaena was grown for nine weeks, Azadirachta, Eucalyptus and Cassia for 12 weeks and Parkinsonia, Prosopis and Casuarina for 13 weeks.

Two days before outplanting, the seedlings were measured to the nearest centimeter with a standard 30 cm ruler and marked with flagging which identified the replications. On the day before outplanting, the seedlings were watered heavily and removed from the containers in the order that the trial map specified and placed in plastic lined boxes which were placed in the shade when filled. Each box contained between 180 and 320 trees depending upon which container types were put in the box. The trial name, site number and plot numbers were written on the boxes with a permanent marker and the box was left open until all 18 of the boxes had been filled.

The following day, the seedlings were transported to the site in Ganthier, placed in the shade. By 8:30 a.m., 18 laborers (eight male diggers, eight female planters and two male box carriers) had been hired to plant sites 1 and 3. Nine laborers and two animators were assigned to each site and instructed how the trial was to be planted. Joel Timyan, PhD candidate in forest ecology at the University of Georgia supervised the planting of site 1 and Dieubon Devilas, my Haitian assistant, and I supervised the planting of site 3. Each digger was given a 2.5 m staff to measure the distance between each hole and assigned a row. Holes measuring 25 cm x 20 cm x 20 cm were dug in the rows with a Haitian hoe. The diggers were instructed not to get ahead of the planters by more than five holes so that the soil would not dry out before the seedlings were planted.

After the holes were dug, the supervisory personnel placed the seedlings in the holes at which time the planters who were assigned each their own rows, planted and heeled-in the seedlings. Supervisors observed if seedlings were .jayed or planted improperly and corrected the situation when necessary.

The planting of the trial continued uninterrupted until 7:30 p.m. at which time both sites had been completed. The only problem encountered was when Dieubon allowed the workers to plant 1 1/2 extra plots beyond the end markers of the trial while I checked on Timyan's progress.

On the following day, beginning at 6:00 a.m., Dieubon and I supervised the planting of site 2. The trial was planted without problems and was finished at 5:30 p.m. Two weeks later, True-test raingauges were erected on posts approximately 1.5 m above the ground at each site. The local plantation guardian was hired to read the raingauges on a daily basis.

Survival was measured at 1, 6, 10, 17, and 24 months and height was measured at 6, 10, 17, and 24 months. The six and ten month measurements were measured with a two meter carpenter's rule to the nearest centimeter and the 17 and 24 month heights were measured to the nearest 10 cm with a three meter fiberglass measuring rod. Diameter at breast height (1.3 m) was measured to the nearest centimeter at 24 months with 50 cm Haglof calipers.

Water catchments measuring one meter in diameter were constructed under each tree at six and 16 months. Branches below 1.5 meters were pruned from all trees at 18 months. This did not include secondary or tertiary stems.

Analyses of variance were performed on the individual height measurements to examine the differences between blocks, species, soil mixes and containers at the .05 level of significance. For significant main effects, the Duncan's multiple range test was used to identify which treatment means were significantly different from the others.

Plot means for survival were also grouped by species, soil mixes and containers. Analyses of variance were performed on survival percentages after they had been transformed using an arcsine square root function. Duncan's multiple range test was again used to identify significant differences between treatments within the main effects.

Bon Repos (Nadal plantation)

The study site was located approximately 17 km east of Port-au-Prince in the Cul-de-Sac Plain (Lat. 18° 38'N, Long. 72° 14'W). The topography of the site is generally flat and the altitude is 30 meters above mean sea level.

The site selection was based on the availability of the land, the ability to protect the site from animal and human trespass, the proximity of the site to Port-au-Prince and the semi-arid (850 mm) site conditions.

The climatic conditions only exhibit minor fluctuations throughout the year. Mean monthly temperatures range from 24°C in January to 28°C in July (OAS, 1972). Annual rainfall is about 850 mm which falls in two distinct rainy seasons; a very brief April/May season and a longer season from August to October.

The trial is located on a deep, tannish brown alluvial soil which ranges from clay to sandy silt. Composite soil samples were taken at a depth of 0-10 and 50-60 centimeters. The samples were analyzed at Agricultural Services Inc., Bon Repos, Haiti. The 0-10 cm results showed that the conductivity was 0.74 mmhos/cm, ph was 7.4, phosphorus was 48.5 ppm and the potassium was 300 ppm. The 50-60 cm results showed that the conductivity was 7.5 mmhos/cm, ph was 7.6, phosphorus was 46 ppm and the potassium was 420 ppm.

The site which consisted mainly of *Prosopis juliflora* and *Acacia* species was prepared during the months of August and September with a 80 cm ripper pulled by a John Deere 6040 tractor. One pass was made on contour at three meter intervals which ripped a furrow in the soil 60 cm deep and 30 cm wide. During this operation, the vegetation on the furrow, including the roots were removed. In addition, any hardpan or clay layer was broken up to a depth of 60 centimeters. The vegetation between the rows was cleared by local farmers during the following week.

Three tree species planted in the AOP were selected for planting in this trial. These species were *Azadirachta indica, Leucaena leucocephala*, and *Prosopis juliflora*. Though Prosopis is not widely planted in the AOP, this author strongly feels that in B/C zones 11-17 it is one of the best performing species. All of the seed was obtained from ODH in June 1985.

Four soil mixes were tested in this trial. These were Fafard No.2, which is a Canadian growing medium containing sphagnum peatmoss, vermiculite, perlite and micronutrients; Fafard No.2 and Terrasorb, which is a water absorbing chemical polymer; 50% Haiti mix/50% sphagnum peatmoss, which is generally the mix specifications used by ODH and 50% Haiti mix/50% sphagnum peatmoss and Terrasorb.

Four container types were also tested in this trial. These were the Plantband, Winstrip, Sixes Rootrainer, and the Fives Rootrainer.

The containers were described earlier in this report, except for the Sixes Rootrainers which is described below. The Sixes Rootrainer is a molded plastic container, which has vertical grooves that guide the roots to the bottom opening. The container, which resembles and open book when unassembled, is formed by bringing the two pages together, thus resembling a closed book. The container, which was supplied by PADF and manufactured by Spencer-Lemaire Company of Edmonton, Alberta, Canada, had a depth of 14.0 cm, a top diameter of 2.54 cm, a soil capacity of 90 cc, and a density of 584 cavities/square meter. The container measurements and volumes are summarized in Table 2.

Table 2. Bon Repos Container Dimensions and Volumes

Container	Top dimension	Depth	Volume *
Plantband	3.81cm x 3.81cm	12.70cm	184.40cc
Winstrip	2.54cm x 2.54cm	15.24cm	98.30
Sixes Rootrainer	2.30cm x 2.80cm	14.00cm	90.00
Fives Rootrainer	2.54cm x 2.54cm	10.80cm	62.30

* Container volume is less than the product of the top dimensions and the depth because the of the taper of the container.

The trial covered 2.3 hectares and had four replications of each species/container/mix combination. Each plot contained 20 trees and all seedlings were planted at a 2.0 m x 3 m spacing.

The seedlings were grown between 13 and 17 weeks in the ODH nursery at Cazeau under my supervision. Specifically, Leucaena, Azadirachta and Prosopis were grown for 13, 16 and 17 weeks, respectively and each species/container/mix combination was grown in their respective replications in the nursery. These seedlings were held in the nursery beyond the PADF recommended growth period because of a lack of rain until late October and a site change, which had a rainy season that was three weeks later than planned.

The seedlings were measured and boxed using the same procedures that were employed in the Ganthier container/mix trial. At 5:00 a.m., the following day, the boxes were transported to the site and the 34 laborers (eight diggers, eight planters, eight water carriers, eight waterers and two bucket fillers) were assigned to their positions. The planting of the trial was supervised by me, my assistant Dieubon, and two other people. Each digger was given a two meter staff to measure the distance between each hole and assigned a row. Holes measuring 25 cm x 20 cm x 20 cm with small water catchment basins were dug in the rows with a Haitian hoe. After the holes and catchment basins were dug, the supervisory personnel placed the seedlings in the holes at which time the planters who were assigned each

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their own rows, planted and heeled-in the seedlings. The supervisors observed the planting operation and corrected the planters if seedlings were jayed or planted improperly. After each seedling was planted, it was watered with one gallon of water. The trial was planted without problems and was completed at 6:30 p.m.

Survival was recorded monthly for the first ten months and height was measured at planting, six and ten months. Six and ten month heights were measured to the nearest ten centimeters with a two meter carpenter's rule or a three meter fiberglass measuring rod. Plot means for survival were calculated and analyses of variance were performed to examine the survival differences between species, containers, mixes and replications at the .05 level of significance. For significant main effects, the Duncan's multiple range test was used to identify which treatments were significantly different from the others. The statistical analysis for height was performed the same way, except individual tree heights were used in the analysis.

CHAPTER 3

RESULTS AND DISCUSSION

Ganthier

Leucaena Survival

The analysis of variance showed that there were no significant survival differences for containers or mixes throughout the trial. This demonstrates that Leucaena is very aggressive in establishing itself and that the influence of containers and mixes on survival is minimal. The ANOVA also showed that there was a significant survival difference for replications at 34 months. The Duncan's test showed that replications 1 and 3 were not significantly different, but both had significantly better survival than replication 2.

Leucaena Height

The analysis of variance showed that there were significant differences found among containers, mixes and replications at outplanting and six months. At ten and 17 months, significant differences were found among containers and mixes, and containers, respectively. At 22 and 34 months, significant height differences were found among containers and replications.

Container Influence on Leucaena Height

The Duncan's multiple range test showed that the winstrip produced the tallest seedlings at outplanting (Table 3). The two Rootrainers, however, produced the tallest trees at 6, 10, 17, 22 and 34 months. This was most probably attributable to the training effect of the container grooves on the roots. It may be that the Rootrainer assisted Leucaena in establishing more roots at greater depths where moisture was more readily available, thus causing the added height growth.

Table 3. Leucaena Height in Centimeters by Containers over Time

Containers	Months 0	6	10	17	22	34
Plantband	21.1 a,b	111 b,c	246 c	310 c	332 b	369 b
Hillson	16.1 c	126 a	296 a	361 a	378 a	416 a
Winstrip	21.8 a	102 c	228 d	288 c	324 b	363 b
Fives	17.6 c	115 b	276 b	340 b	370 a	406 a
Todd Planter	20.3 b	109 b,c	248 c	309 c	331 b	345 b

Lower case letters (a,b,c,d) indicate statistically significant differences; those with the same letter are not statistically different at the 0.05 level of significance.

Mix Influence on Leucaena Height

The Duncan's multiple range test showed that Pro-mix grew a significantly taller seedling than the Haiti mix because it had better aeration and drainage, which allowed for greater root growth and thus greater top growth (Table 4). In addition, the Haiti mix had a ph of 8.4 which limited the availability of phosphorus in the soil, and possibly to the seedling. Because phosphorus is most abundant in meristematic tissue, this element is extremely important in the production of roots (Meyers et. al., 1973).

Table 4. Leucaena Height in Centimeters by Mix over Time

Mix	Months 0	6	10	17	22	34
Pro-Mix	21.9 a	108 b	253 b	318 a	350 a	381 a
Haiti Mix	16.9 b	118 a	262 a	322 a	340 a	374 a

The root systems of ten randomly selected seedlings per container were observed three weeks before outplanting. The results showed that root systems grown in Pro-mix were more fully developed than those grown in Haiti mix. Pro-mix root systems had thicker roots and greater numbers of lateral roots.

During the sampling of the root systems, nodules were found on the Leucaena roots grown in Haiti mix, whereas no nodules were found on the Pro-mix grown Leucaena. Remember that Haiti mix is

15% soil, which is the source of the rhizobium. This would explain the greater height of Leucaena grown in Haiti mix at six and ten months. Eventually, the Leucaena grown in Pro-mix became inoculated by the Leucaena rhizobia present in Haitian soils. There were no significant height differences due to mix at 17, 22, and 34 months. It is unlikely that the small amount of mix would have an influence on height growth after one year, especially with a fast growing species like Leucaena. The observation of nodules is important however, as this shows a positive growth response from the nodulation of this species. Therefore, AOP seedlings and especially Leucaena should be inoculated with the appropriate rhizobium before outplanting.

Prosopis Survival

The analysis of variance showed that at 6, 10, 17 and 22 months, there were significant survival differences found among containers and replications. At 34 months, significant survival differences were found among replications.

Container Influence on Prosopis Survival

The Duncan's multiple range test showed that the three largest containers by volume had significantly better survival than the two smallest containers by volume (Table 5). Although there were no significant survival differences at 34 months, the Plantband, Hillson Rootrainer and the Winstrip clearly exhibited better survival than the Fives Rootrainer and the Todd planter throughout the trial. Much of these survival differences were attributable to the container volume.

Table 5. Prosopis Survival in Percent by Containers over Time

Container	Months 6	10	17	22	34
Plantband	82.8 a	82.0 a	82.0 a	78.7 a	78.5 a
Hillson	89.8 a	89.0 a	88.2 a	85.5 a	84.7 a
Winstrip	82.5 a	79.2 a	78.3 a	78.3 a	78.3 a
Fives	59.2 b	54.2 b	54.2 b	54.2 b	54.2 a
Todd Planter	57.0 b	56.2 b	56.2 b	56.2 a,b	50.7 a

Prosopis Height

The analysis of variance showed that there was a significant height difference found among containers and mixes at outplanting. At 6, 17 and 34 months, significant height differences were found among containers, mixes and replications, while at 10 and 22 months, significant height differences were found among containers and replications.

Container Influence on Prosopis Height

The Duncan's multiple range test showed that the Winstrip again grew a significantly taller seedling than the other containers at outplanting (Table 6). In general, the Plantband, Winstrip and Hillson Rootrainer grew taller seedlings than the other two containers throughout the trial. Prosopis is a deep rooted species, which also establishes an extensive lateral root system. During the first two months of the trial, the rainfall was adequate, but during the following five months, the rainfall was very sporadic, and included a period of three months without any effective rainfall. These conditions would favor deeper containers which would help establish lateral root systems at greater depths where more moisture is available. Because the Plantband did not decompose, it inhibited lateral root egress, which forced many of the lateral roots out the bottom of the container. This helped the seedlings establish lateral root systems at greater depths and thereby contributed to their better height growth. The Hillson Rootrainer had good height growth because of the training effect on the lateral roots, and the Winstrip because of its greater depth.

Table 6. Prosopis Height in Centimeters by Containers over Time

Containers	Months 0	6	10	17	22	34
Plantband	13.3 c	70.0 a	161 a,b	287 a	354 a	473 a
Hillson	14.9 b	73.6 a	152 b,c	257 b,c	341 a,b	447 a,b
Winstrip	16.0 a	77.1 a	170 a	279 a,b	342 a	452 a
Fives	11.4 d	58.1 b	146 c	253 c	315 b	416 b
Todd Planter	10.6 d	41.3 c	117 d	197 d	251 c	351 c

Mix Influence on Prosopis Height

The Duncan's multiple range test showed that Pro-mix again grew seedlings that were significantly taller than seedlings grown in Haiti mix at outplanting (Table 7). Though Prosopis is a nitrogen fixing species, nodules were not observed during an examination of its root system about three weeks before outplanting. The formation of mycorrhizal associations are very likely in Haiti mix because it contains soil. Thus, rhizobial associations would be inhibited by the mycorrhizal associations and the potential for that plant to fix nitrogen would be reduced initially (personal communication - Dr. Joann Roskoski, 1986). Conversely, Prosopis seedlings grown in the sterile Pro-mix could not have formed mycorrhizal associations. When the seedlings were outplanted, the uninoculated roots grew into the native soil and rhizobial associations were established. About six months after the seedlings were planted, 20 native Prosopis trees were excavated and their root systems examined for nodules. Nodules in great abundance were found on all of the tree roots, thus determining that the Prosopis rhizobium was present in the soil.

Table 7. Prosopis Height in Centimeters by Mix over Time

	Months					
Mix	0	6	10	17	22	34
Pro-Mix	16.9 a	69.2 a	149 a	250 b	320 a	418 a
Haiti Mix	9.6 b	64.4 b	156 a	272 a	335 a	457 a

Therefore, Prosopis in Pro-mix was significantly taller than Prosopis in Haiti mix at six months because of a more developed Pro-mix root system, the earlier rhizobial association and the potential mycorrhizal association in the Haiti mix which inhibited subsequent rhizobial associations. The significant mix difference at 17 months is most likely caused by microsite differences.

Parkinsonia Survival

The analysis of variance showed that at all measurements there was a significant survival difference found among replications. In general, replication 2 and 3 were significantly better than replication 1. The analysis of variance showed no significant survival differences among containers and mixes. Because these differences were quite large, Tables 8 and 9 are included.

Throughout the trial, the seedlings grown in the Plantband showed better survival than the other containers. The Plantband had 33 and 17 percent better survival than the Todd planter and the Winstrip, respectively. Both of the Rootrainers had good survival performances, which may have been attributable to the training effects of the lateral roots.

Table 8. Parkinsonia Survival in Percent by Containers over Time

Containers	Months 6	10	17	22	34
Plantband	88.0 a	86.3 a	86.3 a	86.3 a	85.5 a
Hillson	79.2 a	79.2 a	78.3 a	76.5 a	73.0 a
Winstrip	75.7 a	72.3 a	72.3 a	69.0 a	68.2 a
Fives	75.5 a	75.5 a	75.5 a	75.5 a	74.7 a
Todd Planter	57.8 a	53.7 a	52.8 a	52.8 a	52.8 a

Table 9 shows that Parkinsonia seedlings grown in Pro-mix had about 13% better survival throughout the trial than seedlings grown in Haiti mix. Parkinsonia does not produce an extremely fiberous root system and thus, it has difficulty in binding the rootplug together, especially for the heavier Haiti mix. Loose Haiti mix rootplugs were noted at outplanting, and this is probably the reason for the constant survival difference between the two mixes.

Table 9. Parkinsonia Survival in Percent by Mix over Time

Mix	Months 6	10	17	22	34
Pro-Mix	82.7 a	80.7 a	80.0 a	78.6 a	77.6 a
Haiti Mix	70.6 a	66.1 a	66.1 a	65.5 a	64.1 a

Parkinsonia Height

The analysis of variance showed that there were significant height differences found among containers, mixes and replications at outplanting, six and ten months. Significant height differences were found among mixes and replications at 17 and 22 months and at 34 months among replications only.

Container Influence on Parkinsonia Height

Height differences by container for this species were very small, though significant (Table 10). The Plantband and the Winstrip grew the tallest seedlings at outplanting. The Rootrainers and the Winstrip appeared to produce the best height growth. There were no significant container effects at or after 17 months.

Table 10. Parkinsonia Height in Centimeters by Containers over Time

Containers	Months 0	6	10	17	22	34
Plantband	23.2 a	75.9 a	103 b	168 a	198 a	235 a
Hillson	21.3 b	77.1 a	105 a,b	175 a	206 a	261 a
Winstrip	22.8 a	79.5 a	110 a,b	175 a	209 a	253 a
Fives	17.1 d	74.1 a	113 a	182 a	207 a	255 a
Todd Planter	18.5 c	64.8 b	102 b	172 a	210 a	252 a

Mix Influence on Parkinsonia Height

Clearly, seedlings of Parkinsonia grown in Pro-mix had significantly better height growth than those grown in Haiti mix until 34 months, at which time there were no significant height differences between the two mixes (Table 11). Significant height differences were probably a result of differing physical and chemical properties of the mixes.

Table 11. Parkinsonia Height in Centimeters by Mix over Time

Mix	Months 0	6	10	17	22	34
Pro-Mix	21.5 a	79.4 a	112 a	180 a	214 a	260 a
Haiti Mix	15.3 b	69.5 b	101 b	167 b	194 b	239 a

Azadirachta Survival

The analysis of variance showed that there was a significant survival difference found among containers and replications throughout the four month period. In general, replication 2 had significantly better survival than replication 1 and and it had better survival than replication 3 which had the poorest survival after outplanting.

Container Influence on Azadirachta Survival

The Duncan's multiple range test showed that all containers were not significantly different, except for the Fives Rootrainer which had significantly less survival at six and ten months (Table 12). At ten months, the Plantband, Hillson

Rootrainer and the Todd planter were not significantly different, though the Plantband had the best survival. The Hillson Rootrainer and the Todd planter were also not significantly different from the Winstrip. At 17, 22 and 34 months, all containers were not significantly different, except for the Fives Rootrainer which had significantly less survival.

Table 12. Azadirachta Survival in Percent by Containers over Time

Containers	Months 6	10	17	22	34
Plantband	86.7 a	86.7 a	85.0 a	85.0 a	85.0 a
Hillson	79.8 a	77.3 a,b	74.8 a	73.2 a	72.3 a
Winstrip	70.0 a	69.2 b	69.2 a	69.2 a	68.3 a
Fives	50.5 b	47.2 c	41.0 b	40.2 b	39.3 b
Todd Planter	75.7 a	72.8 a,b	70.2 a	67.8 a	63.7 a

That the Todd planter exhibited significantly better survival than the Fives Rootrainer is unusual. However, the author feels that its good survival performance is mainly attributable to the random location of the container on good microsites. This was evident from a visual survey of ground vegetation, which showed that plots containing the Todd planter appeared to have more vegetative ground cover at replications 1 and 2 than for other containers. The amount of vegetative ground cover in a semi-arid zone such as this is generally an indication of heavier soil types such as clay which generally have greater amounts of available moisture for plant growth.

Azadirachta Height

The analysis of variance showed that significant height differences were found among containers throughout the trial, except at 17 months. It also showed that mix was significant at outplanting, 22 and 34 months, while replication was significant throughout the trial except at outplanting.

Container Influence on Azadirachta Height

The Winstrip again grew seedlings that were significantly taller than seedlings grown in the other container types (Table 13). Throughout the trial, the Todd planter exhibited better height growth than other containers. The author feels that this like the enhanced survival was attributable to the random location of the container on good microsites.

Table 13. Azadirachta Height in Centimeters by Containers over Time

Containers	Months 0	6	10	17	22	34
Plantband	12.5 b	45.8 b	134 b	216 b	313 b,c	448 b
Hillson	12.7 b	54.2 a,b	140 b	208 b	323 b	451 b
Winstrip	15.4 a	51.7 b	144 b	211 b	296 c	400 c
Fives	12.3 b	48.9 b	158 a	251 a	354 a	426 b
Todd Planter	12.2 b	59.9 a	160 a	223 b	363 a	516 a

Mix Influence on Azadirachta Height

The Duncan's multiple range test showed that pro-mix again grew significantly taller seedlings than Haiti mix (Table 14). However, at 6, 10 and 17 months, there were no significant height differences found between the mixes, though significance was found at 22 and 34 months. This author feels that the significant differences found at 22 and 34 months were attributable to microsite conditions rather than mix.

Table 14. Azadirachta Height in Centimeters by Mix over Time

Mix	Months 0	6	10	17	22	34
Pro-Mix	16.0 a	52.4 a	149 a	223 a	311 b	427 b
Haiti Mix	10.3 b	51.6 a	143 a	216 a	341 a	469 a

Bon Repos (Nadal plantation)

The Bon Repos container/mix trial was planted with a randomized complete block design. After the six month height measurement, it became apparent that there were significant soil differences between replications. Specifically, an area with a greater amount and depth of clay was identified, which covered 40, 16 and 10% of replications 2, 1, and 3, respectively. The clay area did not significantly influence seedling survival, though it did significantly influence height. Significant height differences were found between the clay and less-clay areas for all species, containers and mixes (Table 15, 16 and 17). The analysis of variance for the entire trial, including both clay and less-clay areas showed that there were significant height differences found among all main effects and two-way interactions at outplanting, six and ten months except for mix and the mix/rep interaction at six months.

The high degree of significance found in these results are partially due to the large means from the clay area which strongly influenced the ANOVA. A separate ANOVA which took soils (clay/less clay) into account, showed that there were significant

Table 15. Mean Seedling Height in Centimeters by Species Between Clay and Less-clay Areas Over Time.

Species (Soil Type)	Months 0	6	10
Azadirachta (clay)	12.8	42.2	87.1
(less-clay)	12.9	36.0	60.6
Leucaena (clay)	19.9	164	300
(less-clay)	21.3	100	141
Prosopis (clay)	28.0	102	191
(less-clay)	27.9	71	117

Table 16. Mean Seedling Height in Centimeters by Container Between Clay and Less-clay Areas Over Time.

Container (Soil Type)	Months 0	6	10
Plantband (clay)	25.4	91.8	168
(less-clay)	25.0	76.3	120
Winstrip (clay)	20.8	125.8	231
(less-clay)	21.8	68.8	104
Sixes (clay)	19.9	128.4	244
(less-clay)	20.2	67.3	109
Fives (clay)	16.0	111.7	221
(less-clay)	15.0	66.8	111

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differences among soils. Because the clay area confounded the analysis for the entire trial and because it only represented 16.5 percent of the trial area, the results of the trial were analyzed without the data from the clay area so that a more representative sample of what is actually happening in the trial can be examined. Therefore, all results reported hereafter are from the less-clay area.

Table 17. Mean Seedling Height in Centimeters by Mix Between Clay and Less-clay Areas over Time.

Mix (soil type)		Months 0	6	10
Pm/50% peat	(clay)	22.0	144.1	260
	(less-clay)	21.0	70.1	111
Pm/50% peat + T	(clay)	19.7	109.3	218
	(less-clay)	20.9	68.5	111
Hm/50% peat	(clay)	20.4	99.1	191
	(less-clay)	20.0	71.7	111
Hm/50% peat + T	(clay)	21.6	121.0	210
	(less-clay)	20.0	69.4	110

Pm = Pro-mix Hm = Haiti mix T = Terrasorb

Leucaena Survival

The analysis of variance showed that there were no significant survival differences among containers and mixes throughout the trial. This demonstrates that Leucaena is very drought tolerant, is very aggressive in establishing itself and thus it survives well in most any container and mix.

Leucaena Height

The analysis of variance showed that significant height differences were found among containers and mixes at outplanting. At six and ten months, significant height differences were found among containers and replications.

Container Influence on Leucaena Height

The Duncan's multiple range test showed that at outplanting, the height of the Leucaena seedlings was directly related to container volume, in that the containers with the greatest volume

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grew the biggest seedlings (Table 18). At six months, the Plantband grew seedlings that were significantly taller than seedlings grown in the other three containers. There was no significant height difference between the other three containers.

Table 18. Leucaena Height in Centimeters by Containers over Time

Containers	Months 0	6	10
Plantband	28.8 a	106.8 a	155.1 a
Winstrip	21.2 b	96.2 b	123.4 c
Sixes Rootrainer	19.7 c	98.3 b	144.2 a,b
Fives Rootrainer	14.5 d	95.8 b	137.6 b

At ten months Plantband was again taller than all other containers, however, it was not significantly taller than the Sixes Rootrainer. The Sixes Rootrainer was also not significantly taller than the Fives Rootrainer, and the Winstrip produced the shortest Leucaena trees. Moisture availability was the major limiting factor on height growth in this trial. About three weeks after the seedlings were outplanted, the rains diminished and during the following four months, 41 mm of rain fell (12 mm were in amounts too small to be effective for tree growth). In short, the seedlings were severely water stressed during the latter three months of that period. Because the Plantband did not decompose, the lateral roots were forced out the bottom of the container and established themselves at this depth, where moisture availability was greater than at shallower depths. Lateral root egress was not inhibited in the other three containers, thus many of their lateral roots were established at shallower depths. Later, during the drought, the seedlings which had established many of their roots at the shallow depths were more severely water stressed than those seedlings which had established their roots at greater depths. Therefore, this is probably why the Plantband had the best height growth.

Azadirachta Survival

The analysis of variance showed that significant survival differences were found among containers at months one through nine. There were no significant survival difference among containers at ten months.

Container Influence on Azadirachta Survival

The Duncan's multiple range test showed that, in general, Azadirachta survival throughout the trial was significantly better in the Plantband than any of the other containers, except for the Sixes Rootrainer at one, two, five and ten months (Table 19). Significant survival differences were not found between the other containers except at one and two months.

Azadirachta Height

The analysis of variance showed that significant height differences were found among containers and mixes at outplanting. Mixes were not significant at six and ten months, though significance was found among containers and replications.

Table 19. Azadirachta Survival in Percent by Containers over Time

Months	Containers: Plantband	Winstrip	Sixes	Fives
1	98.9 a	95.4 b	98.2 a	97.7 a,b
2	98.9 a	95.4 b	97.9 a,b	96.9 b,c
3	98.9 a	95.0 b	96.1 b	95.9 b
4	98.9 a	95.0 b	96.1 b	95.9 b
5	93.9 a	80.7 a,b	83.1 a,b	79.9 b
6	93.1 a	80.3 b	82.4 b	78.4 b
7	93.1 a	79.7 b	82.4 b	77.7 b
8	93.1 a	79.9 b	82.4 b	77.7 b
9	93.1 a	79.9 b	81.4 b	77.0 b
10	73.5 a	61.7 b	65.7 a,b	56.6 b

Container Influence on Azadirachta Height

The Duncan's multiple range test showed that at outplanting the greatest container volume grew the biggest seedling, with the exception of the Plantband, which grew a significantly smaller seedling than the Winstrip and the Sixes Rootrainer (Table 20).

Poor Azadirachta height growth in the Plantbands at outplanting was due to frequent rains, overwatering and the container's ability to hold water. At six and ten months, the Sixes Rootrainer had the best height growth, though it was not significantly different from the Winstrip and the Plantband. The Fives Rootrainer had the least height growth, though it was not significantly different from the Winstrip at six months and the Winstrip and the Plantband at ten months.

Table 20. Azadirachta Height in Centimeters by Containers over Time

Containers	Months 0	6	10
Plantband	12.4 b	37.7 a	60.2 a,b
Winstrip	14.2 a	35.7 a,b	61.1 a,b
Sixes	14.0 a	39.1 a	66.8 a
Fives	11.0 c	31.4 b	52.8 b

Mix Influence on Azadirachta Height

There was no mix influence on Azadirachta height at six and ten months. The Duncan's multiple range test showed that at outplanting both Pro-mix based mixes grew significantly taller Azadirachta seedlings than both Haiti mix based mixes. In addition, Haiti mix with terrasorb grew a significantly taller seedling than Haiti mix without terrasorb at outplanting.

Prosopis Survival

The analysis of variance showed that significant survival differences were found among containers only, at months five through ten.

Container Influence on Prosopis Survival

The Duncan's multiple range test showed that from month five to ten, the Plantband had significantly better survival than the Fives Rootrainer (Table 21). Throughout this same period, the Sixes Rootrainer and the Winstrip were not significantly different than either the Plantband or the Fives Rootrainer.

Prosopis Height

The analysis of variance showed that significant height differences were found among containers, mixes and replications at outplanting and at ten months. Significant height differences were found among containers and replications at six months.

Table 21. Prosopis Survival in Percent by Containers over Time

Months	Containers: Plantband	Winstrip	Sixes	Fives
1	100.0 a	99.6 a	99.6 a	99.5 a
2	100.0 a	99.6 a	99.6 a	99.2 a
3	100.0 a	99.6 a	99.6 a	99.2 a
4	100.0 a	99.6 a	99.6 a	99.2 a
5	99.6 a	96.4 a,b	98.9 a,b	95.8 b
6	99.6 a	96.4 a,b	98.5 a,b	95.4 b
7	99.6 a	96.4 a,b	98.5 a,b	95.0 b
8	99.6 a	96.4 a,b	98.5 a,b	95.0 b
9	99.6 a	96.4 a,b	98.1 a,b	95.0 b
10	99.2 a	96.4 a,b	98.1 a,b	94.6 b

Container Influence on Prosopis Height

The Duncan's multiple range test showed that there were significant height difference between all containers and once again, the greater the container volume, the taller the seedlings were (Table 22). At six months the Plantband was significantly taller than the other three containers which were not significantly different from each other. At ten months the Plantband still had the best height growth, but was not significantly different from the Fives Rootrainer. The good performance of Prosopis in the Plantband was probably attributable to the lateral roots being forced out the bottom of the container and establishing themselves at greater depths where moisture was more readily available. Remember that the drought (i.e. lack of adequate moisture) was the major limiting factor to early height growth.

Table 22. Prosopis Height in Centimeters by Containers over Time

Containers	Months: 0	6	10
Plantband	33.9 a	77.8 a	125.2 a
Winstrip	29.4 b	70.3 b	113.6 b
Sixes	27.6 c	68.2 b	111.4 b
Fives	20.6 d	69.1 b	118.7 a,b

Mix Influence on Prosopis Height

The Duncan's multiple range test showed that Haiti mix produced significantly taller seedlings at outplanting than Haiti mix with Terrasorb and Pro-mix (Table 23). Haiti mix with Terrasorb was not significantly different than Pro-mix with Terrasorb. There were no significant height differences between mixes at six months, and at ten months the Pro-mix based mixes were significantly taller than the Haiti mix based mixes. The height differences between the two mixes at ten months most likely was a result of microsite differences and not to a result of mix.

Table 23. Prosopis Height in Centimeters by Mix Over Time

Mix	Months 0	6	10
Pm	27.4 c	73.0 a	120.2 a
Pm/T	28.2 a,b	72.3 a	125.4 a
Hm	28.5 a	70.1 a	113.5 b
Hm/T	27.8 b,c	69.5 a	110.4 b

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

These conclusions and recommendations are made for the containers and mixes tested in this trial only and the results should not be inferred to other containers and mixes, even if there are similarities between them. In addition, the seedling survival and height growth, and thus the results, were directly influenced by the nursery management techniques. The objective of the seedling production phase of the trial was to produce well hardened seedlings which had 1.5 to 2.5 shoot/root ratio based on height.

Conclusions

Ganthier

Leucaena survival is not significantly influenced by containers or mixes, though its survival would possibly be influenced by smaller containers and poorer quality mixes than those used in the trial.

Leucaena height is significantly influenced by containers and mixes. In general, Leucaena seedlings grown in the two rootrainers grew significantly taller Leucaena seedlings than other containers after outplanting. Pro-mix grew a significantly taller seedling at outplanting than Haiti mix for all species tested including Leucaena. For Leucaena at six and ten months however, Haiti mix grew significantly taller Leucaena seedlings.

Containers do have a significant influence on the survival of Prosopis. It appears that containers with greater volume yield better survival. Prosopis height is influenced by containers and mixes, such that, the containers with greater volume have better survival and pro-mix consistently grows Prosopis that is significantly taller than Haiti mix.

The survival of Parkinsonia is not significantly influenced by containers and mixes, but Parkinsonia height is. However, the height differences by container for this species are very small and it appears that the Winstrip, Hillson and Fives rootrainers produce the best height growth after outplanting. Like Prosopis, Parkinsonia grows consistently better in pro-mix than in Haiti mix.

The survival of Azadirachta is significantly influenced by containers. Again, the containers with the greater volumes produce the best survival. The plantband and the Hillson rootrainer produce the best survival for this species.

Azadirachta height is significantly influenced by containers and mixes. Height differences by container were very small, especially after considering the Todd planter was randomly placed on good microsites. No specific container can be identified as producing the best height for this species. At outplanting, Pro-mix grows a significantly taller Azadirachta seedling than Haiti mix. After outplanting however, mix does not influence Azadirachta height.

In summary, the best combination of survival and height growth by containers for all species is the plantband, closely followed by the Hillson rootrainer. These containers had the greatest container volumes. The fives rootrainer and the Todd planter had the poorest survival/height growth combination. These containers had the smallest container volumes. Thus, container volume is directly related to seedling survival.

Bon Repos (Nadal plantation)

The survival rates of Leucaena and Prosopis were exceptionally high considering that there was an acute lack of rainfall for four months shortly after the trial was planted. In general, survival by container was a function of container volume in that the greater the container volume, the better the survival.

Leucaena is a very fast growing species, especially during the first year. But, because the species experienced 47% dieback during the second dry season, this clearly shows that this species is not adapted to the low rainfall and the high evapotranspiration potential of this site.

Azadirachta is a slow grower during the first six to eight months and without proper maintenance, it is easily smothered by weeds. This species must be weeded at least twice during the first year.

Prosopis is a moderately fast growing species and is extremely well adapted to the semi-arid conditions of the site. Given the continued dieback of Leucaena, this species should easily outproduce Leucaena in height and biomass within the year.

The plantband produced the best height growth for Leucaena and Prosopis, but in the wetter clay area, it had the poorest height growth. This shows that if moisture is available, containers which allow rapid lateral root egress will most likely produce the best height growth.

Mix influence on survival and height growth is not significant after outplanting. This may not be true however, if the mix is of extremely poor quality. Pro-mix produced taller Azadirachta and Leucaena seedlings than Haiti mix and for Prosopis, the opposite was true. In addition, Terrasorb did not appear to influence survival or height.

In summary, the plantband, which had the greatest container volume, had the best survival/height growth combination by containers for all species. The sixes rootrainer was second and performed slightly better than the winstrip, though it has a slightly smaller container volume. The fives rootrainer, which was the smallest container by volume, again had the poorest survival/height growth combination.

Recommendations

1. A reliable source of inoculant should be located and any tree planted within the AOP should be required to use inoculant, especially for Leucaena and Prosopis.

2. Larger rootrainers should be used in the AOP because they continually exhibited better survival than the fives rootrainer.

3. Leucaena should be grown in Rootrainers, preferably the Sixes and a mix which contains some native soil or inoculant.

4. Prosopis should be the preferred species in low rainfall areas (< 1000 mm), because of its hardiness and good growth performance. It is well known that farmers do not like to plant Prosopis, but after three years in the Ganthier trial, the local people are cutting some of the trees for construction materials.

5. Prosopis should be grown in the Plantband, Winstrip or Sixes Rootrainer as these containers appear to give the best survival and height growth.

6. Prosopis should be grown in Pro-mix as this appears to give the best early height growth after outplanting.

7. Parkinsonia should not be planted in the AOP because Prosopis has better growth performance for the same environmental conditions and is more widely accepted.

8. Azadirachta should not be planted in the Fives Rootrainer, as this gives low survival. The Plantband and the Sixes Rootrainer appear to be the best containers for this species.

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AN EVALUATION OF CURRENT AGROFORESTRY OUTREACH PROJECT, FOOD AND AGRICULTURE ORGANIZATION, AND WORLD BANK SPECIES TRIALS IN HAITI

By

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EXECUTIVE SUMMARY

The primary objective of the Agroforestry Outreach Project (AOP) is to motivate Haitian peasants to plant and maintain trees. Essential to the success of the project and the reforestation effort in Haiti is the selection of appropriate tree species, which are adapted to the various environmental conditions in Haiti. Appropriate selection will insure that with proper weeding and protection, the trees will exhibit maximum growth and survival, thus motivating Haitian peasants to plant and maintain the trees. This report, however, does not discuss wood preferences or properties, both of which are factors that farmers consider, but does address the field performance of project trees under varying ecological conditions.

The process for selecting appropriate species is made through the use of species trials. This report is based on the measurement of 36 species trials (21 AOP, nine FAO and six World Bank) throughout Haiti. The trials are classified according to the Holdridge Biological and the Buffum/Campbell zones. Species trials, when properly established and maintained, allow reliable growth and survival comparisons between species. Despite the lack of uniform establishment and maintenance procedures, thus complicating the interpretation of the data, these trials revealed that the initial five tree species selected for the project namely *Azadirachta indica, Cassia siamea, Casuarina equisetifolia, Eucalyptus camaldulensis* and *Leucaena leucocephala* are good performers. Leucaena was the best performer in every lowland trial where it was present. Other species that are highly recommended for use in the AOP are *Acacia auriculiformis, Calliandra calothyrsus, Eucalyptus tereticornis* (11034), *E. camaldulensis* (10939), *E. microtheca* (10321) and *Leucaena diversifolia*. Provenance testing for many of these species is also recommended.

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CHAPTER 1

INTRODUCTION

The USAID/Haiti funded Agroforestry Outreach Project (AOP) has been very successful in revitalizing the reforestation effort in Haiti, showing that, in fact, peasants do want trees. The primary purpose of the project is to motivate Haitian peasants to plant and maintain substantial numbers of trees over the life of the project (USAID, 1984). The trees, which can serve as a viable cash crop, provide short-term economic returns to the peasants. Essential to this is the use of fast growing tropical hardwood species which have been properly selected for the various environmental conditions in Haiti (Murray, 1981) . Initially, the species selected for the project were *Leucaena leucocephala*, *Azadirachta indica*, *Cassia siamea*, *Eucalyptus camaldulensis* and *Casuarina equisetifolia* (USAID, 1981). These species were selected because of their past performance in Haiti and in other forestry projects around the world.

The purpose of this report is to summarize available data for survival and growth rate by ecological zone from existing species trials established by FAO, World Bank, AOP grantees and the University of Maine. Secondly, to use this information to make conclusions and recommendations about the current species selection in Haiti and in making recommendations for the establishment of new species trials and the selection of new species for use in Haiti.

In November 1984, a master list of established species trials was produced by Thomas Greathouse, Senior Forestry Advisor, so that project personnel would be made aware of current species selection and performance and to eliminate repetitive species trial research. The list contained 39 species trials including the World Bank trial in Cabaret (formerly Duvalierville) and the FAO trial in Furcy. Eleven trials were not measured under this contract because of severe mortality, animal damage, or damage from cutting. Four more trials in northwestern Haiti were not measured because of time constraints brought about by the political situation in Haiti. Therefore, this report summarized the remaining 21 AOP trials, and nine FAO and six World Bank trials.

CHAPTER 2

METHODS AND MATERIALS

The trials were measured over a period of 14 months from June, 1985 to August, 1986. All the trees were measured to the nearest ten centimeters using either a three meter fiberglass measuring rod or a thirteen meter extendible measuring rod.

At each trial, the diameter at breast height (1.3 m) was only measured if 50 percent of the trees in the plot containing a given species had an average d.b.h. of 24 millimeters or greater. Measurements in millimeters were taken with a fifty centimeter Haglof calipers. Survival was based on a 100 percent tally of each plot. The analysis of species height and survival was prepared by calculating the mean of each plot.

The FAO and World Bank species trial information was obtained from Elia Mora de Beliard (Forester/PFN) who measured the trials in 1985.

Trial results, conclusions and recommendations were reported according to the widely accepted Holdridge Biological Zones (HBZ) and the Haiti specific Buffum/Campbell (B/C) zones. The Buffum/Campbell system is an environmental classification system for Haiti based upon elevation, rainfall and parent soil type (Figure 1). According to this system (Table 1), Haiti has 63 B/C zones of which the largest 25 zones represent 91.5 percent of Haiti's land area (Ashley and Grosenick, 1986). Inferences were not made about species performance in B/C zones containing only one trial because of the small sample of trees representing that particular zone, however, these trials were incorporated into the summary performance tables (Tables 3 to 7).

Because many of the trials were established using inappropriate technical and statistical research methodologies, which are described on pages 6 to 8 of this report, and because of the high mortality (small sample sizes) for many of the trials, analysis of variance was not appropriate.

Table 1 The Buffum/Campbell Environmental Zones.

Parent Soil Group	Elevation	<400 m			400-800 m			>800 m		
	Rainfall (MAP)	<1000mm	1000-1500mm	>1500mm	<1000mm	1000-1500mm	>1500mm	<1000mm	1000-1500mm	>1500 mm
	Limestone 1 (1)	11	21	31	41	51	61	71	81	91
	Limestone 2 (2)	12	22	32	42	52	62	72	82	92
	Limestone 3 (3)	13	23	33	43	53	63	73	83	93
	Basalt (4)	14	24	34	44	54	64	74	84	94
	Andecites And Dacites (5)	15	25	35	45	55	65	75	85	95
	Quartz Diorites (6)	16	26	36	46	56	66	76	86	96
	Alluvium (7)	17	27	37	47	57	67	77	87	97

Source: Memo by Bill Buffum, Pan American Development Foundation, Port-au-Prince, Haiti. December 1984.

(Ashley and Grosenick, 1986)

Table 2. Area of the Buffum/Campbell Zones in Haiti and Species Trial Location Within Them.

B/C ZONE	No. of Species Trials In B/C Zone	% of Haiti	Rank Order
31		9.3	1
61		8.3	2
21	1	8.0	3
32	1	6.2	4
91	1	5.8	5
17	9	5.1	6
11	1	4.6	7
13		4.1	8
51	2	4.1	9
27	3	3.7	10
37	2	3.7	11
41		3.7	12
22	1	3.0	13
81	1	2.8	14
24	1	2.5	15
12	5	2.1	16
64		2.1	17
23	1	2.0	18
54		1.7	19
34	1	1.6	20
66		1.6	21
35	1	1.5	22
36		1.5	23
65		1.5	24
94	3	1.0	25
52	1	0.2	40
53	1	0.1	43

CHAPTER 3

RESULTS AND DISCUSSION

Experimental Design Error

The results and discussion will be based on a total of 36 trials (21 AOP, nine FAO and six World Bank). The difficulties in evaluating the data from these trials and in reaching meaningful conclusions are enormous; there are 36 trial sites in 16 Buffum/Campbell zones, and more than 130 species and provenances to be measured.

Furthermore, many of these trials were established without proper consideration of the appropriate technical and statistical research methodologies. This potentially introduced an unidentifiable and unquantifiable effect into the results of the trials. Therefore, whether or not neem grew better than Cassia at a particular site might be because it was a better tree for that site, or possibly because of one or more inappropriate research methodologies which were applied in the establishment of the trials. The following are examples of these inappropriate research methods:

1) Seedlings grown in different nurseries were planted in the same trial, producing a high variability among seedling and plug characteristics, such as the degree of root development, shoot/root ratio, degree of hardening-off, soil mix compaction, plug moisture and fertilizer content at outplanting, amount of plug disturbance, and amount of time in transit to the trial site. All of these factors influence the height growth and survival of any given species. Thus the greater the variability among seedling and plug characteristics at outplanting (ie. nursery production methods) the greater the chances will be to mask the growth and survival differences between species.

2) Seedlings in the same replication were planted on different days. A replication should represent uniform conditions, meaning it should be planted on the same day. Thus, planting the parts of a replication on separate days, allows the seedlings that were planted in more favorable weather conditions to perform better. In addition, the seedlings that were planted on the following day endured an added day of physical stress in the boxes.

3) Seedlings in different replications were planted weeks apart, though this is not as critical as seedlings within replications being planted on different days. Again, seedlings that are established during more favorable weather conditions will generally perform better.

4) Seedlings in different containers and mixes were planted in the same replication and trial. Significant height and survival differences have been found among containers and mixes (Dupuis, 1986) clearly demonstrating that significant height and survival differences between species using this methodology is not solely due to the species themselves.

5) Seedlings which were held over in the nursery for an extra season were planted with seedlings that were one season of age. The seedling characteristics will be different between these two groups, therefore, true height growth and survival differences between species will be masked.

6) More than one seedling per plug were planted in several trials. This will affect the height growth and survival of the seedlings. In addition, it leaves one with the decision of which seedlings to measure.

Therefore, considering all of the the different variables influencing species performance, a general overview of species performance by height and survival would be more appropriate and of greater value to project personnel than a comparison of species performance among individual trial sites. The latter has the potential to create misinterpretations because of unknown variables influencing species performance, especially since most of the trials lack detailed descriptions of trial establishment and maintenance procedures.

General Overview

In lowland trials younger than 36 months, *Leucaena leucocephala* registered the best overall performance for both height growth and survival. Leucaena performed the best in every lowland trial where it was present except for two ODH trials at Cazeau. In these two trials, Leucaena ranked fifth among 25 and third among 15 species. In upland trials such as Colin (800 m) and Mare Rouge (625 m), Leucaena was a good performer ranking sixth and eleventh among 35 and 25 species, respectively.

In all trials, Leucaena exhibited rapid height growth during the initial 18 month period after planting. This early rapid height growth allowed the plant to establish its canopy above that of the surrounding vegetation, especially during the rainy season. Weed competition was lessened due to its early rapid height growth, thus bettering its chances to survive.

Beyond this 18 to 24 month period, however, the growth rate of Leucaena declined, whereas for other species such as Eucalyptus, rapid height growth continued. On arid sites with dry seasons of six to seven months (Ganthier, 700 mm), Leucaena was prone to having the terminal leader or leaders die back during the dry season. This was not pest or disease related, but rather a drought avoidance mechanism in which the succulent new growth from the previous rainy season died because of the inability of the plant to support this new growth during the dry season. In some cases this dieback represented as much as 90% of the tree's total height. Arid land species such as neem and Prosopis seem unaffected in this manner by the dry season. Initially, these species exhibited slow top growth, but after ten to fifteen months, their height growth increased rapidly.

Eucalyptus camaldulensis, *Cassia siamea*, *Azadirachta indica* and *Acacia auriculiformis* were good performers throughout the trials. In general, Eucalyptus had better height growth and form than the other species; on wetter sites its height growth and survival were excellent. In an 8.5 year FAO trial (B/C zone 34; HBZ:subtropical moist forest), *E. camaldulensis* provenance number (10666), though not the tallest tree had the greatest wood volume per tree with approximately 0.285 m^3. It outproduced all other Eucalyptus species by 400 percent.

Other species/provenances of Eucalyptus which performed well were:

	Survival (%)	Volume (m^3/tree)
E. stricklandii (9927)	62.9	0.067
E. tereticornis (10975)	62.9	0.058
E. camaldulensis (10930)	81.4	0.056
E. camaldulensis (10266)	88.8	0.045
E. tereticornis (10914)	70.3	0.043
E. tereticornis (11034)	88.8	0.043

It is important to note that *E. tereticornis* (11034) was the best performer in B/C zone 17, subtropical dry forest, and a very good performer in B/C zone 94, lower montane wet forest. This is due to the 32 degree latitudinal range of this species, which is the greatest North-South range of any Eucalyptus (NAS, 1984).

Eucalyptus also performed well on upland sites, at greater than 400 m. On drier sites (Passe Catabois, 900mm and Ganthier, 700mm) its height and survival performance was overshadowed by Cassia and neem (Tables A32 and A15, respectively). In Passe Catabois, *Acacia auriculiformis* was not significantly taller than Eucalyptus, but its survival and biomass production were much better. Cassia and neem also had good form, though with more branching than Eucalyptus. *Albizia lebbek* was also a good performer, though not to the extent of Cassia.

Indigenous and naturalized species are becoming an integral part of the outplanted trees in the AOP. In general, indigenous and naturalized species have equivalent survival, but generally slower height growth than the exotic species. There is no doubt that the farmers have been asking for indigenous and naturalized species because they are familiar with them, and desire their products. Furthermore, because many of the exotics do not get the proper and timely weeding that they require, they do not perform well and thus lead farmers to request indigenous species which they feel may grow faster and be more useful than the trees AOP proposed.

Indigenous and naturalized species that have performed well in the species trials thus far are *Colubrina arborescens*, *Haematoxylon campechianum*, *Catalpa longissima*, *Simaruba glauca* and *Swietenia macrophylla*.

B/C zone 12 (Subtropical dry forest)

Buffum/Campbell Zone 12 which contains five species trials covers approximately 2.1% of Haiti. This zone is characterized by an altitude of 0 to 400 meters, rainfall of 500 to 1000mm per year, and limestone soils with sandstone and clay impurities. It also has two 1 to 3 month rainy seasons and at least seven months of dry season yearly.

Very Good to Excellent Performers

The following is a list of species which performed very well in B/C zone 12. The species listed are in descending order of performance:

Leucaena leucocephala

Cassia siamea

Azadirachta indica

Eucalyptus camaldulensis (provenance unknown)

Moringa oleifera

Leucaena leucocephala outperformed every species in both height and survival in this B/C zone. Overall, survival was seventy-four percent. At Cabaret (Table A3), K-8 had greater height growth than K-28 and K-67.

Azadirachta indica and *Cassia siamea* performed as equals in this zone, though *Azadirachta* performed better where rainfall was less than 800 mm. Conversely, where rainfall was greater than 800 mm, Cassia performed better, and both tree forms were straight.

It is recommended that on sites where neem is big enough, a neem coppice study should be conducted to investigate the production of harvestable wood biomass as compared to that of an uncut stand.

Generally, *E. camaldulensis* (provenance unknown), had less rapid growth and slightly lower survival than neem and Cassia. Again, the selection of the appropriate provenance is very important for successful reforestation with this species.

Moringa oleifera outperformed every species at the Cabaret site except Leucaena. Unfortunately, the wood quality is poor and the tree serves as a good nesting place for termites. The leaves, which are sold in vegetable markets throughout Southeast Asia are nutritious and extremely high in calcium and other essential minerals. The national health program in the Philippines is currently emphasizing the planting of this species in household gardens.

Good Performers

Good performers in this zone include *Acacia auriculiformis, Bursera simaruba, Eucalyptus microtheca, Eucalyptus stricklandii, Eucalyptus tereticornis, Gliricidia sepium, Haematoxylum campechianum,* and *Tecoma stans* (chevalye). *Casuarina equisetifolia, Eucalyptus camaldulensis* are potential species for this zone, though their survival was quite low, as well as *Parkinsonia aculeata* which is disliked by farmers.

Poor Performers

Indigenous species such as *Albizia lebbek* (naturalized), *Cassia emarginata, Catalpa longissima, Colubrina arborescens, Guazuma ulmifolia, Lysiloma latisiliqua, Simaruba glauca, Swietenia macrophylla* (naturalized) and *Swietenia mahogani* will grow in this zone, but there are many other species to select from that are more productive. In addition, these trees do not provide peasants with short-term economic returns. The following species performed poorly in two or more species trials in B/C zone 12. However, the author feels that both of the *Prosopis* species should be tested again in this B/C zone.

Albizia lebbek

Catalpa longissima

Colubrina arborescens

Prosopis alba

Prosopis juliflora

Uncertain Performers

The following species performed poorly in one species trial in this B/C zone. Because factors which contributed to its poor performance are not known, no definitive statement can be made about its performance in this B/C zone without further study. In this report, "uncertain performers" in all B/C zones are defined as such.

Cassia emarginata

Casuarina cunninghamiana

Casuarina glauca

Cordia alliodora

Eucalyptus citriodora

Guazuma ulmifolia

Hibiscus elatus

Lysiloma latisiliqua

Pinus caribaea var. hond.

Schaefferia stricklandii

Simaruba glauca

Swietenia macrophylla

Swietenia mahogani

Tectona grandis

B/C Zone 17 (Subtropical dry forest)

Buffum/Campbell zone 17 covers 5.1% of Haiti and contains nine species trials. This zone is characterized by an altitude of 0 to 400 meters, a yearly rainfall of 500 to 1000mm, which falls in two 1 to 3 month rainy seasons, at least seven months of dry season, and alluvial soils intermixed with layers of gravel, sand, and clay.

Very Good to Excellent Performers

The following is a list of species which performed very well in B/C zone 17. The species listed are in descending order of performance.

Leucaena leucocephala (K-8, K-28, K-67)
Azadirachta indica

Eucalyptus tereticornis (11034)

Eucalyptus microtheca (10321)

Eucalyptus camaldulensis (10939)

Casuarina equisetifolia (S. Africa)
Casuarina cunninghamiana (10879)

Leucaena leucocephala had rapid early growth, enabling it to compete well with the weeds and within the first two years, it outperformed all other species. At sites with less than 800 mm of rainfall, Leucaena growth was slow or stagnant after 1.5 to 3 years. During the dry season when the trees experienced water stress, the leaves folded and dropped; during the extended dry season (5 to 7 months), the trees died back. It is recommended, that at these sites Leucaena be cut every two to three years and the coppices managed so that wood biomass production will be maximized over several rotations. Unfortunately, risk of animal damage is greatly increased with this system because of the easily accessible fresh green coppice growth.

After 20 months in the Jean Rabel trial, K-8 had slightly better growth than K-28 and K-67. The question remaining, is which Leucaena provenances will perform the best, giving the specific desired wood products for a particular set of environmental conditions. For example, which Leucaena provenance will perform the best in a hedgerow where the emphasis is on leaf biomass production. It is strongly recommended, therefore, that:

1) A literature search be conducted on Leucaena provenances and their specific uses.

2) A letter* be written to Dr. James L. Brewbaker and Michael D. Benge requesting Leucaena provenance information. The environmental site conditions and the desired Leucaena usage for these Haitian sites should be included in the letter, in addition to a request for a list of quality Leucaena seed dealers.

3). Provenances of Leucaena seed in research quantities be ordered so that preliminary provenance testing of this species can begin immediately.

Normally, *Azadirachta indica* has slow height growth and excellent survival during the initial 8 to 16 month period after planting. During this period, neem develops its root system and therefore needs weeding so that the tree will not be stunted by the surrounding vegetation. Beyond this eight to sixteen month period, neem grew rapidly, both in height and dbh.

In the Vaudreuil trial in Ganthier, harvested this year, ten year old neem had the greatest dbh (17.4 cm) of any species. During the dry season this species maintained active growth; during the extended dry season the trees maintained their leaf cover and turgid condition. Although this species is very well suited to this zone, the genetic base of this species in Haiti is very limited. It is strongly recommended, therefore, that:

1) A letter be written to the International Neemtree Research and Development Programme in Paris, France, requesting the following:

-- neem provenance and seed dealer information

-- assistance in obtaining other neem seed sources for Haiti

-- neem seed viability research results or methods by which to extend the viability of neem seed

2) When a response is obtained, order new sources of neem seed and begin neem seed viability research or test the suggested method for extending the viability.

3) Begin a neem coppice study, especially in B/C zone 17 where wood is in short supply.

4) Have animator training programs stress the fact that neem grows slowly during the first year because it is developing its root system. Secondly, and more importantly, neem must be weeded throughout the first year if good growth is to follow in the second and third year.

* All letters should be written on USAID letterhead by the senior forestry advisor in cooperation with one member from each AOP grantee and a member of the AFORP team.

5) If Haiti obtains new seed sources of neem they should be tested in trials against the Haiti neem. If it is found that their performance is better than the Haiti neem, the trial should be protected and seed collected from these trees for AOP planting.

Eucalyptus tereticornis (11034) outperformed every Eucalyptus species in height growth, survival, dbh and volume in this B/C zone (Table A27). Its survival was 37% which was better than the other four provenances of the species in this trial. Eucalyptus species are very site specific, and therefore, a concerted effort must be made to match the specific provenance with the site conditions. This is illustrated in this trial, in which five provenances of *E. tereticornis* were planted. After nine years, the range of heights recorded were 13.0 m, 6.7 m, 5.0 m, 2.0 m and 0 m. Recommendations for this species are as follows:

1) Seed of *E. tereticornis* (11034) should be purchased and distributed to each grantee for outplanting as soon as possible. The nursery requirements of this species and the location of the outplantings by farmer should be recorded so that the AOP can actively assess the performance of this species under rural farm conditions.

2) Have animator training programs stress the fact that Eucalyptus **must** be thoroughly weeded throughout the first year if good growth is to follow in the second and third year.

Eucalyptus microtheca (10321) has potential on dry sites with alkaline clay or silty clay soils. Unfortunately, this species has considerable genetic variability thus requiring provenance trials before attempting to incorporate it into the AOP. CSIRO Division of Forest Research in Canberra has begun a provenance study of this species and information may be available from J.C. Doran (listed above).

Eucalyptus camaldulensis (10939) performed very well in a nine year old FAO trial in Ganthier (Table A27). It was outperformed by *E. tereticornis* (11034) and was equalled by *E. microtheca* (10321), which had significantly greater survival. *E. camaldulensis* had good form but generally had poor to fair survival (25 to 40%) Recommendations for this species are as follows:

1) More seed sources of this species are strongly recommended for provenance trials in all B/C zones.

2) A letter should be written to J.C. Doran, Division of Forest Research, CSIRO, requesting provenance information, especially for the Broken Hill (New South Wales) provenance which is recommended for arid climates. In addition, a request should be made for assistance in obtaining seed sources. The letter should include the environmental site conditions of Haiti.

Casuarina equisetifolia (S. Africa) performed very well in the ten year old Vaudreuil trial in Ganthier (Table A36). Volume per tree was almost 0.1 m^3 and the tree was always straight. Survival was between 25 to 50% which is about equal to the current survival of this species in AOP species trials. Growth of this species in the AOP has been rather disappointing, possibly due to the lack of *Frankia* and other mycorrhizal fungi which form symbiotic relationships with the Casuarina roots and allow it to fix nitrogen and more easily absorb minerals, especially phosphorus and some trace minerals. Another possible reason for its poor growth in the AOP is that the species does not compete well against weeds, especially grasses. Recommendations for this species follow.

1) Conduct a study of the effects of *Frankia* on *C. equisetifolia* and other *Casuarina* species.

2) A letter be written to C.J. Borough, Division of Forest Research, CSIRO and D.M. Griffin, Australian National University requesting the following:

-- provenance and seed dealer information about *C. equisetifolia*.

-- assistance in obtaining provenances of *C. equisetifolia* which have potential for good growth in Haiti.

3) If other provenances of *C. equisetifolia* are obtained, test them in trials against the *C. equisetifolia* (Haiti).

4) Have animator training programs stress the fact that Casuarina **must** be weeded throughout the first year if good growth is to follow in the second and third year.

Casuarina cunninghamiana (Australia) outperformed *C. equisetifolia* (Haiti) in height growth, survival and volume in a nine year old FAO trial in Ganthier (Table A28). This species should continue to be tested on dry alluvial sites, but has greater potential in areas with alluvial soils and higher rainfall.

Good Performers

Casuarina cristata (11176) did not always have a straight bole, but it performed as well as *C. equisetifolia* (Haiti) in wood volume production and had significantly better survival (Table A28). This species is suitable for this B/C zone and therefore further testing of this species is recommended, especially for dry alluvial sites. Other species that performed well were *Eucalyptus deglupta* (11214), *E. camaldulensis* (10666 and 10911), *E. cerbra* (8832) and *E. siderophloia*.

Indigenous species such as *Simaruba glauca*, *Swietenia macrophylla*, *Swietenia mahogani* and *Catalpa longissima* exhibited good survival in this B/C zone, but were out produced two to tenfold in volume by the previously mentioned exotic species.

Poor performers

The following species performed poorly in two or more species trials in B/C zone 17.

Catalpa longissima	*Simaruba glauca*
Colubrina arborescens	*Swietenia macrophylla*
Sesbania grandiflora	*Swietenia mahogani*

Uncertain Performers

The following species performed poorly in one species trial and therefore, no definitive statement can be made about their performance in this B/C zone without further study. Because *Eucalyptus* species are very site specific, the provenance of the species will be listed, thus designating the provenance an uncertain performer and not the species. The author feels that *Acacia nilotica* should again be tested in this B/C zone because it is very well adapted to the environmental conditions of this zone.

Acacia aneura	*Eucalyptus gomphocephala* (Middle Orient)
Acacia farnesiana	*Eucalyptus leucoxylon* (9602)
Acacia nilotica	*Eucalyptus leucoxylon* (9607)
Acacia pychantha	*Eucalyptus occidentalis* (7382)
Acacia tchad	*Eucalyptus oleosa* (9910)
Acacia tortilis	*Eucalyptus paniculata* (10719)
Ailanthus altissima	*Eucalyptus paniculata* (11741)
Albizia lebbek	*Eucalyptus pimpiniana* (9404)
Calliandra calothyrsus	*Eucalyptus salmonophloia* (9919)
Casuarina fauca	*Eucalyptus stricklandii* (9927)
Casuarina glauca (8645)	*Eucalyptus tereticornis* (10826)
Casuarina stricta (8112)	*Eucalyptus tereticornis* (10914)
Cedrela odorata (Haiti)	*Eucalyptus tereticornis* (10954)

Cercidium praecox	*Eucalyptus tereticornis* (10975)
Eleagnus angustifolia	*Eucalyptus torguata* (9930)
Eucalyptus astrinlens (10879)	*Eucalyptus transcontinentalis* (9932)
Eucalyptus brockwayi (10104)	*Hibiscus elatus* (Vaudreuil)
Eucalyptus dumosa (0526)	*Parkinsonia aculeata*
Eucalyptus dundasii (6831)	*Prosopis alba* (0388)
Eucalyptus exerta (11028)	*Prosopis velutina* (0450 and 0457)
Eucalyptus flocktoniae (7981)	*Schaefferia frutescens*
Eucalyptus gomphocephala (9805)	*Sesbania formosa*
Eucalyptus gomphocephala (9876)	*Tectona grandis*

B/C Zone 27 (Subtropical moist forest)

This Buffum/Campbell zone covers 3.7% of Haiti, and contained three species trials at Cazeau. This zone is characterized by an altitude of 0 to 400m, a yearly rainfall of 1000 to 1500mm, which falls in two 2 to 3 month rainy seasons, at least five months of dry season per year, and alluvial soils intermixed with layers of gravel, sand, and clay.

Very Good to Excellent Performers

The following is a list of species which performed very well in B/C zone 27. The species are listed in descending order of performance.

Eucalyptus camaldulensis (12542)	*Cassia siamea*
Eucalyptus camaldulensis (12964)	*Acacia auriculiformis*
Sesbania grandiflora	*Leucaena leucocephala (K-8)*
Eucalyptus stricklandii	*Gliricidia sepium*
Eucalyptus camaldulensis (1403)	

Eucalyptus camaldulensis (12542 and 12964) out performed all other species in height growth except for *Sesbania grandiflora* which equalled its height growth (Table A5 and A6). All three species/provenances had excellent survival at 93 percent. Although both species/provenances had straight form, the wood quality of Sesbania is greatly inferior to that of Eucalyptus. In another trial (Table A7), *E. stricklandii* and *E. camaldulensis* (1403) performed better than any other species.

Cassia siamea, Acacia auriculiformis, Leucaena leucocephala (K-8) and *Gliricidia sepium* exhibited better than six meters of height growth and 80% survival. Cassia had straight form, while the other species had multiple stems. Crown closure for these species in this 2.5 m x 5.0 m spacing was 95, 85, 75, and 60% for Leucaena, Cassia, Acacia, and Gliricidia, respectively.

Good Performers

Acacia nilotica, Albizia lebbek, Azadirachta indica, Catalpa longissima, Conocarpus erectus, Eucalyptus camaldulensis (1202 and 12186), *Eucalyptus microtheca (10321), Pithecellobium dulce* and *Prosopis juliflora* were good performers in this zone. The first and latter two species are disliked by farmers because they have thorns. Acacia, Albizia, Azadirachta, Catalpa, Conocarpus, Eucalyptus species/provenances Pithecellobium, and Prosopis had crown closures of 35, 75, 60, 30, 35, 40, 100, and 95, respectively.

Poor Performers

Tamarindus indica was the only species which performed poorly in two or more species trials in this B/C zone.

Uncertain Performers

The following species/provenances performed poorly in one species trial and therefore, no definitive statement can be made about their performance in B/C zone 27 without further study. The starred species should be selected for further testing in this B/C zone. In addition, the Eucalyptus species which do not specify the provenance should be tested again because it is the provenance that is site specific.

Eucalyptus tereticornis (13469)	*Swietenia macrophylla* *
Eucalyptus dumosa *	*Swietenia mahogani* *
Eucalyptus tereticornis (1160)	*Shinus roble*
Eucalyptus citriodora *	*Tamarindus indica*
Eucalyptus robusta (12972)	*Calophyllum brasiliense*
Eucalyptus saligna *	*Ficus benjamina*
Eucalyptus occidentalis *	*Melicoccus bijugatus*
Eucalyptus brassiana *	*Parkinsonia aculeata*
Eucalyptus alba *	*Casuarina equisetifolia (1439)*

Acacia nilotica (erect)

Delonix regia

Acacia farnesiana

Pinus brutia

Pinus occidentalis

Casuarina equisetifolia (13136)

Cedela odorata

Casuarina cunninghamiana (1433)

Acacia confusa

Pinus caribaea var. hond.

Haematoxylum campechianum *

Cassia emarginata

Guazuma ulmifolia (1362)

Casuarina glauca (13142)

Casuarina glauca (Septropa)

Casuarina equisetifolia *

B/C Zone 37 (Subtropical moist forest)

Two species trials are contained within B/C zone 37, which covers about 3.7% of Haiti. This zone is characterized by an altitude of 0 to 400m, a yearly rainfall of greater than 1500mm, which falls in one 7 to 8 month rainy season, at least three to four months of dry season per year and alluvial soils intermixed with layers of gravel, sand, and clay.

Very Good to Excellent Performers

In general, *Leucaena leucocephala, Cassia siamea*, and *Acacia auriculiformis* had better than 8.5m of height growth in less than 2.5 years. Survival was 98, 90, and 45% for Leucaena, Cassia, and Acacia, respectively (Tables A25 and A26). Cassia had straight form, while the other two species had multiple stems.

Good Performers

Albizia lebbek and *Azadirachta indica* averaged about 6.0m in height and 73% survival in 2.5 years. Azadirachta had straight form, while Albizia had a somewhat straight form until a height of about 2 to 3m at which point the tree forked profusely.

Poor Performers

Casuarina equisetifolia had an average height of 4.0m and 30% survival after 3.25 years. The author feels that this species has the potential to be a very good performer in this B/C zone and attributes its bad performance to a lack of *Frankia* and weeding.

Uncertain Performers

Cassia emarginata and *Parkinsonia aculeata* were eliminated in these two trials.

B/C Zone 51 (Subtropical moist forest)

This B/C zone covers 4.1% of Haiti and contained two upland species trials in Colin L'Estère in northwestern Haiti. This zone is characterized by an altitude of 400 to 800m, a yearly rainfall of 1000 to 1500mm which falls in two 2 to 4 month rainy seasons, at least four months of dry season per year, and limestone soils consisting of clays intermixed with schist flecks and having a pH of about 7.5 to 8.0.

Very Good to Excellent Performers

The older of the two trials (26 months) found *Leucaena leucocephala* (ODH/Haiti) outperforming all other species in both height growth and survival (Table A8). This is quite unusual for *L. leucocephala* as this trial is located at 600 m to 700 m and it usually does not perform well above 400m.

In the nine month old trial, *L. diversifolia* (CATIE 1806) had the best height growth for all species at 1.44 meters (Table 9A). *Calliandra calothyrsus* (CATIE 1707 and 1522), *Eucalyptus camaldulensis* (CSIRO 13801), *Casuarina cunninghamiana* (CSIRO 13512 and 13515), *Casuarina glauca* (CSIRO 13987), *Leucaena leucocephala* (ODH/Haiti) and *Leucaena diversifolia* (CATIE 1624) all had heights of approximately one meter and 100% survival. The selection of the appropriate *L. diversifolia* provenances may be important, because there was a 50% height difference between the two *L. diversifolia* provenances tested in the trial. It is strongly recommended that:

1) A letter be written to Dr. Rodolfo Salazar, CATIE, requesting the following:

-- provenance and seed dealer information about *L. diversifolia*.

-- assistance in obtaining provenances of *L. diversifolia* which have potential for good growth performance in Haiti.

2) When seed is obtained, produce seedlings and outplant them against *L. leucocephala* and the upland Casuarina species in several, easily accessible, small upland trials. Nursery management techniques should be recorded for these species.

Good Performers

The following is a list of species that performed well in B/C zone 51. The species listed are not in descending order of performance.

Casuarina equisetifolia (ODH/Haiti)
Casuarina obesa (CSIRO 14100)
Eucalyptus citriodora (CSIRO 13628)
Eucalyptus gomphocephala (CSIRO 12307)

Colubrina arborescens "kapab"
(NW Haiti)
Colubrina arborescens "bwa ple"
(Haiti)
Catalpa longissima
(Haiti)
Eucalyptus largiflorens
(CSIRO 12156)
Eucalyptus camaldulensis
(Petford)

Poor Performers

Cassia siamea (ODH/Haiti) and *Azadirachta indica* (Petit Goave, Haiti) performed poorly in B/C zone 51.

Uncertain Performers

The following species performed poorly in one species trial and therefore, no definitive statement can be made about their performance in this B/C zone without further study.

Melia azadirachta
(Baie de Henne, Haiti)
Casuarina lechmanmii
(CSIRO 13880)
Gliricidia sepium
(Esparzas, Costa Rica)
Gliricidia sepium
(CATIE 1360)
Guazuma ulmifolia
(Bombardopolis, Haiti)
Caesalpinia velutina
(CATIE 1521)
Eucalyptus exerta
(CSIRO 13818)
Eucalyptus leucophloia
(CSIRO 12357)
Eucalyptus sideroxylon
(CSIRO 13468)
Eucalyptus whitei
(CSIRO 13586)
Eucalyptus cambageana
(CSIRO 12937)
Eucalyptus melanophloia
(CSIRO 13588)
Eucalyptus argillacea
(CSIRO 13942)
Eucalyptus populnea
(CSIRO 8658)
Eucalyptus cladocalyx
(CSIRO 11834)
Eucalyptus ochropholoia
(CSIRO 12507)

B/C Zone 94

This Buffum/Campbell zone covers 1.0% of Haiti and is characterized by an altitude of greater than 800m, a yearly rainfall of greater than 1500mm which falls in one continuous 6 to 8 month rainy season, at least three to four months of dry season per year and soils that are derived from basalt parent material. This zone contained 3 nine year old FAO species trials which tested mainly Eucalyptus species/provenances and Casuarina species. All three trials were located in Furcy and in general, the Eucalyptus species/provenances outperformed the Casuarina species.

Very Good to Excellent Performers

The following is a list of species which performed very well in B/C zone 94. The species listed are in descending order of performance.

Eucalyptus grandis (11204) *Eucalyptus robusta* (11029)

Eucalyptus saligna (11796) *Eucalyptus punctata* (10863)

Eucalyptus cypellocarpa (9135) *Eucalyptus botryoides* (7509)

Eucalyptus tereticornis (11034)

Eucalyptus grandis (11204) outperformed its nearest competitor two to one in volume production and 5.2 m in height growth. Volume production per tree was 0.6 m^3 and survival was 44.4% (Table A14).

Eucalyptus saligna (11796) outperformed all other species and provenances except *E. grandis*. Its volume production was 0.3 m^3 and its survival was 51.8% which was the second best survival out of 27 Eucalyptus species/provenances in the trial.

Other species that performed very well, meaning a volume production per tree of greater than 0.2 m^3 and a survival rate of greater than 30 percent were:

	Volume (m^3/tree)	Survival (%)
Eucalyptus botryoides (7509)	0.259	33.3
Eucalyptus tereticornis (11034)	0.253	44.4
Eucalyptus robusta (11029)	0.249	37.0
Eucalyptus cypellocarpa (9135)	0.245	66.6
Eucalyptus punctata (10863)	0.216	40.7

It is important to note that *E. tereticornis* (11034) was an excellent performer in B/C zone 17 (HBZ: subtropical dry forest) and in Limbe (B/C zone 34, HBZ:subtropical moist forest).

Good Performers

The following is a list of species which performed well in B/C zone 94. The species listed are in descending order of performance.

Eucalyptus punctata (10617) *Eucalyptus globulus* (Haiti)

Eucalyptus robusta (11019) *Eucalyptus paniculata* (10741)

Eucalyptus tereticornis (10914) *Eucalyptus camaldulensis* (10911)

Eucalyptus paniculata (10719) *Eucalyptus camaldulensis* (10266)

Eucalyptus tereticornis (10975) *Eucalyptus tereticornis* (10954)

Eucalyptus diversicolor (11760) *Eucalyptus propinqua* (11833)

Casuarina glauca (Australia 8645)

Poor Performers

There were no species that performed poorly in more than one trial in this B/C zone.

Uncertain Performers

The following species performed poorly in one species trial and therefore, no definitive statement can be made about their performance in B/C zone 94.

Eucalyptus cladocalyx (11180)	*Casuarina glauca* (8645)
Eucalyptus camaldulensis (10930)	*Casuarina equisetifolia* (Inoia)
Eucalyptus siderophloia (Versepuy)	*Casuarina cunninghamiana* (10879)
Eucalyptus camaldulensis (10666)	*Casuarina cristata* (11176)
Eucalyptus viminalis (10993)	*Casuarina stricta* (8112)
Eucalyptus tereticornis (10826)	*Cupressus lusitanica* (Italy)
Eucalyptus microtheca (10321)	*Araucaria cunninghamiana* (Australia)
Eucalyptus occidentalis (7382)	*Pinus halepinsis* (Tunisia)

The Casuarina species tested in this high altitude trial (Table A13) were not high altitude species, and therefore did not perform well. It is important to mention that *Casuarina equisetifolia* and *Casuarina glauca* are not true high altitude tree species, though they are both performing well at 880m in a trial in Puilboreau (Table A35).

There are several Casuarina species for the uplands and especially high altitudes which appear to be promising. *C. junghuhniana* has a natural distribution up to 3000m and competes well against weeds but is a tropical species and may not be able to survive in the subtropical mountain climate of Haiti.

C. oligodon is found up to 2500m and also competes well against weeds. Unfortunately, it is also a tropical species and may not be able to survive in the subtropical mountain climate of Haiti.

C. littoralis is found up to 1200m and grows in areas with 650-1250 mm of rainfall, preferring well drained sites. In a trial at Puilboreau (Table A35), this species did poorly, but the species merits more testing.

Recommendations for this species are as follows:

1) A letter should be written to Syafii Manan, Bogor Agricultural University requesting the following:

-- provenance information about *C. junghuhniana*.

-- assistance in obtaining provenances of *C. junghuhniana* which have potential for good growth performance in Haiti.

2) A letter should be written to:

-- A. Allison, Wau Ecology Institute

-- A. Byron, Environmental Science Council

-- the chief research officer, Office of Forests, Boroko Papua New Guinea

-- K. Thiagalingam, University of Papua New Guinea

requesting the following:

-- provenance information about *C. oligodon*.

-- assistance in obtaining provenances of *C. oligodon* which have potential for good growth performance in Haiti.

3) A letter should be written to:

-- M. Alexandra, Forester, Australian Seed Co.

-- D.J. Boland, Division of Forest Research, CSIRO

-- A. Fleming, Australian National University

requesting the following:

-- provenance information about *C. littoralis*.

-- assistance in obtaining provenances of *C. littoralis* which have potential for good growth performance in Haiti.

4) When Casuarina seed is obtained, produce seedlings of these three species and plant them in several easily accessible small upland/high altitude trials. Nursery management techniques should be recorded for these species.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Many of the AOP species trials were set up using inappropriate technical and statistical research methodologies. The inappropriate technical methods potentially influenced the height growth and survival of the species being tested, thus making the interpretations of the data more difficult and less percise. In short, it increased the probability that differences in height growth and survival between species were caused by non-experimental factors and not by the species themselves. The lack of appropriate statistical (design) methods precluded rigid statistical testing.

2. Species trial information such as seed sources, nursery management techniques, outplanting procedures, maintenance procedures and schedules, measurement schedules and data collection were often poorly recorded and in some cases, were not recorded at all. This again makes the interpretation of the data more difficult and less accurate because in some cases, the lack of species performance can be explained by events such as the lack of rainfall, animal damage and careless weeding.

3. The distribution of species trials within the Buffum/Campbell zones is too limited. Only six B/C zones, which represent 19.7% of Haiti's land area contain two or more trials.

4. In species trials younger than 36 months, *Leucaena leucocephala* was the best performing species in virtually all B/C zones. In drier areas however, the growth rate of Leucaena declined sharply after 18 - 24 months. It also appears that Leucaena (K-8) had equivalent survival but better height growth than Leucaena K-28 and K-67.

5. In dry lowland areas (B/C zones 12 and 17), *Azadirachta indica* performed very well. Its height growth was initially slow, but after 8-16 months, its growth rate increased rapidly. *Cassia siamea* also performed very well in these areas, but it was less drought tolerant than *Azadirachta indica*. In all other lowland areas, these two species performed very well. Other lowland species that performed very well in B/C zone 12 and 17 were *Eucalyptus camaldulensis* (10939), *E. microtheca* (10321), *E. tereticornis* (11034), and *Moringa oleifera* (Table 1). In Tables 3 through 7, the fourth column recommends species that through literature search and experience show promise.

6. Species that performed well in B/C zones 12 and 17 are listed in Table 3.

7. Poor performing species in B/C zone 12 are *Albizia lebbek, Catalpa longissima, Prosopis alba* and *Prosopis juliflora*.

8. Poor performing species in B/C zone 17 are *Catalpa longissima, Colubrina arborescens, Sesbania grandiflora, Simaruba glauca, Swietenia macrophylla* and *Swietenia mahogani*.

9. In lowland moist sites (B/C zone 27), *Eucalyptus camaldulensis* (12542 and 12964) and *Sesbania grandiflora* showed excellent two - year height growth and survival. Very good performances in descending order were also registered by *Eucalyptus stricklandii, Eucalyptus camaldulensis (1403), Cassia siamea, Acacia auriculiformis, Leucaena leucocephala (K-8)*, and *Gliricidia sepium* (Table 4).

10. Species that performed well in B/C zone 27 are listed in Table 4.

11. *Tamarindus indica* was the only poor performing species in B/C zone 27.

12. In lowland wet sites (B/C zone 37), *Leucaena leucocephala, Cassia siamea* and *Acacia auriculiformis* were the best performers.

13. *Albizia lebbek* and *Azadirachta indica* were good performers in B/C zone 37.

14. *Casuarina equisetifolia* was the only poor performing species in B/C zone 37. The author attributes its poor growth and survival to the lack of *Frankia* and weeding.

15. In upland moist sites (B/C zone 51), *L. leucocephala* (ODH) and *L. diversifolia* (CATIE 1806) were the best performers. This is unusual for *L. leucocephala*, which usually does not perform well above 500 m, to be performing so well at 600 - 700 meters. Other species that performed well in this B/C zone were *Calliandra calothyrsus* (CATIE 1707 and 1522), *Casuarina cunninghamiana* (CSIRO 13512 and 13515), *C. equisetifolia* (ODH), *C. glauca* and *Eucalyptus camaldulensis* (CSIRO 13801). See Table 6.

16. Species that performed well in B/C zone 51 were:

Casuarina equisetifolia
(ODH/Haiti)

Casuarina obesa
(CSIRO 14100)

Colubrina arborescens
"Kapab" (NW Haiti)

Colubrina arborescens
"bwa ple" (Haiti)

Catalpa longissima
(Haiti)

Eucalyptus citriodora
(CSIRO 13628)

Eucalyptus gomphocephala
(CSIRO 12307)

Eucalyptus largiflorens
(CSIRO 12156)

Eucalyptus camaldulensis
(Petford)

17. Poor performing species in B/C zone 51 are *Cassia siamea* (ODH/Haiti) and *Azadirachta indica* (Petit Goave, Haiti).

18. In upland wet sites (B/C zone 94) Eucalyptus species significantly outperformed Casuarina species. *E. grandis* (11204) and *E. saligna* (11796) were the best performers. Other Eucalyptus species that performed very well were *E. botryoides* (7509), *E. tereticornis* (11034), *E. robusta* (11029), *E. cypellocarpa* (9135) and *E. punctata* (10863). See Table 7.

19. Species that performed well in B/C zone 94 are listed on page 20.

20. Indigenous species are able to grow in many of the B/C zones, but they do not exhibit rapid growth like the exotics. The best performers in this group are *Colubrina arborescens* and *Haematoxylon campechianum*. Other species that perform well are *Catalpa longissima, Simaruba glauca* and *Swietenia macrophylla*.

21. *Eucalyptus tereticornis* has a very broad latitudinal range and therefore it grows well in many parts of the country.

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Table 3

Buffum/Campbell Zone 11 - 17
Subtropical Dry Forest
Elevation < 400m
Rainfall < 1000mm

Very Good - Excellent	Good	Poor	Additional Recommended Species
Azadirachta indica	Acacia auriculiformis	Albizia lebbek	Acacia nilotica
Cassia siamea (>800mm)	Bursera simaruba	Catalpa longissima	Acacia senegal
Casuarina cunninghamiana * (10879)	Casuarina cristata * (11176)	Colubrina arborescens	Prosopis alba
Casuarina equisetifolia * (S. Africa)	Casuarina equisetifolia * (Haiti)	Prosopis alba	Prosopis juliflora
Eucalyptus camaldulensis (10939)	Colubrina arborescens	Prosopis juliflora	Sesbania sesban
Eucalyptus microtheca (10321)	Eucalyptus stricklandii	Sesbania grandiflora	
Eucalyptus tereticornis (11034)	Gliricidia sepium	Simaruba glauca	
Leucaena leucocephala (K-8, K-28, K-67)	Haematoxylon campechianum	Swietenia macrophylla	
Moringa oleifera	Parkinsonia aculeata	Swietenia mahogani	
	Tectona stans		

* Casuarina performed much better in FAO than AOP species trials.

Table 4

Buffum/Campbell Zone 21 - 27
Subtropical Moist Forest
Elevation < 400m
Rainfall 1000mm - 1500mm

Very Good - Excellent	Good	Poor	Additional Recommended Species
Acacia auriculiformis	Acacia nilotica (spreading)	Tamarindus indica	Calliandra calothyrsus
Cassia siamea	Albizia lebbek		Casuarina cunninghamiana (13127 and 13129)
Eucalyptus camaldulensis (12542, 12964 and 1403)	Azadirachta indica		Casuarina equisetifolia
Eucalyptus stricklandii	Catalpa longissima		Colubrina arborescens
Gliricidia sepium	Conocarpus erectus		Eucalyptus alba
Leucaena leucocephala (K-8)	Eucalyptus camaldulensis (12186 and 1202)		Eucalyptus brassiana
Sesbania grandiflora	Eucalyptus microtheca (10321)		Eucalyptus citriodora
	Pithecellobium dulce		Eucalyptus dumosa
	Prosopis juliflora		Eucalyptus occidentalis
			Eucalyptus saligna
			Haematoxylon campechianum
			Moringa oleifera
			Sesbania bispinosa
			Swietenia macrophylla
			Swietenia mahogani

Table 5

Buffum/Campbell Zone 31-37
Subtropical Moist Forest (1000mm - 2000mm)
Subtropical Wet Forest (2000mm - 4000mm)
Elevation < 400m
Rainfall > 1500mm

Very Good - Excellent	Good	Poor	Additional Recommended Species
Acacia auriculiformis	Albizia lebbek	Casuarina equisetifolia	Calliandra calothyrsus
Cassia siamea	Azadirachta indica	Catalpa longissima	Catalpa longissima
Eucalyptus camaldulensis (10930, 10532, 10666, 10266, 13433, 1202 and 12186)	Eucalyptus camaldulensis (10911)		Colubrina arborescens
	Eucalyptus grandis (11204)		Gliricidia sepium
Eucalyptus robusta (11029)	Eucalyptus maculata (11704)		Moringa oleifera
Eucalyptus stricklandii (9927)	Eucalyptus punctata (10617 and 10863)		Sesbania bispinosa
			Sesbania grandiflora
Eucalyptus tereticornis (10975, 10914, 10954 and 11034)	Eucalyptus robusta (11019)		
Leucaena leucocephala			

Buffum/Campbell Zones 41 - 47 (subtropical dry forest) are not represented by any species trials.

Table 6

Buffum/Campbell Zone 51 - 57
Subtropical Moist Forest (1000mm - 2000mm)
Elevation 400m - 800m
Rainfall 1000mm - 1500mm

Very Good - Excellent	Good	Poor	Additional Recommended Species
Acacia auriculiformis (< 600m)	Casuarina equisetifolia (ODH/Haiti)	Azadirachta indica	Cassia siamea
Calliandra calothyrsus (CATIE 1522 and 1707)	Casuarina obesa (14100)	Caesalpinia velutina	Moringa oleifera
Casuarina cunninghamiana (CSIRO 13515 and 13512)	Catalpa longissima (Haiti)	Cassia siamea	Sesbania grandiflora
Casuarina glauca (CSIRO 13987)	Colubrina arborescens	Guazuma ulmifolia	
Eucalyptus camaldulensis (13801)	Eucalyptus camaldulensis (Petford)		
Eucalyptus tereticornis (13547)	Eucalyptus citriodora (CSIRO 13628)		
Leucaena diversifolia (CATIE 1624 and 1806)	Eucalyptus gomphocephala (12307)		
Leucaena leucocephala (<600 m)	Eucalyptus grandis		
	Eucalyptus largiflorens (12156)		
	Eucalyptus tereticornis (1651 and 13824)		
	Gliricidia sepium (1360)		
	Haematoxylon campechianum		

Buffum/Campbell Zones 61 - 67 and 71 - 77 (subtropical moist forest) are not represented by any species trials, and zones 81 - 87 (lower montane moist forest) are represented by only one trial.

Table 7

Buffum/Campbell Zone 91 - 97
Lower Montane Moist Forest
Elevation > 800m
Rainfall > 1500mm

Very Good - Excellent	Good	Poor	Additional Recommended Species
Eucalyptus botryoides (7509)	Casuarina cunninghamiana (CSC)	Casuarina cristata	Alnus acuminata
Eucalyptus cypellocarpa (9135)	Casuarina equisetifolia (CSR 24 EQS)	Casuarina littoralis (CSIRO 13376)	Alnus nepalensis
Eucalyptus grandis (11204)	Casuarina glauca (CSIRO 13142)	Casuarina stricta	Casuarina junghuhniana
Eucalyptus punctata (10863)	Eucalyptus camaldulensis (10266 and 10911)		Casuarina littoralis
Eucalyptus robusta (11029)	Eucalyptus diversicolor (11760)		Casuarina oligodon
Eucalyptus saligna (11796)	Eucalyptus globulus (Haiti)		Grevillea robusta
Eucalyptus tereticornis (11034)	Eucalyptus paniculata (10719)		
	Eucalyptus propinqua (11833)		
	Eucalyptus punctata (10617)		
	Eucalyptus robusta (11019)		
	Eucalyptus tereticornis (10914 and 10975)		

Recommendations

1. Standard research methods should be set for all AOP species trials including seed source information, nursery management techniques, outplanting and maintenance procedures, measurement schedule and procedure, and data collection. This information must be recorded on standard forms and filed at a grantee office, USAID or the AFORP office.

2. Two or more species trials should be established in B/C zones 31, 61, 13, and 41. These zones, which cover 25.4% of Haiti's land area are currently without trials.

3. At least one more species trial should be established in B/C zones 21, 32, 91, and 11. These zones cover 24.6% of Haiti's land area and currently have one species trial. Additional species trials in these zones should contain some of the species tested in the original species trial for that zone so that growth and survival may be compared between trial sites for the same species.

4. Begin a neem coppice study especially in dry lowland areas (B/C zones 12 and 17) where increased wood production is needed.

5. *Prosopis alba* and *Prosopis juliflora* should be tested again in B/C zone 12.

6. A literature search should be conducted on Leucaena provenances and their specific uses.

7. A letter* should be written to Dr.James L. Brewbaker and Michael D. Benge requesting Leucaena provenance and seed dealer information.

8. From existing information in Haiti, order provenances of Leucaena seed in research quantities so that preliminary testing of this species can begin immediately.

9. A letter should be written to the International Neemtree research and Development Programme in Paris, France requesting the following:

-- neem provenance and seed dealer information.

-- assistance in obtaining other neem seed sources for Haiti.

-- neem seed viability research results or methods by which to extend the viability of neem seed.

* All letters should be written on USAID letterhead by the Senior Forestry Advisor in cooperation with one member from each AOP grantee and a member of the AFORP team.

10. New seed sources of neem should be ordered and tested against Haiti neem. If their performance is better than the Haiti neem, the trial should be protected and seed collected from these trees for planting in the AOP.

11. Begin research on neem seed viability or test the suggested method for extending viability.

12. Animator training programs should stress the fact that neem grows slowly during the first year because it is developing its root system. Secondly, these programs should stress that neem, Casuarina and Eucalyptus must be weeded throughout the first year so that good growth will follow in the second and third year.

13. Seed of *E. tereticornis* should be purchased, grown and outplanted by each grantee as soon as possible. The nursery requirements of this species and the location of the outplantings by farmer should be recorded so that the AOP can actively assess the performance of this species under rural farm conditions.

14. More seed sources of *E. camaldulensis* and *E. microtheca* should be obtained for provenance testing in all B/C zones.

15. A letter should be written to J.C. Doran, Division of Forest Research, CSIRO requesting the following:

-- provenance and seed dealer information about *E. camaldulensis*, especially for the Australian provenances (10939, 12542, 12964, 1202 and 12186) and Broken Hill (New South Wales) provenance which is recommended for arid climates.

-- assistance in obtaining seed sources of the above mentioned provenances.

-- provenance and seed dealer information about *E. grandis*, especially Australian provenance (11204), *E. saligna*, especially Australian provenance (11796), *E. botryoides* (7509), *E.robusta* (11029), *E. cypellocarpa* (9135) and *E. punctata* (10863) and others.

-- the CSIRO provenance study results for *E. microtheca*.

-- provenance and seed dealer information about *E. microtheca*, especially for provenance (10321).

16. Conduct a study on the effects of *Frankia* on *C. equisetifolia* and other *Casuarina* species.

17. A letter should be written to C.J. Borough, Division of Forest Research and D.M. Griffin, Australian National University requesting the following:

-- provenance and seed dealer information about *C. cristata, C. cunninghamiana* and *C. equisetifolia*.

-- assistance in obtaining provenances of these *Casuarina* species which have potential for good growth in Haiti.

18. Test these provenances of Casuarina against the Haiti provenance. If the results are favorable, the trial should be protected and seed collected for use in the AOP.

19. Further testing of *Acacia nilotica* is recommended for B/C zone 17.

20. Further testing of *Eucalyptus dumosa, E. citriodora, E. saligna, E. occidentalis, E. brassiana, E. alba, Haematoxylon campechianum, Swietenia macrophylla*, and *Casuarina equisetifolia* should be done in B/C zone 27.

21. Further testing of *Casuarina equisetifolia* is recommended for B/C zone 37.

22. A letter should be written to Dr. Rodolfo Salazar, CATIE, requesting the following:

-- provenance and seed dealer information about *L. diversifolia*.

-- assistance in obtaining provenances of *L. diversifolia* which have potential for good growth in Haiti.

23. Produce *L. diversifolia* seedlings and outplant them against *L. leucocephala* and the upland Casuarina species in a few small upland trials in easily accessible areas in Haiti. Nursery management techniques should be recorded for these species.

24. A letter should be written to Syafii Manan, Bogor Agricultural University requesting the following:

-- provenance and seed dealer information about *Casuarina junghuhniana*.

-- assistance in obtaining provenances of *C. junghuhniana* which have potential for good growth in Haiti.

25. Produce *C. junghuhniana* seedlings and outplant them in a few small upland trials against Eucalyptus species and *L. diversifolia*. The nursery management techniques should be recorded for these species and the sites should be easily accessible to project personnel.

26. A letter should be written to:

-- A. Allison, Wau Ecology Institute

-- A. Byron, Environmental Science Council

-- the chief research officer, Office of Forests
-- K. Thiagalingam, University of Papua New Guinea

requesting the following:

-- provenance and seed dealer information about *Casuarina oligodon*.

-- assistance in obtaining provenances of *C. oligodon* which have potential for good growth in Haiti.

27. Produce *C. oligodon* seedlings and outplant them in a few small upland trials.

28. A letter should be written to:

-- M. Alexandra, Forester, Australian Seed Co.

-- D.J. Boland, Division of Forest Research, CSIRO

-- A. Fleming, Australian National University

requesting the following:

-- provenance and seed dealer information about *Casuarina littoralis*.

-- assistance in obtaining provenances of *C. littoralis* which have potential for good growth in Haiti.

29. Produce *C. littoralis* seedlings and outplant them in a few small upland trials.

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APPENDICES

APPENDIX 1

SPECIES TRIAL DATA SUMMARY

This appendix contains the summarized data by mean height, survival and dbh for the 36 species trials discussed in this report. Only the most current measurement is given, though other measurements were taken. Additional statistical information such as confidence intervals and standard error are not given because of the difficulties encountered in analyzing these trials. The rainfall is assumed to represent an average year, although for the Cabaret trial, for example, the average rainfall is 900 mm while the actual rainfall in 1985 at that site was 670 mm. Finally, many of the seed sources were unknown, thus causing delays and uncertainties in locating the specific species tested in that trial.

Table A1. BASSIN ZIM (13 months)

Date planted: July 20, 1984
Date measured: August 14, 1985
Forester: Ralph Mathieu (PADF)

B/C zone: 52
HBZ: Subtropical moist forest
Altitude: 400 m
Rainfall: 1450 mm

Trial site: The trial is located on a deep sandy clay to clay soil with a pH of 7.5. The site has a 5-10% slope.
Trial design: randomized complete block
Trees per plot: 25
Number of reps.: 2

Species	Mean Height (m)	Survival (%)	dbh (cm)
Cassia siamea (Limbe, Haiti)	2.45	96	---
Acacia auriculiformis (ODH/Haiti)	2.04	94	---
Haematoxylum campechianon (Papaye, Haiti)	1.50	68	---
Colubrina arborescens (Petit Goave, Haiti)	1.34	64	---

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Table A2.BERGEAUD (35 months)

Date planted: June 1983
Date measured: April 10, 1986
Forester: Mike Bannister (PADF)
B/C zone: 21
HBZ: Subtropical moist forest
Altitude: 35 m
Rainfall: 2000 mm

Trial site: The trial is located on a shallow alkaline soil which has a 10-20 cm brownish grey topsoil and beneath which is white chalky limestone material. The site has a 30% slope.

Trial design: randomized complete block

Trees per plot: 25
Number of reps.: 4

Species	Mean Height (m)	Survival (%)	dbh (cm)
Acacia auriculiformis (ODH/Haiti)	3.45	64	---
Casuarina equisetifolia (ODH/Haiti)	2.70	80	---
Eucalyptus camaldulensis (ODH/Haiti)	2.54	52	---
Cassia siamea (ODH/Haiti)	2.08	68	---
Parkinsonia aculeata (ODH/Haiti)	1.24	7	---
Pinus brutia (ODH/Haiti)	0.80	2	---
Prosopis juliflora (Felker, USA)	0.65	6	---

Table A3. CABARET (24 months)

Date planted: October 1983
Date measured: October 1985
Forester: Elia Mora de Beliard (WB)

B/C zone: 12
HBZ: Subtropical dry forest
Altitude: 80 m
Rainfall: 900 mm

Trial site: The trial is located on a shallow clay to silty clay reddish brown soil which was derived from limestone parent material. The soil is very erodable and the 0-10 cm layer has a pH of 7.8, a conductivity of 8.6 mmhos/cm, 125 ppm of phosphorus and 675 ppm of potassium. At 50-60 cm, the pH was 7.9, conductivity was 6.8 mmhos/cm, 60 ppm phosphorus and 425 ppm potassium.

Trial design: randomized block
Trees per plot: 25

Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (K-8)	3.10	---	---
Leucaena leucocephala (K-28)	1.81	---	---
Azadirachta indica	1.80	---	---
Leucaena leucocephala (K-67)	1.76	---	---
Tecoma stans	1.25	---	---
Gliricidia sepium	1.20	---	---
Acacia farnesiana	1.00	---	---
Parkinsonia aculeata	0.98	---	---
Azadirachta indica	0.84	---	---
Prosopis alba	0.71	---	---
Eucalyptus microtheca	0.62	---	---
Sesbania grandiflora	----	---	---
Cassia siamea	----	---	---
Acacia auriculiformis	----	---	---
Eucalyptus paniculata	----	---	---
Catalpa longissima	----	---	---
Prosopis juliflora	----	---	---
Casuarina equisetifolia	----	---	---
Eucalyptus camaldulensis	----	---	---
Simaruba glauca	----	---	---
Albizia lebbek	----	---	---
Casuarina equisetifolia	----	---	---
Eucalyptus citriodora	----	---	---
Hibiscus elatus	----	---	---
Lysiloma latisiliqua	----	---	---
Swietenia mahogani	----	---	---
Tectona grandis	----	---	---

Table A4. CABARET (18 months)

Date planted: May 1984
Date measured: November 1985
Forester: Elia Mora de Beliard (WB)

B/C zone: 12
HBZ: Subtropical dry forest
Altitude: 80 m
Rainfall: 900 mm

Trial site: The trial is located on a shallow clay to silty clay reddish brown soil which was derived from limestone parent material. The soil is very erodable and has a pH of 7.8. The trial is on a 30-60% slope.

Trial design: randomized block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (K-8)	3.74	---	---
Moringa oleifera	2.40	---	---
Bursera simaruba	1.50	---	---
Sesbania grandiflora	1.50	---	---
Azadirachta indica	1.40	---	---
Haematoxylon campechianum	1.25	---	---
Eucalyptus camaldulensis	1.17	---	---
Eucalyptus stricklandii	1.04	---	---
Eucalyptus camaldulensis	0.85	---	---
Eucalyptus camaldulensis	0.83	---	---
Eucalyptus tereticornis	0.82	---	---
Albizia lebbek	0.73	---	---
Guazuma ulmifolia	0.62	---	---
Prosopis alba	0.55	---	---
Cassia emarginata	0.48	---	---
Eucalyptus camaldulensis	0.45	---	---
Casuarina glauca	----	---	---
Casuarina cunninghamiana	----	---	---
Schaefferia stricklandii	----	---	---
Swietenia macrophylla	----	---	---
Cordia alliodora	----	---	---

Table A5. CAZEAU #4 (25 months)

Date planted: June 3, 1983
Date measured: July 17, 1985
Forester: Peter Welle (ODH)

B/C zone: 27
HBZ: Subtropical moist forest
Altitude: 30 m
Rainfall: 1100-1300 mm

Trial site: The trial is located on a silty loam to silty grey tan soil with a pH of 7.7 to 8.0. The soil is alluvial and partially saline with a high water table (2m).

Trial design: randomized complete block
Trees per plot: 24
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus camaldulensis (12542)	7.64	97	---
Eucalyptus camaldulensis (12964)	7.28	86	---
Acacia auriculiformis	7.11	93	---
Cassia siamea	6.75	96	---
Leucaena leucocephala	6.44	79	---
Prosopis juliflora	5.58	93	---
Albizia lebbek	5.27	84	---
Pithecellobium dulce	5.23	100	---
Conocarpus erectus	4.94	60	---
Eucalyptus saligna	4.91	12	---
Azadirachta indica	4.76	90	---
Eucalyptus occidentalis	4.10	18	---
Eucalyptus microtheca	3.90	82	---
Catalpa longissima	3.44	97	---
Eucalyptus brassiana	3.40	12	---
Eucalyptus alba	3.25	60	---
Parkinsonia aculeata	3.21	93	---
Casuarina equisetifolia	2.51	68	---
Acacia confusa	2.44	48	---
Tamarindus indica	2.35	68	---
Pinus caribaea var. hond.	1.75	9	---
Eucalyptus robusta	1.66	20	---
Acacia farnesiana	1.38	100	---
Pinus brutia	1.00	5	---
Pinus occidentalis	----	0	---

Table A6.CAZEAU #6 (24 months)

Date planted: May 8, 1984
Date measured: May 15, 1986
Forester: Peter Welle (ODH)

B/C zone: 27
HBZ: Subtropical moist forest
Altitude: 30 m
Rainfall: 1100-1300 mm

Trial site: The trial is located on a silty loam to silty grey tan soil with a pH 7.7 to 8.0. The soil is alluvial and partially saline with a high water table (2m).

Trial design: randomized complete block

Trees per plot: 24

Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Sesbania grandiflora	7.32	93	10.5
Gliricidia sepium	6.61	79	8.8
Leucaena leucocephala (K-8)	6.26	90	7.1
Acacia auriculiformis	6.21	66	9.0
Albizia lebbek	5.30	97	5.0
Acacia nilotica (spreading)	3.65	98	4.8
Acacia nilotica (erect)	2.61	96	---
Swietenia macrophylla	2.22	34	---
Swietenia mahagoni	2.18	70	---
Delonix regia	2.15	56	---
Shinus roble	2.02	83	---
Tamarindus indica	1.39	85	---
Calophyllum brasiliense	1.20	44	---
Ficus benjamina	1.09	44	---
Melicoccus bijugatus	0.32	37	---

Table A7. CAZEAU #7 (24 months)

Date planted: May 16, 1984
Date measured: May 22, 1986
Forester: Peter Welle (ODH)

B/C zone: 27
HBZ: Subtropical moist forest
Altitude: 30 m
Rainfall: 1100-1300 mm

Trial site: The trial is located on a silty loam to silty grey tan soil with a pH of 7.7 to 8.0. The soil is alluvial and partially saline with a high water table (2m).

Trial design: randomized complete block

Trees per plot: 24

Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus stricklandii	4.54	89	5.4
Eucalyptus camaldulensis (1403)	4.01	89	4.9
Eucalyptus microtheca (10321)	3.13	78	---
Eucalyptus camaldulensis (1202)	3.11	90	---
Eucalyptus camaldulensis (12186)	3.10	92	---
Acacia auriculiformis (131915)	3.04	38	---
Eucalyptus tereticornis (13469)	2.96	68	---
Eucalyptus dumosa	2.80	82	---
Eucalyptus tereticornis (1160)	2.76	67	---
Haematoxylum campechianum	1.94	79	---
Eucalyptus citriodora	1.90	10	---
Cassia emarginata	1.57	57	---
Guazuma ulmifolia (1362)	1.56	88	---
Casuarina cunninghamiana (1433)	1.42	51	---
Eucalyptus robusta (12972)	1.42	33	---
Casuarina equisetifolia (1439)	1.26	51	---
Casuarina glauca (13142)	1.08	35	---
Casuarina equisetifolia (13136)	1.07	47	---
Casuarina glauca (Septropa)	1.07	39	---
Cedrela odorata	0.77	14	---

Table A8. COLIN 155.1 (26 months)

Date planted: May 18, 1983
Date measured: July 11, 1985
Forester: Gregor Wolf
(CARE)

B/C zone: 51
HBZ: Subtropical moist forest
Altitude: 600-700 m
Rainfall: 1300 mm

Trial site: The trial is located on a shallow, stoney, blackish red clay to silty clay soil with a pH of 7.9. Beneath this soil layer is white chalky limestone material. The trial has a 60% slope.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (ODH/Haiti)	4.70	96	4.3
Eucalyptus camaldulensis	2.02	41	---
Casuarina equisetifolia (ODH/Haiti)	1.99	89	---
Cassia siamea (ODH/Haiti)	1.74	52	---
Catalpa longissima (ODH/Haiti)	1.25	78	---
Azadirachta indica (Petit Goave, Haiti)	0.54	67	---

Table A9. COLIN 155.4 (9 months)

Date planted: October 6, 1984
Date measured: July 11, 1985
Forester: Gregor Wolf
(CARE)

B/C zone: 51
HBZ: Subtropical moist forest
Altitude: 750-800 m
Rainfall: 1300 mm

Trial site: The trial is located on a shallow, stoney, reddish grey clay to silty clay with a pH of 7.9. Beneath this soil layer is white chalky limestone material. The trial has a 80% slope.
Trial design: randomized complete block
Trees per plot: 1
Number of reps.: 6

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena diversifolia (CATIE 1806)	1.44	88	---
Calliandra calothyrsus (CATIE 1707)	1.11	100	---
Eucalyptus camaldulensis (CSIRO 13801)	1.11	100	---
Casuarina cunninghamiana (CSIRO 13512)	1.08	100	---
Casuarina glauca (CSIRO 13987)	1.08	86	---
Leucaena leucocephala (ODH/Haiti)	1.07	100	---
Casuarina cunninghamiana (CSIRO 13515)	1.05	100	---
Calliandra calothyrsus (CATIE 1522)	1.00	100	---
Leucaena diversifolia (CATIE 1624)	0.97	100	---
Casuarina obesa (CSIRO 14100)	0.90	86	---
Colubrina arborescens "Kapab" (NW,Haiti)	0.82	100	---
Eucalyptus citriodora (CSIRO 13628)	0.78	63	---
Eucalyptus gomphocephala (CSIRO 12307)	0.77	100	---
Eucalyptus largiflorens (CSIRO 12156)	0.72	100	---
Eucalyptus camaldulensis (Petford)	0.71	88	---
Catalpa longissima (Haiti)	0.65	100	---
Colubrina arborescens "bwa ple" (Haiti)	0.65	100	---
Eucalyptus sideroxylon (CSIRO 13468)	0.60	100	---
Eucalyptus whitei (CSIRO 13586)	0.55	75	---
Melia azadirachta (Baie de Henne,Haiti)	0.52	100	---
Casuarina leuhmanmii (CSIRO 13880)	0.52	50	---
Eucalyptus cambageana (CSIRO 12937)	0.50	100	---
Casuarina equisetifolia (Haiti)	0.47	100	---
Gliricidia sepium (Esparzas,Costa Rica)	0.43	100	---
Eucalyptus melanophloia (CSIRO 13588)	0.43	100	---
Gliricidia sepium (CATIE 1360)	0.42	100	---
Eucalyptus argillacea (CSIRO 13942)	0.40	75	---
Cassia siamea (Haiti)	0.38	63	---
Eucalyptus excerta (CSIRO 13818)	0.37	88	---
Eucalyptus populnea (CSIRO 8658)	0.35	100	---
Eucalyptus cladocalyx (CSIRO 11834)	0.32	100	---
Eucalyptus ochropholoia (CSIRO 12507)	0.31	88	---
Guazuma ulmifolia (Bombardopolis,Haiti)	0.30	100	---
Eucalyptus leucophloia (CSIRO 12357)	0.23	75	---
Caesalpinia velutina (CATIE 1521)	0.17	100	---

Table A10. COLORA (6 months)

Date planted: November 1985
Date measured: May 1986
Forester: Elia Mora de Beliard (PFN)
Trial site:
Trial design: randomized block
Trees per plot: 25

B/C zone: 22
Altitude: 247 m
Rainfall: 1471 mm

Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala	1.14	93	---
Sesbania grandiflora	0.91	87	---
Acacia auriculiformis	0.90	100	---
Cassia siamea	0.88	100	---
Azadirachta indica	0.84	97	---
Parkinsonia aculeata	0.79	97	---
Schaefferia frutescens	0.75	97	---
Prosopis juliflora	0.73	100	---
Eucalyptus camaldulensis	0.68	92	---
Acacia tortuosa	0.67	100	---
Guazuma ulmifolia	0.67	96	---
Casuarina equisetifolia	0.56	96	---

Table A11. FOND-DES-BLANC (35 months)

Date planted: May 16, 1983
Date measured: April 19, 1986
Forester: Mike Bannister (PADF)

B/C zone: 11
HBZ: Subtropical dry forest
Altitude: 350 m
Rainfall: 800-1000 mm

Trial site: The trial is located on a shallow, stoney, clay to silty clay soil with a pH of greater than 7.0. The site has a 10-20% slope.
Trial design: randomized complete block
Trees per plot: 25
Number of reps.: 4

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus camaldulensis	3.77	3	---
Cassia siamea	3.07	62	---
Acacia auriculiformis	2.60	52	---
Casuarina cristata	2.44	62	---
Parkinsonia aculeata	1.93	54	---
Pinus brutia	----	--	---
Pinus caribaea	----	--	---
Pinus occidentalis	----	--	---

Table A12. FURCY 76-1 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 94
HBZ: Lower montane wet forest
Altitude: 1600 m
Rainfall: 2143 mm

Trial site: The trial is located on a 5-20% slope. The red kaolinite clay soil is derived from basalt parent material and has a pH of 6.5-6.8.

Trial design: randomized complete block

Trees per plot: 9 Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Cupressus lusitanica (Italy)	6.2	92.6	11.7	0.0022
Araucaria cunninghamii (Australia)	4.0	51.8	4.6	0.0002
Pinus halepinsis (Tunisia)	---	----	----	------

Table A13. FURCY 76-3 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 94
HBZ: Lower montane wet forest
Altitude: 1600 m
Rainfall: 2143 mm

Trial site: The trial is located on a 5-20% slope. The red kaolinite clay soil is derived from basalt parent material and has a pH of 6.5-6.8.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Casuarina glauca (Australia 8645)	7.3	66.6	6.8	0.009
Casuarina equisetifolia (India)	7.0	37.0	5.9	0.006
Casuarina cunninghamiana (Australia 10879)	5.5	92.6	4.6	0.003
Casuarina cristata (Australia 11176)	5.1	39.5	4.2	0.002
Casuarina stricta (Australia 8112)	3.0	3.7	3.6	0.001

Table A14. FURCY 76-5 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 94
HBZ: Lower montane wet forest
Altitude: 1420 m
Rainfall: 2143 mm

Trial site: The trial is located on a 6-7% slope. The well drained red kaolinite clay soil is derived from basalt parent material and has a pH of 6.5.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Eucalyptus grandis (11204)*	27.0	44.4	29.5	0.615
Eucalyptus saligna (11796)	21.8	51.8	23.3	0.309
Eucalyptus robusta (11029)	21.0	37.0	21.3	0.249
Eucalyptus cypellocarpa (9135)	20.6	66.6	21.3	0.245
Eucalyptus botryoides (7509)	20.5	33.3	22.0	0.259
Eucalyptus punctata (10863)	20.0	40.7	20.1	0.216
Eucalyptus globulus (Haiti)	19.5	18.5	18.0	0.165
Eucalyptus tereticornis (11034)	19.4	44.4	22.3	0.253
Eucalyptus punctata (10617)	18.4	40.7	17.5	0.146
Eucalyptus tereticornis (10914)	17.0	22.2	20.7	0.191
Eucalyptus paniculata (10719)	17.0	37.0	17.1	0.130
Eucalyptus diversicolor (11760)	16.8	33.3	15.4	0.104
Eucalyptus camaldulensis (10266)	16.7	25.9	14.2	0.088
Eucalyptus robusta (11019)	16.1	40.7	18.1	0.138
Eucalyptus tereticornis (10975)	15.3	33.3	16.5	0.109
Eucalyptus propinqua (11833)	14.6	18.5	16.3	0.102
Eucalyptus tereticornis (10954)	14.4	22.2	15.4	0.089
Eucalyptus camaldulensis (10911)	14.0	25.9	15.6	0.089
Eucalyptus paniculata (10741)	13.8	37.0	15.0	0.089
Eucalyptus cladocalyx (11180)	12.0	7.4	11.3	0.040
Eucalyptus camaldulensis (10930)	10.2	11.1	11.9	0.038
Eucalyptus siderophloia (Versepuy)	9.2	22.2	11.0	0.029
Eucalyptus camaldulensis (10666)	8.6	7.4	9.5	0.020
Eucalyptus viminalis (10993)	8.2	25.9	11.3	0.027
Eucalyptus tereticornis (10826)	6.4	7.4	5.6	0.005
Eucalyptus microtheca (10321)	3.6	7.4	5.1	0.002
Eucalyptus occidentalis (7382)	---	7.4	---	-----

*All of these species are from Australia unless otherwise stated.

Table A15. GANTHIER (22 months)

Date planted: October 12, 1983
Date measured: August 16, 1985
Forester: Roland Dupuis
(UMO)

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 90 m
Rainfall: 700 mm

Trial site: The site is dry agricultural land with a 1-3% slope. The deep alluvial clay to silty/clay soil has a pH of 6.8 and a conductivity of 0.92 mmhos/cm.
Trial design: randomized complete block
Trees per plot: 20
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (ODH/Haiti)	3.18	100	2.9
Azadirachta indica (Petit Goave, Haiti)	2.14	90	---
Albizia lebbek (Grand Goave, Haiti)	1.46	75	---
Eucalyptus camaldulensis (Emu Creek, Australia)	1.42	33	---
Ailanthus altissima (Nicosia, Cyprus)	---	--	---
Calliandra calothyrsus (Bogor, Indonesia)	---	--	---
Sesbania formosa (W.Australia)	---	--	---
Sesbania grandiflora (Bon Repos, Haiti)	---	--	---

Table A16. GRAN BASSIN (27 months)

Date planted: October 26, 1983
Date measured: January 24, 1986
Forester: Mark Webb
(PADF)

B/C zone: 24
HBZ: Subtropical moist forest
Altitude: 70 m
Rainfall: 1300 mm

Trial site: The trial is located on an agricultural field which has a 10% slope. The A horizon which has a depth of 22 cm is a black clay loam soil with whitish mottles at 20 cm. It has a pH of 7.4, a conductivity of 0.34 mmhos/cm, 29 ppm of phosphorus and 13 ppm of potassium. The B horizon has a depth of greater than two meters and is an orangish-brown sandy clay with white mottles. It has a pH of 7.6, a conductivity of 0.28 mmhos/cm, 11 ppm of phosphorus and 13 ppm of potassium.

Trial design: randomized complete block
Trees per plot: 25 Number of reps.: 5

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (ODH/Haiti	3.23	95	---
Cassia siamea (Limbe, Haiti)	2.24	80	---
Eucalyptus camaldulensis (T.S.I.)*	1.48	40	---
Swietenia macrophylla (Limbe, Haiti)	1.48	20	---
Azadirachta indica (Arcahaie, Haiti)	1.19	15	---
Catalpa longissima (Limbe, Haiti)	0.92	40	---

*T.S.I. - Tree Seeds International

Table A17. GRAND FOND (13 months)

Date planted: June 27, 1984
Date measured: July 23, 1985
Forester: Marcia McKenna (CARE)

B/C zone: 12
HBZ: Subtropical dry forest
Altitude: 280 m
Rainfall: 800 mm

Trial site: The trial is located on a dark brown stoney clay with a pH of 8.0. Beneath this soil layer is a white chalky limestone material. The site has a 15% slope.
Trial design: randomized complete block
Trees per plot: 25 Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (Port-de-Paix, Haiti)	1.93	61	---
Eucalyptus camaldulensis (CSIRO 13433)	1.19	60	---
Colubrina arborescens (Jean Rabel, Haiti)	1.05	83	---
Catalpa longissima (Jean Rabel, Haiti)	0.97	41	---
Casuarina equisetifolia (CSIRO 13136)	0.84	17	---
Eucalyptus microtheca (CSIRO 10321)	0.83	50	---
Casuarina glauca (CSIRO 13142)	0.57	18	---
Cassia siamea (Haiti)	0.55	38	---
Parkinsonia aculeata (ODH/Haiti)	0.53	24	---

Table A18. JEAN - RABEL (20 months)

Date planted: June 1984
Date measured: February 1986
Forester: Elia Mora de Beliard (WB)
B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 107 m
Rainfall: 1045 mm
Trial site: The trial is located on a shallow sandy clay.
Trial design: randomized block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (K-8)	2.22	---	---
Leucaena leucocephala (K-28)	2.00	---	---
Leucaena leucocephala (K-67)	1.94	---	---
Haematoxylum campechianum	1.58	---	---
Acacia auriculiformis	1.19	---	---
Cassia emarginata	1.13	---	---
Gliricidia sepium	1.07	---	---
Azadirachta indica	1.06	---	---
Moringa oleifera	1.00	---	---
Parkinsonia aculeata	0.93	---	---
Cassia siamea	0.92	---	---
Eucalyptus tereticornis	0.63	---	---
Albizia lebbek	0.60	---	---
Prosopis velutina (0457)	0.59	---	---
Schaefferia frutescens	0.57	---	---
Prosopis velutina (0450)	0.51	---	---
Prosopis alba (0388)	0.47	---	---
Acacia nilotica	0.39	---	---
Swietenia mahogani	0.23	---	---
Swietenia macrophylla	0.23	---	---
Eucalyptus camaldulensis	0.22	---	---
Eucalyptus microtheca	0.16	---	---
Csauarina fauca	----	---	---
Sesbania grandiflora	----	---	---
Casuarina equisetifolia	----	---	---
Catalpa longissima	----	---	---
Cedrela odorata	----	---	---
Cercidium praecox	----	---	---
Colubrina arborescens	----	---	---

Table A19. LASCAHOBAS (25 months)

Date planted: June 1, 1984
Date measured: July 23, 1986
Forester: Stuart North (PADF)

B/C zone: 32
HBZ: Subtropical wet forest
Altitude: 220 m
Rainfall: 2000 mm

Trial site: The trial is located on marginal agricultural land with a 10% slope. The A horizon is light brown with a pH of 8.1, phosphorus 20 ppm, potassium 13 ppm and a conductivity of 0.54 mmhos/cm. The B horizon has a pH of 8.4, phosphorus 12 ppm, potassium 13 ppm and a conductivity of 0.40 mmhos/cm.
Trial design: completely randomized block.
Trees per plot: 25
Number of reps.: 3-5

Species	Mean Height (m)	Survival (%)	dbh (cm)
Acacia auriculiformis	3.27	81	2.04
Casuarina glauca	1.60	1.3	----
Catalpa longissima	1.00	61	----

Table A20. LIMBE (8.5 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 34
HBZ: Subtropical moist forest
Altitude: 100 m
Rainfall: 1949 mm

Trial site: The trial is situated on a 60% slope and is subject to strong winds. The reddish clay lateritic soil was derived from basalt parent material.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Eucalyptus tereticornis (10975)*	14.5	62.9	12.4	0.058
Eucalyptus tereticornis (10914)	13.5	70.3	11.0	0.043
Eucalyptus tereticornis (10954)	13.0	77.7	9.7	0.032
Eucalyptus stricklandii (9927)	12.0	62.9	14.6	0.067
Eucalyptus tereticornis (11034)	11.5	88.8	12.0	0.043
Eucalyptus camaldulensis (10930)	11.0	81.4	14.0	0.056
Eucalyptus camaldulensis (10532)	11.0	92.6	10.8	0.034
Eucalyptus camaldulensis (10666)	10.5	77.7	32.2	0.285
Eucalyptus camaldulensis (10266)	10.5	88.8	12.8	0.045
Eucalyptus robusta (11029)	10.5	74.0	11.9	0.039
Eucalyptus punctata (10617)	10.0	29.6	9.4	0.023
Eucalyptus camaldulensis (10911)	10.0	59.3	10.0	0.026
Eucalyptus grandis (11204)	9.5	48.1	8.7	0.019
Eucalyptus maculata (11704)	9.0	55.5	8.4	0.016
Eucalyptus punctata (10863)	8.0	62.9	8.6	0.015
Eucalyptus robusta (11019)	8.0	70.3	11.5	0.028
Eucalyptus crebra (11684)	7.0	44.4	6.8	0.008
Eucalyptus exserta (11028)	7.0	33.3	8.1	0.012
Eucalyptus flocktoniae (7981)	7.0	18.5	7.8	0.011
Eucalyptus paniculata (11741)	7.0	59.3	7.0	0.009
Colubrina ferruginosa (Haiti)	5.8	33.3	9.4	0.013
Eucalyptus siderophloia (12094)	4.0	18.5	4.4	0.002
Eucalyptus microtheca (10321)	4.0	48.1	6.2	0.004
Eucalyptus paniculata (10719)	4.0	18.5	4.5	0.002
Eucalyptus wandoo (8682)	3.5	7.4	4.8	0.002
Eucalyptus crebra (8832)	---	---	---	-----
Eucalyptus leucoxylon (9602)	---	---	---	-----
Eucalyptus occidentalis (7382)	---	---	---	-----
Eucalyptus sideroxylon (9022)	---	---	---	-----

*All of these species are from Australia unless otherwise stated.

Table A21. LIMONADE (42 months)

Date planted: October 26, 1982
Date measured: April 15, 1986
Forester: Mark Webb (PADF)

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 20 m
Rainfall: 1000 mm

Trial site: The trial is located on dry agricultural land with no slope. The A horizon is about 18 cm thick and is a brownish black sandy clay with a pH of 8.3, a conductivity of 0.03 mmhos/cm, 14 ppm of phosphorus and 25 ppm of potassium. The B horizon is an orange brown gravelly clay with a pH of 8.3, a conductivity of 0.64 mmhos/cm, 11 ppm of phosphorus and 25 ppm of potassium.

Trial design: randomized complete block

Trees per plot: 150

Number of reps.: 1

Species	Mean Height (m)	Survival (%)	dbh (cm)
Azadirachta indica (ODH/Haiti)	5.03	55	7.5
Leucaena leucocephala (Quartier Morin)	4.90	65	4.7
Cassia siamea (Vaudreuil)	4.81	20	5.4
Hibiscus elatus (Vaudreuil)	3.70	1	4.2
Pithecellobium saman (Vaudreuil)	3.03	77	3.8
Tectona grandis	2.86	3	3.2
Simaruba glauca (Vaudreuil)	2.80	2	---
Lysiloma latisilique	2.15	3	---
Swietenia macrophylla (Vaudreuil)	1.80	2	---
Catalpa longissima (Vaudreuil)	1.60	-	---
Swietenia mahagoni (Vaudreuil)	----	-	---

Table A22. MARE GRAND BOIS (8 months)

Date planted: November 20, 1984
Date measured: July 24, 1985
Forester: Marcia McKenna (CARE)

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 35 m
Rainfall: 600 mm

Trial site: The trial is located on a yellowish clay to silty clay, deep soil with a pH of 7.8. The site has a 3% slope.

Trial design: randomized complete block

Trees per plot: 1

Number of reps.: 6

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (Jean Rabel, Haiti)	2.30	100	---
Eucalyptus camaldulensis (Petford)	1.24	53	---
Cassia siamea (Bassin Bleu, Haiti)	1.16	73	---
Colubrina arborescens (Nan Couteau, Haiti)	1.13	66	---
Azadirachta indica (Gonaives, Haiti)	1.02	95	---
Casuarina equisetifolia (ODH/Haiti)	0.61	40	---

Table A23. MARE ROUGE (9 months)

Date planted: October 4, 1984
Date measured: July 10, 1985
Forester: Marcia McKenna (CARE)
B/C zone: 53
HBZ: Subtropical moist forest
Altitude: 625 m
Rainfall: 1200 mm
Trial site: The trial is located on a deep, reddish clay, soil with a pH greater than 7.5. The site has a 1-2% slope.
Trial design: randomized complete block
Trees per plot: 1
Number of reps.: 6

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus tereticornis (13547)	1.50	100	---
Leucaena diversifolia (1624)	1.20	100	---
Calliandra calothyrsus (1522)	1.20	100	---
Eucalyptus camaldulensis (13801)	1.00	100	---
Casuarina cunninghamiana (13515)	1.00	83	---
Eucalyptus grandis	1.00	66	---
Eucalyptus tereticornis (1651)	1.00	66	---
Leucaena diversifolia (1806)	0.90	100	---
Gliricidia sepium (1360)	0.90	100	---
Eucalyptus tereticornis (13824)	0.80	100	---
Leucaena leucocephala	0.80	100	---
Eucalyptus grandis	0.70	66	---
Casuarina glauca	0.70	66	---
Casuarina cumminghamiana (13512)	0.70	66	---
Eucalyptus drepanophylla	0.60	100	---
Colubrina arborescens "bwa ple"	0.60	83	---
Colubrina arborescens "kapab"	0.60	66	---
Eucalyptus exserta	0.60	66	---
Casuarina equisetifolia	0.50	83	---
Catapa longissima	0.40	66	---
Guazuma ulmifolia	0.30	66	---
Cassia siamea	0.30	50	---
Eucalyptus sideroxylon	0.30	33	---
Caesalpina velutina	0.18	66	---
Eucalyptus citriodora	----	--	---

Table A24. MIRAGOANE (6 months)

Date planted: November 1985
Date measured: May 1986
Forester: Elia Mora de Beliard (WB)

B/C zone: 23
HBZ: Subtropical moist forest
Altitude: 123 m
Rainfall: 1455 mm

Trial site: The trial is located on a silty sand with a pH of 7.8. The site has a 12-50% slope.

Trial design: randomized block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus camaldulensis	0.66	99	---
Acacia spectablis	0.57	100	---
Acacia auriculiformis	0.57	95	---
Leucaena leucocephala	0.56	96	---
Cassia siamea	0.53	99	---
Sesbania grandiflora	0.49	66	---
Parkinsonia aculeata	0.48	97	---
Casuarina glauca	0.44	100	---
Albizia lebbek	0.41	100	---
Pithecellobium saman	0.36	98	---
Prosopis juliflora	0.34	100	---
Schaefferia frutescens	0.33	99	---
Tamarindus indica	0.33	99	---
Guazuma ulmifolia	0.32	99	---
Simaruba glauca	0.24	83	---
Cassia emarginata	0.18	100	---

Table A25. MIREBALAIS (38 months)

Date planted: May 25, 1983
Date measured: August 13, 1985
Forester: Stuart North (PADF)

B/C zone: 37
HBZ: Subtropical moist forest
Altitude: 244 m
Rainfall: 1731 mm

Trial site: The trial is located on a shallow light brownish clayey silt with a pH of 7.7. Beneath this soil layer is sand and gravel. The site has a 5-10% slope.

Trial design: randomized complete block

Trees per plot: 20   Number of reps.: 5

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala (ODH/Haiti)	9.60	98	7.1
Cassia siamea (ODH/Haiti)	8.70	92	7.1
Azadirachta indica (ODH/Haiti)	5.60	90	5.1
Albizia lebbek (ODH/Haiti)	5.00	89	4.1
Casuarina equisetifolia (ODH/Haiti)	3.20	65	---
Cassia emarginata (ODH/Haiti)	----	--	---

Table A26. NUMA/LES CAYES (28 months)

Date planted: May 1983
Date measured: October 4, 1985
Forester: Mike Bannister (PADF)
B/C zone: 37
HBZ: Subtropical moist forest
Altitude: 20 m
Rainfall: 2035 mm
Trial site: The trial is located on a deep alluvial soil with no slope and a pH greater than 7.0.
Trial design: randomized complete block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Cassia siamea (ODH/Haiti)	8.45	87	8.1
Acacia auriculiformis (ODH/Haiti)	8.42	45	8.6
Albizia lebbek (ODH/Haiti)	7.02	68	7.7
Azadirachta indica (ODH/Haiti)	6.33	48	6.5
Casuarina equisetifolia (ODH/Haiti)	4.81	26	5.7
Parkinsonia aculeata (ODH/Haiti)	----	--	---

Table A27. O'GORMAN - GANTHIER 76-6 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 55 m
Rainfall: 828 mm

Trial site: The site is dry agricultural land with a 1% slope. The deep alluvial soil has a pH of 6.5 - 6.8.

Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Eucalyptus tereticornis (11034)	13.0	37.0	13.0	0.0575
Eucalyptus microtheca (10321)	10.5	77.7	11.5	0.0360
Eucalyptus camaldulensis (10939)	10.0	40.7	12.0	0.0378
Eucalyptus deglupta (11214)	9.5	37.0	10.7	0.0285
Azadirachta indica (Haiti)	9.0	92.6	10.0	0.0235
Eucalyptus camaldulensis (10666)	9.0	25.9	9.7	0.0221
Eucalyptus camaldulensis (10911)	7.5	40.7	6.5	0.0091
Eucalyptus siderophloia (Versepuy)	7.5	33.3	9.0	0.0159
Eucalyptus crebra (8832)	7.0	25.9	8.7	0.0139
Eucalyptus tereticornis (10975)	6.7	29.6	7.3	0.0093
Eucalyptus tereticornis (10914)	5.0	22.2	6.0	0.0047
Eucalyptus dumosa (0526)	5.0	7.4	4.7	0.0029
Eucalyptus torquata (9930)	4.6	11.1	4.0	0.0019
Eucalyptus gomphocephala (9876)	4.5	3.7	2.0	0.0005
Eucalyptus paniculata (11741)	4.0	14.8	5.7	0.0034
Catalpa longissima (Haiti)	3.0	7.4	2.0	0.0003
Eucalyptus leucoxylon (9607)	2.8	3.7	2.7	0.0005
Eucalyptus leucoxylon (9602)	2.5	3.7	2.7	0.0005
Eucalyptus paniculata (10719)	2.0	3.7	2.7	0.0004
Simaruba glauca (Haiti)	2.0	3.7	2.0	0.0002
Eucalyptus tereticornis (10954)	2.0	11.1	2.0	0.0002
Eucalyptus occidentalis (7382)	2.0	3.7	1.5	0.0001
Eucalyptus gomphocephala (9805)	2.0	3.7	1.4	0.0001
Eucalyptus salmonophloia (9919)	1.5	3.7	1.9	0.0001
Eucalyptus brockwayi (10104)	0.8	3.7	1.3	0.00004
Eucalyptus dundasii (6831)	---	---	---	------
Eucalyptus exserta (11028)	---	---	---	------
Eucalyptus flocktoniae (7981)	---	---	---	------
Eucalyptus pimpiniana (9404)	---	---	---	------
Eucalyptus tereticornis (10826)	---	---	---	------
Eucalyptus stricklandii (9927)	---	---	---	------
Eucalyptus oleosa (9910)	---	---	---	------
Eucalyptus transcontinentalis (9932)	---	---	---	------
Eucalyptus astringens (10879)	---	---	---	------

Table A28. O'GORMAN - GANTHIER 76-7 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 55 m
Rainfall: 828 mm

Trial site: The site is dry agricultural land with a 1% slope. The deep alluvial soil has a pH of 6.5 - 6.8.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Casuarina cunninghamiana (10879)	8.5	66.6	8.0	0.014
Casuarina equisetifolia (Haiti)	8.0	25.9	4.8	0.005
Casuarina cristata (11176)	7.0	59.2	5.0	0.005
Casuarina glauca (8645)	4.0	7.4	3.2	0.001
Casuarina equisetifolia (Haiti)	3.5	29.6	2.6	0.001
Casuarina stricta (8112)	2.0	3.7	2.0	0.0002

Table A29. O'GORMAN - GANTHIER 76-8 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 55 m
Rainfall: 828 mm

Trial site: The site is dry agricultural land with a 1% slope. The deep alluvial soil has a pH of 6.5 - 6.8.

Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Parkinsonia aculeata (Cyprus)	3.5	77.7	3.5	0.001
Acacia tortilis (Kenya)	3.2	77.7	3.2	0.0005
Acacia aneura (10204)	1.8	7.4	1.3	0.0001
Acacia farnesiana (11147)	1.2	88.8	2.2	0.0002
Acacia pychantha (8476)	0.4	22.2	---	---
Acacia tchad (Australia)	---	----	---	---

Table A30. O'GORMAN - GANTHIER 76-9 (9 years)

Date planted: 1976
Date measured: 1985
Forester: FAO

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 55 m
Rainfall: 828 mm

Trial site: The site is located on dry agricultural land with a 1% slope. The deep alluvial soil has a pH of 6.5 - 6.8.
Trial design: randomized complete block
Trees per plot: 9
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Azadirachta indica (Haiti)	11.0	100.0	11.6	0.039
Swietenia mahogoni (Haiti)	6.0	85.2	5.2	0.004
Simaruba glauca (Haiti)	6.0	40.7	3.7	0.002
Simaruba sp. (Haiti)	4.0	48.1	5.2	0.003
Swietenia macrophyla (Haiti)	1.0	3.7	5.2	0.001
Eleagnus angustifolia (Turkey)	---	----	---	-----
Cedrela odorata (Haiti)	---	----	---	-----

Table A31. PAILLANT - SALAGNAC (6 months)

Date planted: November 1985
Date measured: May 1986
Forester: Elia Mora de Beliard (WB)
B/C zone: 81
HBZ: Lower montane moist forest
Altitude: 980 m
Rainfall: 1347 mm
Trial site: The trial is located on a reddish lateritic clay soil.
Trial design: randomized block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus camaldulensis	0.60	96	---
Casuarina stricta	0.37	95	---
Casuarina glauca	0.31	97	---
Casuarina robusta	0.29	99	---
Casuarina cunninghamiana	0.26	99	---
Casuarina equisetifolia	0.21	97	---
Casuarina stricta	0.20	99	---

Table A32. PASSE CATABOIS 251.1 (26 months)

Date planted: May 26, 1983
Date measured: July 24, 1985
Forester: Marcia McKenna (CARE)
B/C zone: 12
HBZ: Subtropical dry forest
Altitude: 120 m
Rainfall: 987 mm
Trial site: The trial is located on a deep stoney brown silty clay soil with a pH of 7.8 and a 1-2% slope.
Trial design: randomized complete block
Trees per plot: 25
Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala	3.92	78	3.8
Cassia siamea	3.56	73	3.1
Azadirachta indica	2.93	61	3.0
Eucalyptus camaldulensis	2.75	18	2.4
Acacia auriculiformis	2.70	56	1.8
Casuarina equisetifolia	2.48	10	---
Parkinsonia aculeata	1.70	65	---
Catalpa longissima	1.24	31	---
Prosopis juliflora	----	--	---
Pinus caribaea var. hond.	----	--	---

Table A33. PASSE CATABOIS 252.2 (9 months)

Date planted: November 8, 1984
Date measured: July 24, 1985
Forester: Marcia McKenna (CARE)

B/C zone: 12
HBZ: Subtropical dry forest
Altitude: 120 m
Rainfall: 987 mm

Trial site: The trial is located on a deep stoney brown silty clay soil with a pH of 7.8 and a 0-40% slope.
Trial design: randomized complete block
Trees per plot: 1
Number of reps.: 6

Species	Mean Height (m)	Survival (%)	dbh (cm)
Leucaena leucocephala	1.12	83	---
Eucalyptus camaldulensis	0.91	83	---
Azadirachta indica	0.56	74	---
Cassia siamea	0.51	60	---
Casuarina equsetifolia	0.50	38	---
Colubrina arborescens	0.36	45	---

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Table A34. PLAISANCE (18 months)

Date planted: October 26, 1984
Date measured: April 16, 1986
Forester: Mark Webb (PADF)

B/C zone: 35
HBZ: Subtropical moist forest
Altitude: 360 m
Rainfall: 1900 mm

Trial site: The trial is located on a hillside garden site with a slope of 10-100%. The A horizon is an orange-red clay having a depth of 18 cm and a pH of 7.3, a conductivity of 0.26 mmhos/cm and 11 ppm of phosphorus and potassium. The B horizon is an orange clay with a pH of 7.3, a conductivity of 0.28 mmhos/cm, 11 ppm of phosphorus and 13 ppm of potassium.

Trial design: completely randomized block

Trees per plot: 25 Number of reps.: 1

Species	Mean Height (m)	Survival (%)	dbh (cm)
Eucalyptus robusta (CSIRO)	4.29	60	3.3
Eucalyptus camaldulensis (CSIRO 13433)	4.10	76	---
Eucalyptus camaldulensis (CATIE 1202)	4.01	70	---
Eucalyptus camaldulensis (CSIRO 12186)	4.00	80	---
Eucalyptus citriodora (CSIRO)	3.54	27	---
Grevillea robusta (T.S.I.)*	2.37	60	---
Casuarina equisetifolia (T.S.I.)*	2.03	12	---
Swietenia macrophylla (Haiti)	1.82	62	---
Catalpa longissima (Haiti)	1.00	6	---
Casuarina cunninghamiana (T.S.I.)*	----	--	---

*T.S.I. - Tree Seeds International

Table A35. PUILBOREAU (38 months)

Date planted: November 5, 1982
Date measured: January 22, 1986
Forester: Mark Webb
(PADF)

B/C zone: 91
HBZ: Lower montane moist forest
Altitude: 880 m
Rainfall: 1800 mm

Trial site: The trial is located on a rocky mountain side with a slope of 40-130% and a soil depth ranging from one meter at the bottom of the trial to approximately 40 cm at the top of the trial. The A horizon is about 15 cm deep and is a black gravelly clay loam with a pH of 7.6, 6 ppm of phosphorus and 50 ppm of potassium. The B horizon is a brown-black to orange brown clay.

Trial design: randomized complete block

Trees per plot: 25 Number of reps.: 2 and 4

Species	Mean Height (m)	Survival (%)	dbh (cm)
Casuarina equisetifolia (CSR 24 EQS)	4.29	70	---
Casuarina glauca (CSIRO 13142)	3.58	90	---
Casuarina cunninghamiana (C.S.C.)	3.41	85	---
Pinus occidentalis (Kenscoff, Haiti)	1.48	17	---
Casuarina stricta (C.S.C.)*	---	35	---
Casuarina littoralis (CSIRO 13376)	---	26	---
Casuarina cristata (CSIRO 13131)	---	10	---

*C.S.C. - Carter Seed Company

Table A36. VAUDREUIL - GANTHIER 75-1 (10 years)

Date planted: 1975
Date measured: 1985
Forester: FAO

B/C zone: 17
HBZ: Subtropical dry forest
Altitude: 50 m
Rainfall: 828 mm

Trial site: The site is dry agricultural land with a 1% slope. The alluvial, fine-textured soil is a silty-loam with a high component of clay. The soil has a pH of 7.5-8.0 and is lacking in organic matter.
Trial design: randomized complete block
Trees per plot: 25 Number of reps.: 3

Species	Mean Height (m)	Survival (%)	dbh (cm)	Volume (m^3 /tree)
Casuarina equisetifolia (South Africa)	15.2	56.0	15.6	0.097
Casuarina equisetifolia (South Africa)	14.3	49.3	16.1	0.096
Casuarina cristata (South Africa)	11.2	30.6	11.2	0.035
Azadirachta indica (Haiti)	10.5	97.3	17.4	0.079
Simaruba glauca (Haiti)	10.0	53.3	12.2	0.038
Swietenia macrophylla (Costa Rica)	10.0	74.6	11.8	0.037
Swietenia mahogani (Haiti)	8.2	89.3	10.8	0.026
Catalpa longissima (Haiti)	7.5	65.3	9.3	0.016
Eucalyptus gomphocephala (Middle Orient)	2.6	1.3	5.5	0.002

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THREE DIRECT SEEDING TRIALS

IN HAITI

By

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The author is a research forester for the University of Maine Agroforestry Outreach Research Project. The work reported here was sponsored under USAID Project No. 521-0122.

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CHAPTER 1

INTRODUCTION

Direct seeding is the manual or mechanical planting of seed on the soil surface or in holes and covered with soil. Direct seeding, along with cuttings and clones is the only way in which mankind grows plant materials. Agriculture is almost entirely based on direct seeding. In forestry, however, seedling production is the mainstay of the reforestation effort in the world today. Technically, one could say that the seedlings were originally direct seeded into the containers, but this does not appropriately represent the material being outplanted. It is obvious that direct seeding of a variety of forest tree species has proven successful in many countries under varied conditions.

The potential application of direct seeding within the AOP is limited. Several factors are essential if the direct seeding of forest tree species is to be successful in Haiti. These are:

1) A population that desires trees

2) Available land for growing trees

3) The ability to easily collect large quantities of the appropriate seed species

4) The ability of the project to store and distribute seed in a timely manner so that farmers are able to plant the seed well before the rainy season

The purpose of this report are to summarize the results of three direct seeding trials which were established under this contract and determine whether this technique should be applied in AOP.

CHAPTER 2

METHODS AND MATERIALS

Three study sites were selected on which to perform the direct seeding research. The sites were located in Ganthier, Cabaret (formerly Duvalierville) and Saut d'Eau. The site selection criteria were based on the availability of land, the ability to protect the site from animal and human trespass, the proximity to Port-au-Prince, and the amount of rainfall. Thus, the three sites represented a variety of rainfall conditions, namely, dry (720mm) with a two percent slope, dry (900mm) with a 40% slope, and wet (1800mm) with a 16% slope. The percent slope was determined using the ocular method.

The survival data for each site was summed by plot means and the means were transformed using an arcsine square root function and analyzed with ANOVA. If significance was found between the main effects, the new Duncan's multiple range test was used to find significant differences between the treatments. The individual tree heights were analyzed by ANOVA, and if significant differences were found between the main effects, the new Duncan's multiple range test was applied.

Ganthier

The study site was located approximately 25 km east of Port-au-Prince in the Cul-de-Sac Plain (Lat. 18° 40'N, Long. 72° 10'W). The site is generally flat and the altitude is 90 meters above mean sea level.

The climatic conditions of the site exhibit only minor fluctuations throughout the year. Mean monthly temperatures range from 24° C in January to 28° C in July (OAS, 1972). Annual rainfall is about 720 mm which falls in two distinct rainy seasons; a very brief April/May season and a longer season from August through October.

The soils are high in base saturation, pH and organic matter and are characterized by thick, poorly defined surface horizons. The soil texture generally ranges from clay to silty clay.

Composite soil samples were taken at a depth of 0-10 and 50-60 centimeters. The samples were analyzed at Agricultural Services Inc., Bon Repos, Haiti. The results showed that conductivity was 0.85 mmho/cm, the pH was 6.8, phosphorus was 18 ppm and potassium was 56 ppm.

The site was prepared for planting on April 25, 1985 by two local farmers who dug shallow trenches 20 centimeters wide, 10

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centimeters deep and 30 meters in length with a Haitian hoe. During this process the vegetation, which consisted mostly of grasses and a few members of the Caesalpiniaceae and Mimosaceae sub-families was cleared. The trenches were oriented in an east-west direction and were spaced at one meter intervals.

The seeds of *Pithecellobium dulce*, *Leucaena leucocephala*, and *Prosopis juliflora*) were collected at ODH. *Colubrina arborescens* was collected near Jean Rabel by CARE. Germination tests were performed on each seed lot under subdued light in petri dishes before the seeds were sown. In addition, seeds of each species required a different scarification method so that an acceptable percentage of germination resulted. Pithecellobium received no seed treatment, whereas Leucaena was soaked in 80° C water for three minutes and Prosopis and Colubrina were soaked for five seconds in boiling water. Germination percentages of [illegible], 56, 30 and 20 were found after ten days for Pithecellobium, Leucaena, Prosopis and Colubrina respectively (Table 1).

The trial was planted on April 25, 1985 using a randomized complete block design containing three replications of each species. Leucaena and Pithecellobium seed were sown every 15 centimeters in the row and 25-30 mm deep, while Colubrina and prosopis were sown two seed every 15 centimeters and 10-15 mm deep. The seeds were sown at different depths because of their size. The trial was fenced one month after planting to prevent browsing by goats and sheep.

During the first two months, germination was recorded on a weekly basis. After this period, germination was recorded at 13, 17 and 24 weeks. Seedling heights were recorded at eight and 24 weeks after direct seeding. Rainfall was recorded throughout the trial period. The trial was destroyed during the political disturbance of February, 1986.

Cabaret

The study site was located about 25 km NNW of Port-au-Prince along the north shore of Port-au-Prince Bay (Lat. 18° 44'N, Long. 72° 26'W). The area consists of rolling and steep hills with severely eroded ravines and hillsides throughout. The vegetation on the site consisted of 80% *Prosopis juliflora* and *Acacia* species and the remaining vegetation was composed of other members of the Caesalpiniaceae, Mimosaceae, Cactaceae and Graminaceae sub-families. The altitude of the site is 100 meters above mean sea level.

The climatic conditions of the site exhibit very small fluctuations throughout the year. The mean monthly temperatures range from 25° C in January to 28.5° C in August (OAS, 1972). The annual rainfall is 900 mm which falls in two rainy seasons; April/May and August/October.

The trial is located in Buffum/Campbell zone 17, on a shallow, very erodable reddish brown, clay to silty clay soil which was derived from limestone parent material. Composite soil samples were taken at a depth of 0-10 cm and 50-60 centimeters. The 0-10 cm layer had a pH of 7.6, a conductivity of 13 mmho/cm, 13 ppm of phosphorus and 25 ppm of potassium. At a depth of 50-60 cm, the pH was 7.4, conductivity was 10 mmho/cm, 15 ppm of phosphorus and 50 ppm of potassium. The trial has a 40 percent slope.

The site was cleared of woody vegetation on May 2-3, 1985 by two local farmers using machetes. The trial was fenced and three water diversion canals and five contours canal were constructed on the upper perimeter of the trial to control excess water entering the trial site from the adjacent hill. Shallow trenches with the same dimensions as those in Ganthier were dug perpendicular to the slope in an east-west orientation and three meters apart making certain that a small bund of soil was left on the downhill side of the trench to collect water. The seeds were sown on May 9, 1985 using the same spacing and design as in Ganthier.

The seed for this trial was the same as for the Ganthier trial. The scarification treatments for Prosopis and Colubrina however, were altered to obtain a higher germination percentage than was found in the Ganthier trial. Prosopis was soaked in 80° C water for 1 1/2 minutes and Colubrina was boiled for 7 seconds, resulting in germination percentages after ten days of 76 and 25 respectively (Table 2).

Germination was recorded on a weekly basis for the first two months. After this period, germination was recorded at 11, 22, 46, 59 and 64 weeks. Seedling heights were recorded at 8, 23, 45, 58 and 64 weeks after direct seeding.

Saut d'Eau

The study site was located approximately 30 km NNE of Port-au-Prince between the Artibonite and La Tombe rivers (Lat. 18° 50'N, Long. 72° 14'W). The area is rolling hills with fertile valleys and bottomland. The site has a 16% slope and an altitude of 250 meters. Before the trial, the site was used to graze horses, cows and goats. The vegetation on the site consisted mainly of grasses with a few weedy shrub species.

The climatic conditions of the site exhibit very small fluctuations throughout the year. The mean monthly temperatures range from 23° C in January to 26° C in August (OAS, 1972). The annual rainfall is about 1800 mm which falls mostly in a single rainy season from April to October.

The trial is located on a shallow, blackish brown, stoney silty clay soil which was derived from limestone parent material. A composite soil sample was taken in late April, 1985 at a depth of 0-10 and 50-60 centimeters. The 0-10 cm layer had a pH of 6.8, a conductivity of 3.2 mmho/cm, 16 ppm of phosphorus and 100 ppm of potassium. At a depth of 50-60 cm, the pH was 8.0, conductivity was 0.4 mmho/cm, 12 ppm of phosphorus and 25 ppm of potassium.

The site was prepared on May 15, 1985 by two local farmers who cleared the site of vegetation with machetes and dug shallow trenches 20 centimeters wide, 10 centimeters deep and 15 meters in length with a Haitian hoe. The trenches were oriented in a northwest-southeast direction and were spaced at one meter intervals.

Four tree species; *Albizia lebbek*, *Colubrina arborescens*, *Cassia siamea* and *Leucaena leucocephala* were sown at this site. The seed lots of Colubrina and Leucaena were the same as those used in Ganthier and Cabaret. Albizia and Cassia which were collected at ODH. Cassia required no seed treatment, whereas Albizia was soaked for 1.5 minutes in 80° C water. The other two species had the same scarification treatments used in the Cabaret trial. Before the seeds were sown, germination tests were performed on each seed lot in petri dishes. Germination percentages of 70, 56, 50 and 25 were found after ten days for Albizia, Leucaena, Cassia and Colubrina respectively (Table 3).

The trial was planted on May 16, 1986 using a randomized complete block design containing six replications of each species. Albizia, Cassia and Leucaena were planted every 15 centimeters in the row and 25-30 mm deep while Colubrina was planted two seeds every 15 centimeters and 10-15 mm deep. Again, the seed were planted at different depths because of their size.

Germination and survival were recorded on a weekly basis for the first two months. After this period, the germination was recorded 11, 15, 22, 44, 53 and 62 weeks. Seedling height was recorded at 8, 22, 44 and 62 weeks after direct seeding. The rainfall was recorded daily throughout the trial period.

CHAPTER 3

RESULTS AND DISCUSSION

Ganthier

In discussing the results of the direct seeding trial, it is helpful to understand how each species germinated under ideal moisture conditions, in order to more accurately interpret the results. Listed below in Table 1 are the controlled germination test results for 100 seeds of each species which were germinated under subdued light in petri dishes.

Table 1 Percent germination over time by species

Species	Days 1	2	3	4	5	6	7	8	9	10
Colubrina	0	0	0	0	1	1	1	8	19	20
Leucaena	2	16	38	40	44	51	53	56	56	56
Pithecellobium	6	26	48	64	77	85	92	93	93	94
Prosopis	0	6	10	16	22	22	25	30	31	31

The soil was moist when the seeds were sown because of a 22 mm rainfall on the evening of April 23. In addition, 7 mm of rain fell on April 25 after the trial was planted.

Survival

Prosopis and Colubrina, which are both small-seeded species, did not germinate in this trial. This may be due to the following circumstances:

1. These species were planted at a depth of 10-15 millimeters. At this depth, the soil was more easily dried by the sun than soil at greater depths. Further, had the original vegetative cover not been cleared from the planting site, these species may have germinated because the soil would have been protected from the sun and thus remained moister for a longer period. When Prosopis regenerates under natural conditions, many of the seeds germinate on the moist soil surface, which is protected from the sun by the shade of the mother tree. Therefore, for a given amount of soil moisture, seeds planted at

shallower depths or in direct sunlight have less chance to germinate because the length of time during which they experience favorable germination conditions is shortened.

2. These species require at least one day to germinate (Table 1). Because the germination conditions at planting time were not ideal, the seeds needed additional time to germinate. During this time however, the soil was dried and the seeds were not able to germinate or germinated and died in the soil.

3. The rains were spaced too far apart for shallow planted seed to germinate. Leucaena and Pithecellobium exhibited rapid early germination because they were planted at a depth of 25-30 mm and thus were able to take advantage of the soil moisture, and because under favorable moisture conditions, these species germinate rapidly. In addition, the soil at this depth did not dry out until the fourth week, at which time many of the seedlings had achieved good root penetration into the moister soil below.

In general, Leucaena and Pithecellobium had similar germination/survival curves over the 24 week life of the trial (Figure 1) with Pithecellobium having significantly greater germination and survival throughout. During the second week of the trial, both species continued to germinate despite the lack of rain. During the third through fifth week, 41, 9.5 and 0 mm, respectively, of rainfall fell and throughout this period, Pithecellobium exhibited exceptional germination. Leucaena had good germination during the third week and would have continued to do so during the fourth and fifth weeks, but goats and sheep entered the trial and consumed eight percent of the young seedlings.

The sixth to tenth week period was rainless, except for the seventh week in which 9 mm fell. The 9 mm rain during the seventh week slowed the decline in germination and survival of both species, but overall during the sixth to tenth week, Pithecellobium and Leucaena declined 40 and 12.8 percent, respectively. Beyond this period, rainfall was more than adequate for additional germination, but survival rates declined. This is an important observation which shows that the survival of direct seeded material consists of the daily germination and mortality of seeds and the continued survival of seedlings. This dynamic system is always in motion and through the weekly survival counts, a "snapshot" view of the system was recorded. Therefore, it is not known whether all of the seed had germinated by the 24th week or if there were still some which had not yet germinated. What is known, is that the longer seeds remain in the ground ungerminated, the greater their chances of not germinating because of insect and animal predation, diseases and physical displacement by water.

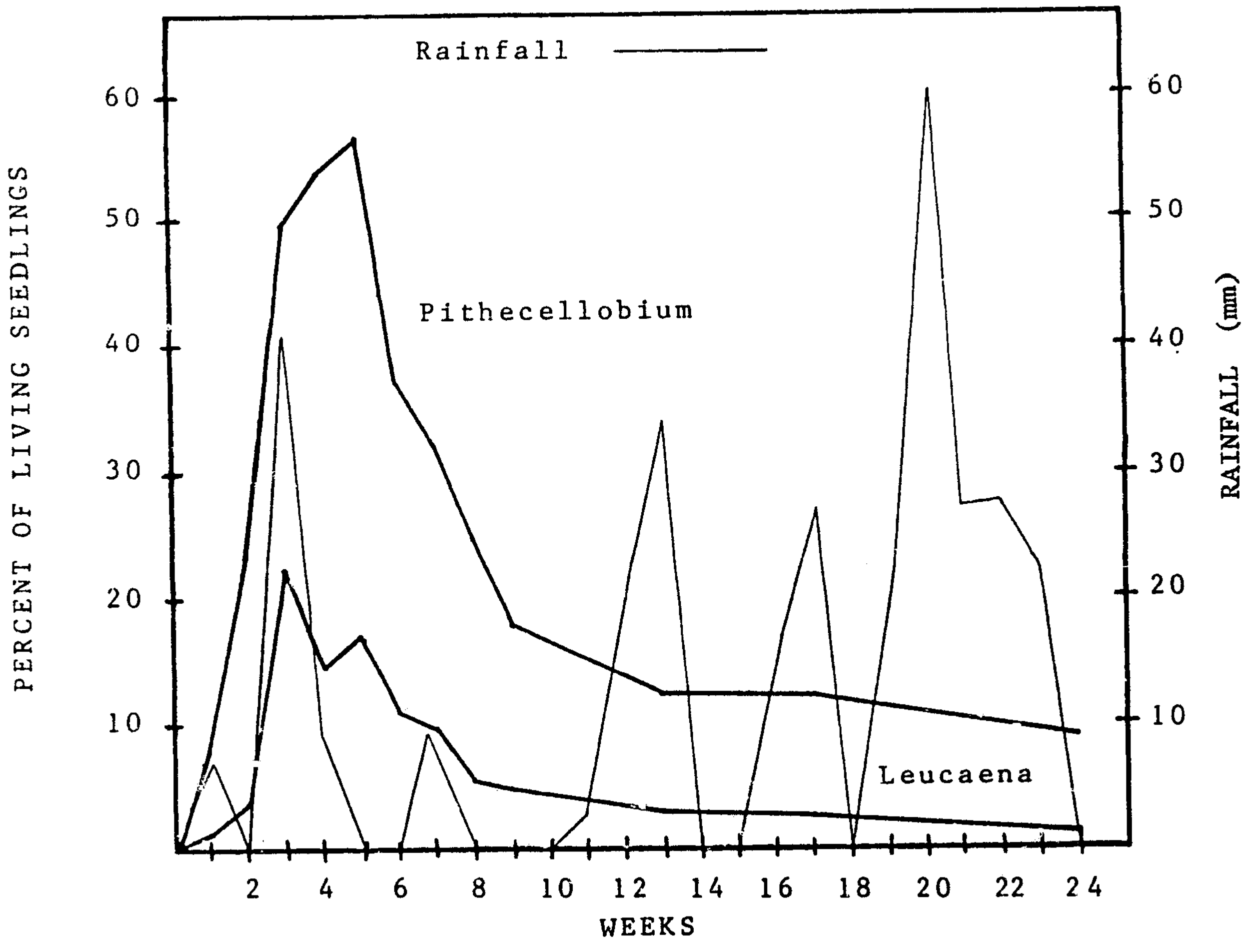

Figure 1 Ganthier - Sample of Living Seedlings as a Percentage of Seeds Sown

Height

The eight week height growth showed that Pithecellobium was significantly taller than Leucaena with 7.3 and 4.8 cm, respectively. At 24 weeks, there were no significant differences in height between the two species which averaged 11.4 and 11.1 cm for Pithecellobium and Leucaena, respectively.

Cabaret

Listed below in Table 2 are the germination test results for 100 seeds of each species which were germinated in petri dishes under subdued light.

Table 2 Percent germination over time by species

Species	Days									
	1	2	3	4	5	6	7	8	9	10
Colubrina	0	0	0	0	6	10	13	17	23	25
Leucaena	2	16	38	40	44	52	53	56	56	56
Pithecellobium	6	26	48	64	77	85	92	93	93	94
Prosopis	4	24	37	42	47	49	55	64	75	78

The soil was damp, but not really moist when the seeds were sown on May 9, 1985. Later that evening however, 7 mm of rain fell.

Survival

Colubrina did not germinate in this trial because the rains washed additional soil on top of the small seeds and thus they were not able to push their primary leaves to the soil surface. The other three species however, germinated during the first week because of the following reasons:

1) The soil moisture conditions were very favorable from the 35 mm of rain that fell during that week.

2) These species had larger seeds which were less affected by the added soil covering.

3) These species inherently had more rapid germination (Table 2).

During the second week, Pithecellobium exhibited a phenomenal germination increase of 53.3% while Leucaena and Prosopis increased 11.4 and 11.5% respectively (Figure 2). This

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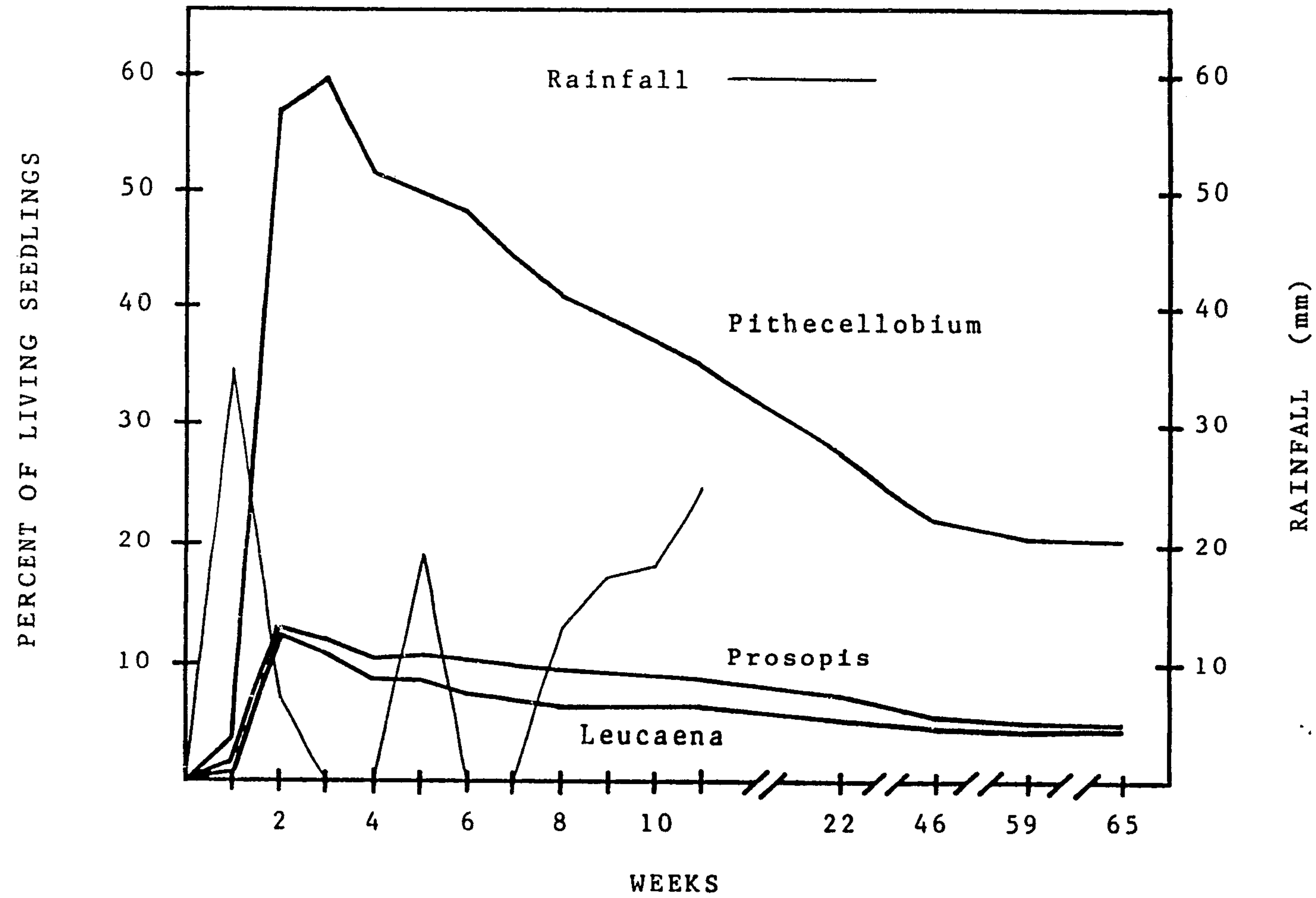

Figure 2 Cabaret - Sample of Living Seedlings as a Percentage of Seeds Sown

clearly showed that Pithecellobium was able to rapidly take advantage of available moisture while Leucaena and Prosopis did not. Possibly, by the time that these two species had imbibed enough water to germinate, the available moisture in the soil was no longer there and the seeds died shortly after germination. Furthermore, many of these seed which were not visible at the soil surface, would not have been recorded in this study. This would account for the overall low survival of these two species. The next five weeks were rainless except for the fifth week which had 19 mm in one shower. During this period, germination and seedling survival declined, though during the fifth week, Leucaena and Prosopis had increased germination.

Rainfall from the eight to the eleventh week had good weekly totals, but these consisted of many small rains which may not have penetrated the soil enough to supply moisture to the seedlings. It is important to remember that after two to three months most of the seeds either have already germinated or for factors stated earlier, will not germinate. Beyond the eleventh week until the last measurement during the 65th week, survival for all species declined. This was due to at least a two-week drought between each measurement period and a two-month drought between the 22nd and 46th weeks. With the exception of the first week, Pithecellobium had significantly better survival than Leucaena and Prosopis throughout the trial. At no time were the latter two species significantly different from each other in survival.

Height

Leucaena was significantly taller than Pithecellobium and prosopis at every height measurement except at eight weeks where there were no significant height differences between species. Throughout the trial, there were no significant height differences found between Pithecellobium and Prosopis. As would be expected, all of the species grew rapidly in the rainy seasons (weeks 8-22 and 45-58) and more slowly in the dry seasons (weeks 23-44 and 59-64). (See Figure 3) During the second rainy season, both Leucaena and Prosopis had larger growth rates than in the first rainy season with Prosopis having the greater percentage increase from the first season. During the second dry season, Leucaena's growth rate declined while that of Prosopis increased. The growth rate of Prosopis in the second dry season should have been greater, but because of careless weeding by several of the local farmers, many of the leader shoots were cut and thus growth rates appeared to be surpressed.

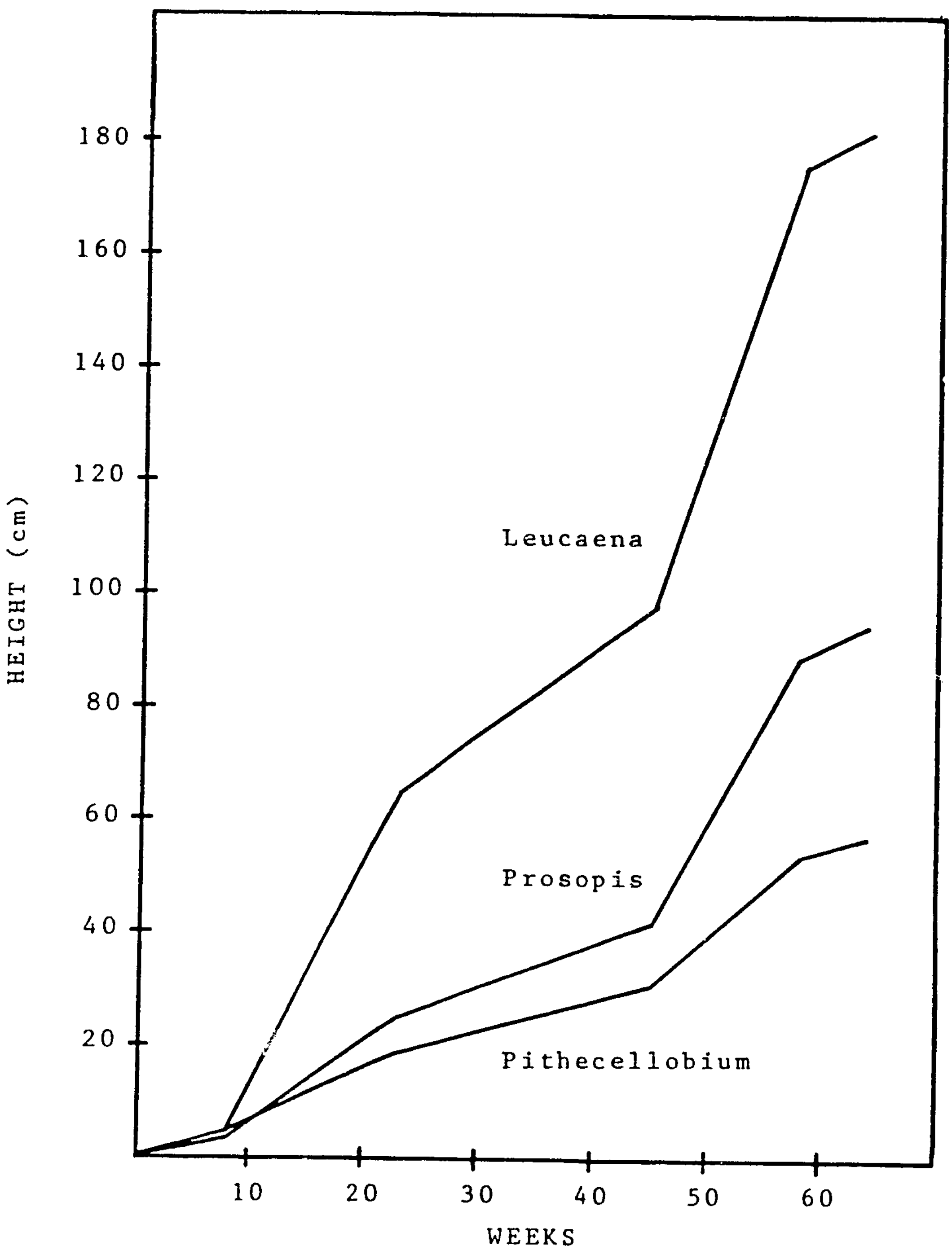

Figure 3 Cabaret - Height of Sown Seedlings over Time

Saut d'Eau

Listed below in Table 3 are the germination test results for 100 seeds of each species which were germinated in petri dishes under subdued light.

Table 3 Percent germination over time by species

Species	Days 1	2	3	4	5	6	7	8	9	10
Albizia	2	19	42	44	52	60	63	66	68	70
Cassia	1	9	22	35	38	46	48	50	50	50
Colubrina	0	0	0	0	6	10	13	17	23	25
Leucaena	2	16	38	40	44	52	53	56	56	56

The soil was very moist when the seeds were sown on May 16, 1985 because on the three previous days, 28, 10 and 25 mm of rain fell.

Survival

Colubrina did not germinate in this trial, though there were adequate amounts of rainfall after the first two weeks. There is a possibility that with some of the large rains in June and July, the small seeds were covered with more soil and therefore the seeds could have germinated, but would not have been able to push their primary leaves above the soil surface before they died.

In general, the Albizia, Cassia and Leucaena germination/survival curves were quite similar (Figure 4). Albizia was the only species that germinated during the first week with 1.5 percent. Though no rain fell during the second week, there was enough moisture at the 25-30 mm depth that Cassia and Leucaena germinated with 1.3 and 1.5 percent, respectively. Albizia, because of its rapid germination in the germination test, continued to germinate well during the second week. During the third, fourth and fifth weeks, chickens and turkeys destroyed many of the young Albizia seedlings by walking on them, scratching them up and pecking off their tops. This also occurred with Leucaena during the fourth and fifth weeks. It appeared that the weeded alleyways along the direct seeded rows served as an animal path through the tall grass. Albizia and Leucaena seedlings that were up to four weeks of age appeared to break easily from top or sideways pressure, whereas Cassia did not. In addition, the chickens and turkeys did not seem to disturb the Cassia which may explain why it attained the highest germination

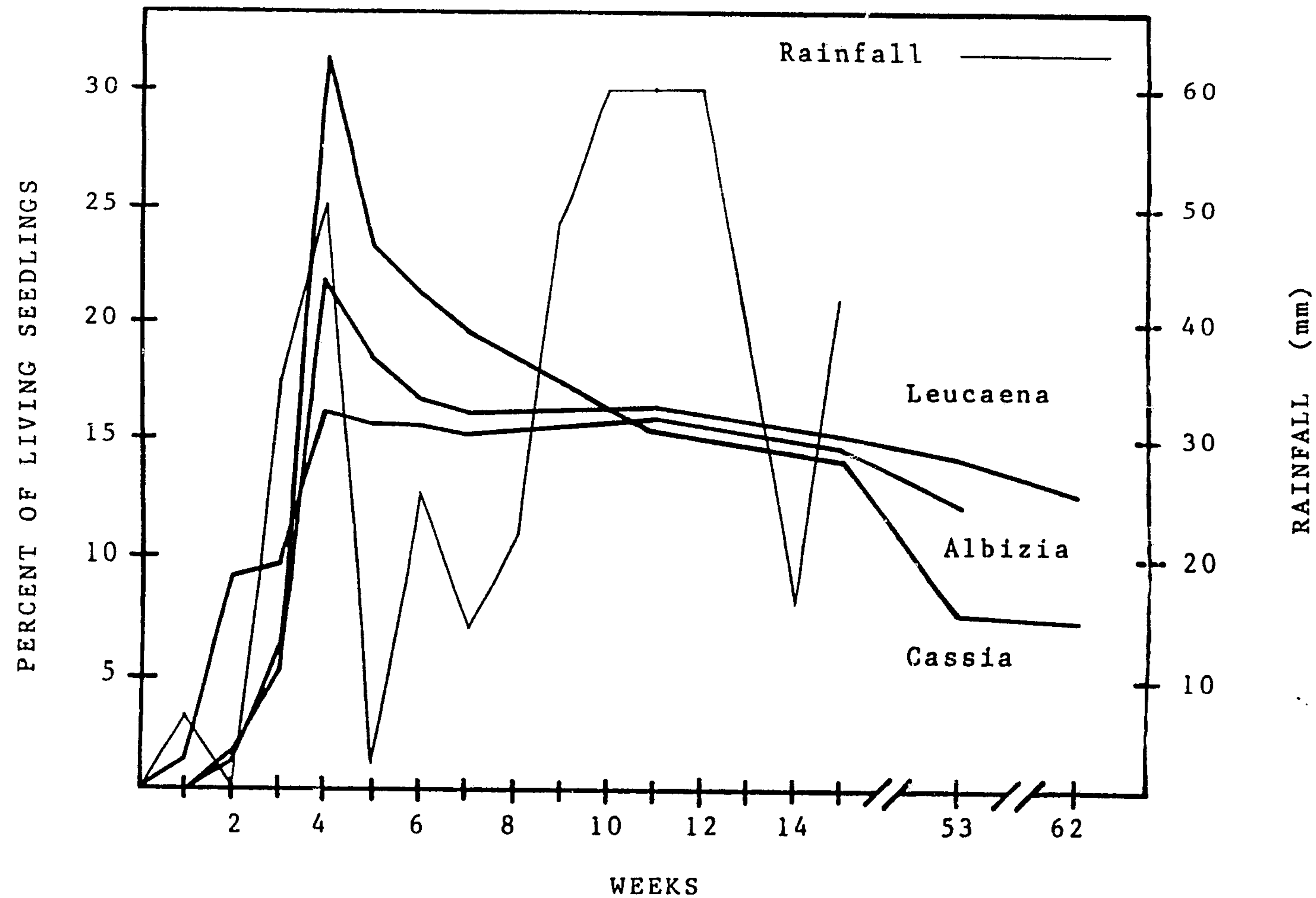

Figure 4 Saut d'Eau - Sample of Living Seedlings as a Percentage of Seeds Sown

of all species. This occurred during the fifth week. As the seedlings grew, the chickens and turkeys became less interested in them and shifted their preference to other weedy species. During the fifth week, 2.5 mm of rain fell, and because there were many newly germinated Cassia seedlings from the previous week which had little or no resistance against moisture stress, many of them died. This is illustrated very well in Figure 4 from week four to five. During the sixth and seventh weeks, all species experienced declining germination and survival rates though the rainfall was quite adequate. This may have been due to the rapid increase in light and nutrient competition the seedlings were experiencing for the flush of weed growth during the first seven weeks of the trial.

During the seventh to eleventh week, Albizia and Leucaena had a slight increase in germination, while Cassia continued to decline. This showed that these two species still had seeds which were able to germinate, while Cassia did not. The continued decline of Cassia until the eleventh week was attributed to the mortality of the newly germinated seeds from the third to fourth week. Beyond the eleventh week, many of the seed had already germinated, thus the survival curve was becoming based more on the survival of the seedlings with less influence from newly germinated seeds.

From the fifteenth to 53rd week seedling survival declined, especially for Cassia. For all species, this was most likely due to a 2.5 month period from November to January in which only 11.5 mm of rain fell. For Cassia, the greater mortality was also attributable to its shallow rooting habit, which makes the tree more susceptible to drought. During the final measurement period, the trial was heavily weeded by local farmers without supervision. During this process they completely weeded out Albizia and the smaller seedlings of Cassia and Leucaena which they probably did not notice.

Height

Height at eight weeks showed that Leucaena and Albizia were significantly taller than Cassia, but that there were no significant height differences between the two (Figure 5).

Height at 22 and 44 weeks showed that Leucaena was significantly taller than either of the other species. There were no significant height differences between Albizia and Cassia at any time. At 62 weeks, Leucaena was significantly taller than Cassia.

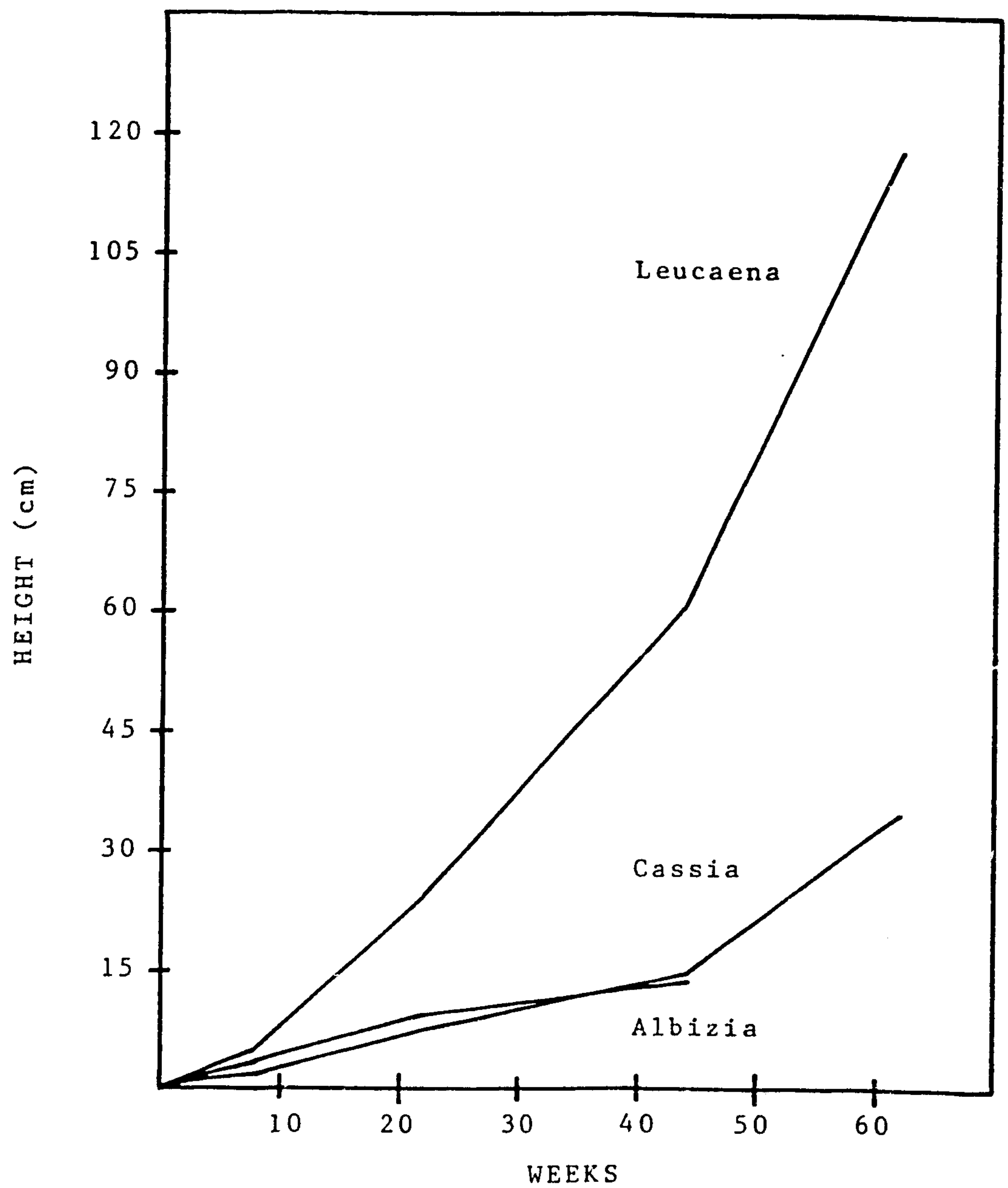

Figure 5 Saut d'Eau - Height of Sown Seedlings over Time

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The findings of this study suggest that the direct seeding technology, if applied and managed correctly, can successfully provide trees to rural Haitian farmers. This technology however, may only be applicable to areas receiving greater than 800 mm of rain because tree seeds exhibit good germination and early growth when moist topsoil conditions of a duration of no less than three weeks are present. These conditions are infrequent in areas of low rainfall, though, at times they may occur.

The study shows that the following factors should be considered when trying to successfully direct seed forest trees.

1) Medium to large seeded tree species that exhibit rapid germination and early seedling growth should be selected. In the three direct seeding trials, those species that did not exhibit rapid germination, did not germinate at all. Specifically, Prosopis did not germinate in the Ganthier trial because the seed could not rapidly take advantage of the available moisture. In the Cabaret trial, Prosopis had good germination because an improved scarification method was used, which enabled the seed to imbibe water rapidly and germinate much more quickly than with the previously used scarification method.

2) The selection of species that exhibit early downward root penetration is advantageous if young seedlings are to survive after the rains diminish. This is especially true after the rainy season because the availability of moisture for the seedlings becomes greater as their roots penetrate deeper into the soil.

3) Continuous weeding throughout the first year should be done to allow the seedlings to maximize their growth and establish themselves without competition from the surrounding vegetation. Though with some species such as Leucaena, weeding is not as critical, it has most always enhanced first year growth. Small seedlings, which are not weeded, do not exhibit rapid early growth until they become established and are easily smothered by the surrounding vegetation. Thus, without proper weeding, the seedlings remain small, stunted and in competition with the weeds for longer periods of time.

3) The construction of small basins or trenches in which the seed are planted on the sidewalls so that they are not covered by eroded materials entering the basins. These basins serve to more effectively collect water for more rapid early

germination and growth, and to provide a containment for the seed so that they are not washed away with the rains.

4) The seed must be planted at the appropriate depth in relation to the seed size. Small seed that are planted too deep will not survive because of the lack of light after germination and larger seed that are planted too shallow may not germinate because of the rapid drying of the surface soil.

The application of this technology in the AOP by the rural farmer is controllable. Therefore, if this technique is to be applied successfully in the AOP, it will require carefully planned extension activities for the farmers. In the end, farmer success with this technology will be directly related to the amount of assistance or extension services received. This is especially true when the technology is specifically applied for hedgerows.

Recommendations

These recommendations are made under the assumptions that the rural farmer will actively pursue the appropriate management practices (eg. seed depth, water catchments and weeding) of this technology. If this is not the case, then the recommendation for this technology is that it is not applicable within the AOP.

1) Research should be conducted on the effects of seed depth, water catchments and weeding on seed germination and early growth. This research should also be conducted in conjunction with the establishment of hedgerows. Emphasis should be placed on improving the scarification methods and cultural practices and broadening the selection of species to be direct seeded. Below is a list of potential direct seeding candidates.

Acacia auriculiformis	*Albizia lebbek*
Calliandra calothyrsus	*Cassia siamea*
Gliricidia sepium	*Gmelina arborea*
Leucaena leucocephala	*Pithecellobium dulce*
Prosopis juliflora	*Sesbania bispinosa*
Sesbania grandiflora	*Sesbania sesbans*

2) Small direct seeding demonstrations should be established near or adjacent to nurseries. These should clearly demonstrate to the farmers who come to the nursery to get their seedlings the effects of weeding and water catchment basins on germination and growth of direct seeded and container grown seedlings.

3) *Colubrina arborescens* should not be used as a direct seeded species.

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THE EFFECTS OF TOP-PRUNING

OUTPLANTED SEEDLINGS

IN HAITI

By

Roland A. Dupuis

The author is a research forester for the University of Maine Agroforestry Outreach Research Project. The work reported here was sponsored under USAID Project No. 521-0122.

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ACKNOWLEDGEMENTS

The author would like to thank ODH for the use of its facilities in the growing of the seedlings for this trial, and Projet Forestier National (PFN) and Bill Faxton of Emanuel Faith Mission for their generosity in providing land for this study. He would also like to thank the AFORP staff and Richard Pellek for their review of this text. Finally, much credit goes to my assistant and companion Dieubon Devilas who was instrumental in the successful completion of this study.

CHAPTER 1

INTRODUCTION

The Agroforestry Outreach Project has been actively encouraging Haitian farmers to plant and maintain trees for the last five years. During this period, over 25,000,000 seedlings have been planted with a survival rate of about 50 percent. According to the mid-project evaluation, however, this survival rate was low, but acceptable and thus it was recommended that efforts be made to increase the survival of seedlings planted by the project (USAID, 1983).

Survival rates are influenced by many environmental, technological and sociological factors. One of the most important technological factors influencing survival is the degree to which the seedling is hardened-off at the time of planting. Seedlings that are more hardened-off generally have greater survival. Top-pruning, which is the removal of the upper portion of the seedling before outplanting, may increase seedling survival by reducing transpiration losses. This is especially true for tall seedlings that have large height shoot/root ratios.

The purpose of this study was to examine the effects of top-pruning on survival and height growth and to determine whether this technique should be applied in the AOP.

CHAPTER 2

METHODS AND MATERIALS

Two study sites were selected on which to perform the top-pruning research. Sites located in Cabaret (formerly Duvalierville) and Saut d'Eau were selected because of the availability of land and because each site represented significantly different amounts of rainfall, 900mm and 1800mm, respectively. The site descriptions and environmental conditions are discussed below.

Cabaret

The study site was located about 25 km NNW of Port-au-Prince along the north shore of Port-au-Prince Bay (Lat. 18° 44'N, Long. 72° 26' W). The area has rolling and steep hills with eroded ravines and hillsides throughout. The vegetation on the site consisted of 80 percent *Prosopis juliflora* and *Acacia* species. The remaining woody vegetation was composed of other members of the Mimosaceae and Caesalpiniaceae subfamilies of Fabaceaea, and the Cactaceae and Gramineae subfamilies of Poaceae.

The climatic conditions of the site exhibit very small fluctuations throughout the year. The mean monthly temperatures range from 25° C in January to 28.5° C in August (OAS, 1972). The annual rainfall is 900 mm which falls in two rainy seasons; April/May and August/October. The altitude of the site is 100 meters above mean sea level.

The trial is located in Buffum/Campbell zone 12 on a shallow, very erodable, reddish brown, clay to silty clay soil which was derived from limestone parent material (Buffum, 1984). Composite soil samples were taken at a depth of 0-10 cm and 50-60 centimeters. The 0-10 cm layer had a pH of 7.8, a conductivity of 8.6 mmhos/cm, 125 ppm of phosphorus and 675 ppm of potassium. At a depth of 50-60 cm, the pH was 7.9, conductivity was 6.8 mmhos/cm, 60 ppm phosphorus and 125 ppm of potassium. The trial has a two percent slope.

Azadirachta indica, Casuarina equisetifolia and *Colubrina arborescens* were tested at this site. The Casuarina and neem seedlings were ODH stock grown in 70% peatmoss/30% Haitian mix and 40% peatmoss/60% Haitian mix, respectively, using the winstrip. The Colubrina seedlings was CARE stock grown in Pro-Mix using the "fives" rootrainer. Because the analysis made comparisons between treatments for a particular species, different container and mix types were acceptable for use in the trial. Half of the seedlings of each species were pruned to two-thirds of the mean height of that species at about three weeks before the seedlings were to be outplanted.

The trial site was cleared of vegetation two days before planting by three local farmers using machetes. The holes which measured 25cm x 20cm x 20cm were dug on the morning of planting by two farmers using hoes. Two seedling treatments (pruned and control) for each species were planted in four 20 tree replications on June 6, 1986.

Survival was measured at one, two, three, four, ten, twelve and fourteen months. Height was measured at planting, six, ten and fourteen months using a metric carpenter's rule. The data was analyzed with a t-test, which examined the differences between the two treatments for a particular species. Because the survival data are recorded as percentages, it was transformed for analysis using an arcsine square root function. The trial was weeded by farmers at five, ten and twelve months.

Saut d'Eau

The study site was located approximately 30 km NNE of Port-au-Prince between the Artibonite and La Tombe rivers (Lat. 18° 50'N, Long. 72° 14'W). The area has rolling hills with fertile valleys and bottomland. The site has a 16 percent slope and an altitude of 250 meters. Before the trial, the site was used to graze horses, cows and goats. The vegetation on the site consisted mainly of grasses and a few weedy shrub species of the Caesalpiniaceae subfamily.

The climatic conditions of the site exhibit very small fluctuations throughout the year. The mean monthly temperatures range from 23° C in January to 26° C in August (OAS, 1972). The annual rainfall is about 1800 mm which falls mostly in a single rainy season from April to October.

The trial is located in Buffum/Campbell zone 24 on a shallow, blackish-brown, stony silty clay soil which was derived from limestone parent material (Buffum, 1984). A composite soil sample was taken at a depth of 0-10 cm and 50-60 centimeters. The 0-10 cm layer had a pH of 7.4, a conductivity of 0.8 mmhos/cm, 14 ppm of phosphorus and 125 ppm of potassium. At a depth of 50-60 cm, the pH was 7.7, conductivity of 0.6 mmhos/cm, 10 ppm of phosphorus and 36 ppm of potassium.

The trial at this site contained *Catalpa longissima, Cassia siamea, Casuarina equisetifolia* and *Eucalyptus camaldulensis*, all of which were ODH stock planted in 40% peatmoss/60% Haitian mix, 60% peatmoss/40% Haitian mix, 70% peatmoss/30% Haitian mix and 40% peatmoss/60% Haitian mix, respectively, using the winstrip. The seedlings were pruned to two-thirds of the mean height for that species about three weeks before they were to be planted, except Catalpa, which was pruned the day before planting because of its small size.

The trial site was cleared of vegetation by two local farmers about a week before the trial was planted. Holes which measured 25cm x 20cm x 20cm were dug by two farmers on the day of planting. Two seedling treatments for each species were planted in four 20 tree replications on June 7, 1986.

Survival was measured at one, two, three, four, ten, twelve and fourteen months. The survival data was transformed using an arcsine square root function and analyzed with t-tests, which examined survival differences between the treatments for specific species. Height was measured with a metric carpenter's rule at planting, four, ten and fourteen months and analyzed with t-tests. The trial was weeded by farmers at five, ten and twelve months.

CHAPTER 3

RESULTS AND DISCUSSION

Cabaret

Survival

There were no significant survival differences found between treatments for any species. It is interesting to note the mortality which occurred during the first month of the trial. On the day before the trial was planted, 19 mm of rain fell. The previous four weeks, and the four weeks following the trial were totally without rain. The unpruned neem was unaffected by the drought, whereas the top-pruned neem suffered 2.5% mortality (Figure 1). Casuarina experienced 40% mortality, thus showing that top-pruning was ineffective at increasing early survival of Casuarina (Figure 2). Colubrina exhibited 20% more mortality for top-pruned seedlings than unpruned seedlings in the first month (Figure 3). This showed that top-pruning was detrimental to Colubrina with respect to early survival.

After 14 months however, the unpruned seedlings for all three species had better average survival than the top-pruned seedlings. The survival differences ranged from 2.5% for Colubrina to 15% for neem.

The survival of the neem, which was 96.3%, was a result of well hardened-off seedlings. This also showed that neem is well adapted to the environmental conditions of the site. Conversely, the survival of unpruned casuarina, was 11.3%, which was possibly a result of the lack of *Frankia* and other mycorrhizal associations.

Height

As would be expected, top-pruned seedlings were significantly shorter. However, the six, ten and fourteen month heights for Casuarina showed no significant differences between the treatments (Figure 2A). This was mainly attributable to the high mortality experienced by the species and the large variances in the populations.

Colubrina had significant height differences between treatments at six months, but none were found at ten and fourteen months (Figure 3A). The unpruned seedlings were again taller than the pruned seedlings.

Neem showed significant height differences between the two treatments at six, ten and fourteen months (Figure 1A). The unpruned seedlings were in all cases taller than the pruned seedlings.

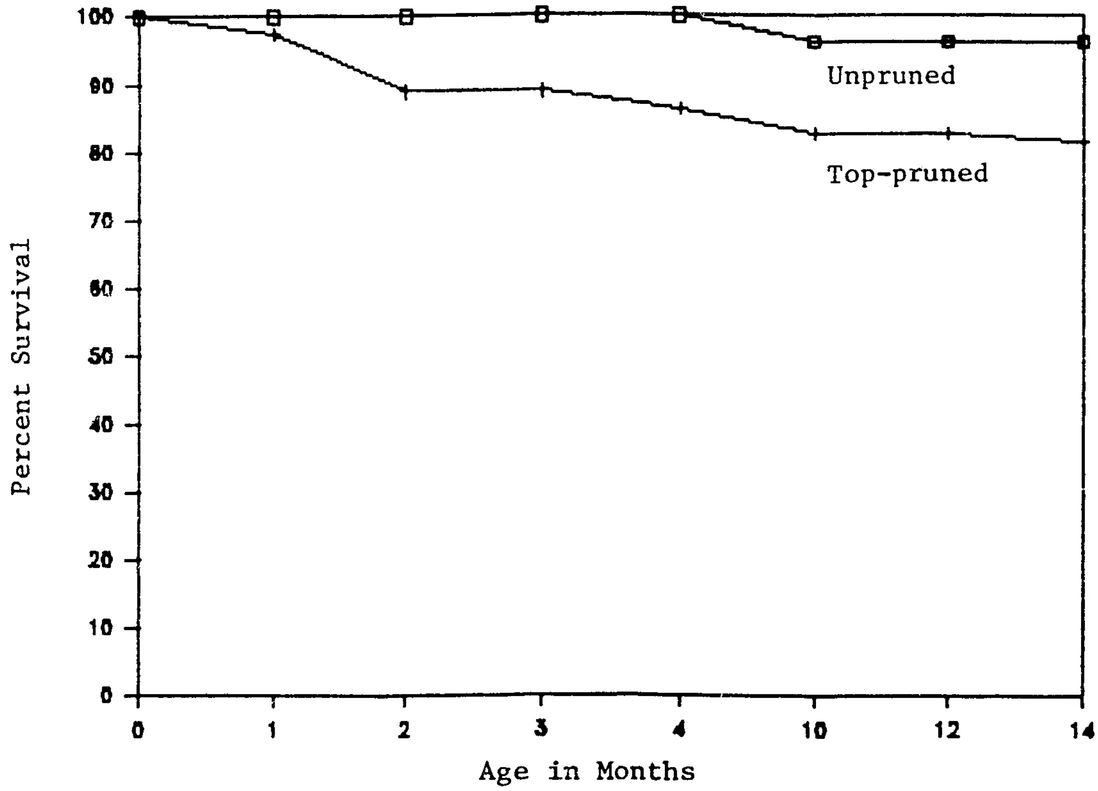

Figure 1 Survival of Azadirachta at Cabaret

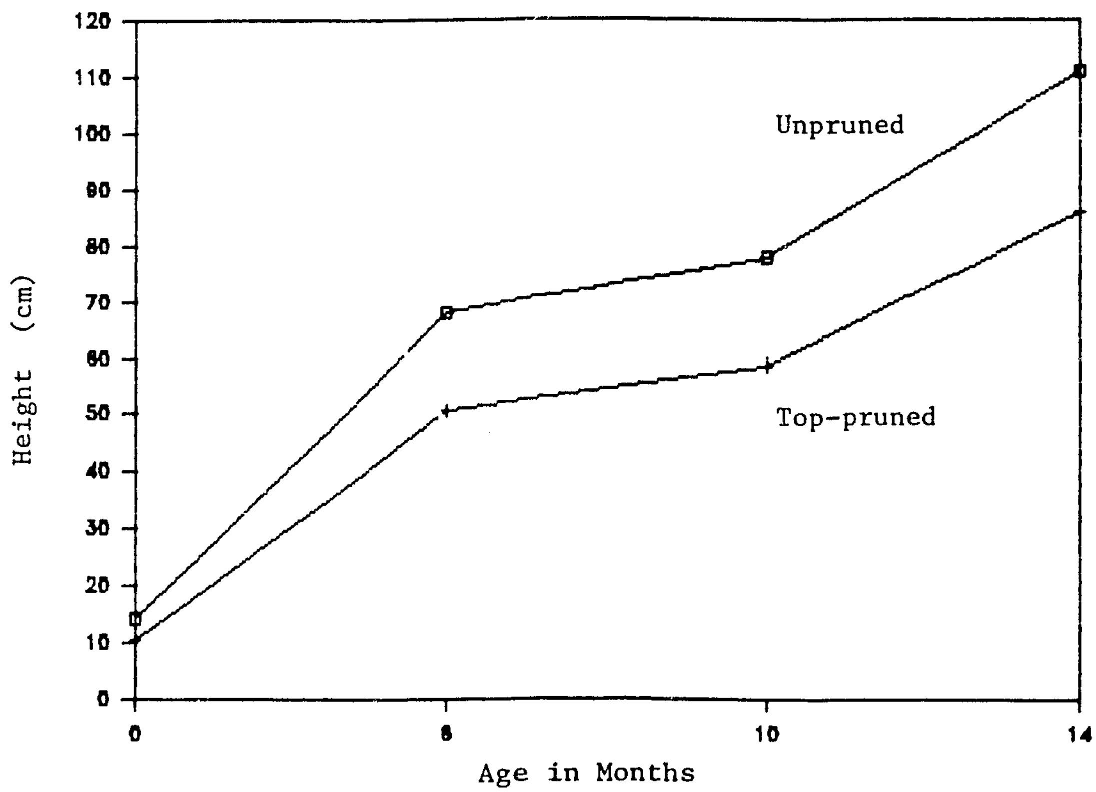

Figure 1A Height Growth of Azadirachta at Cabaret

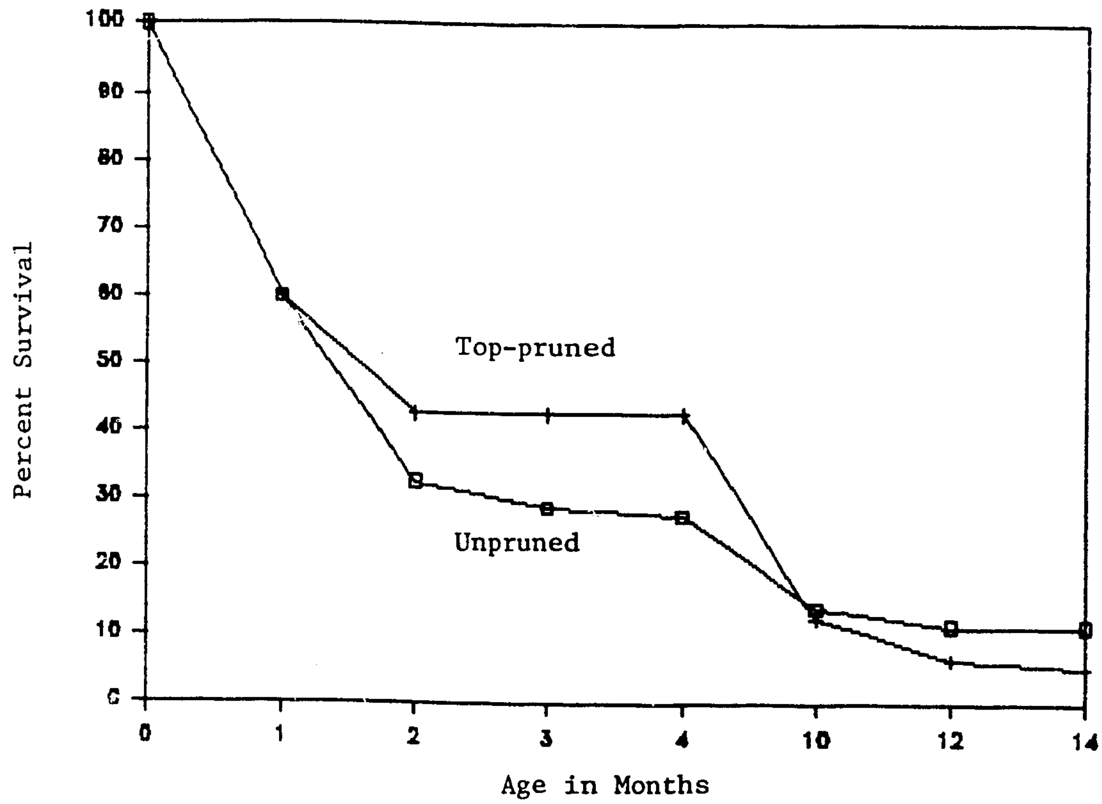

Figure 2 Survival of Casuarina at Cabaret

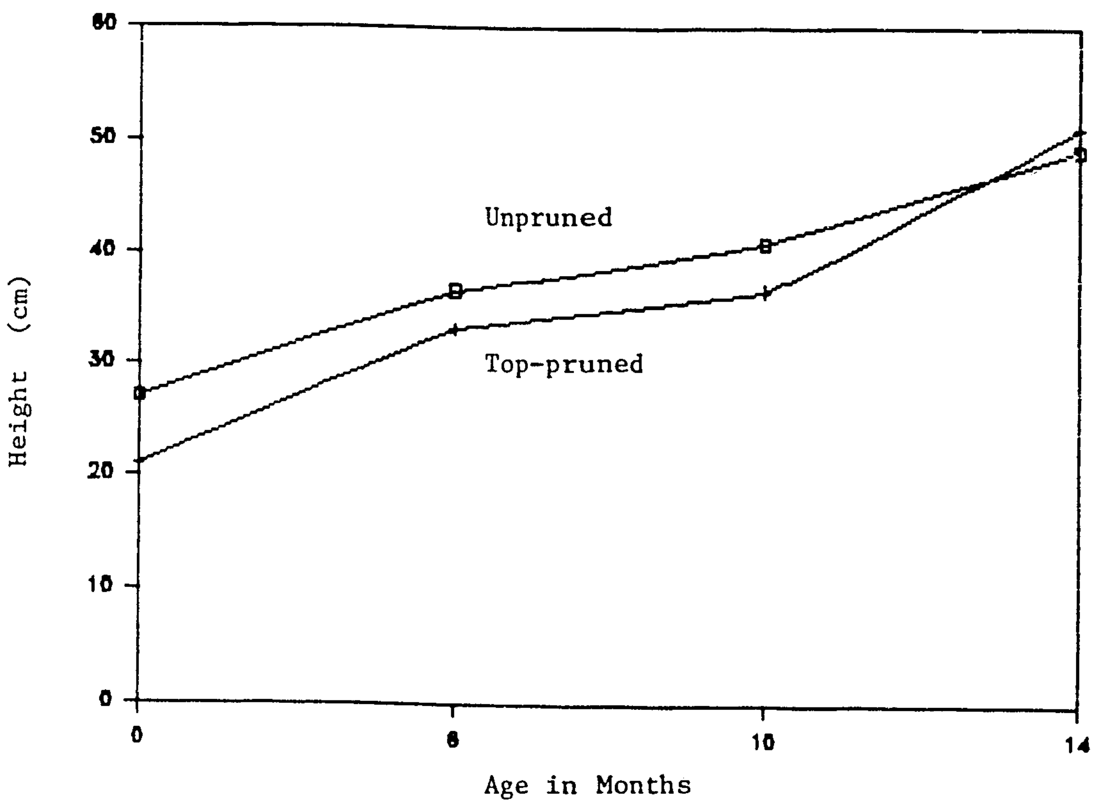

Figure 2A Height Growth of Casuarina at Cabaret

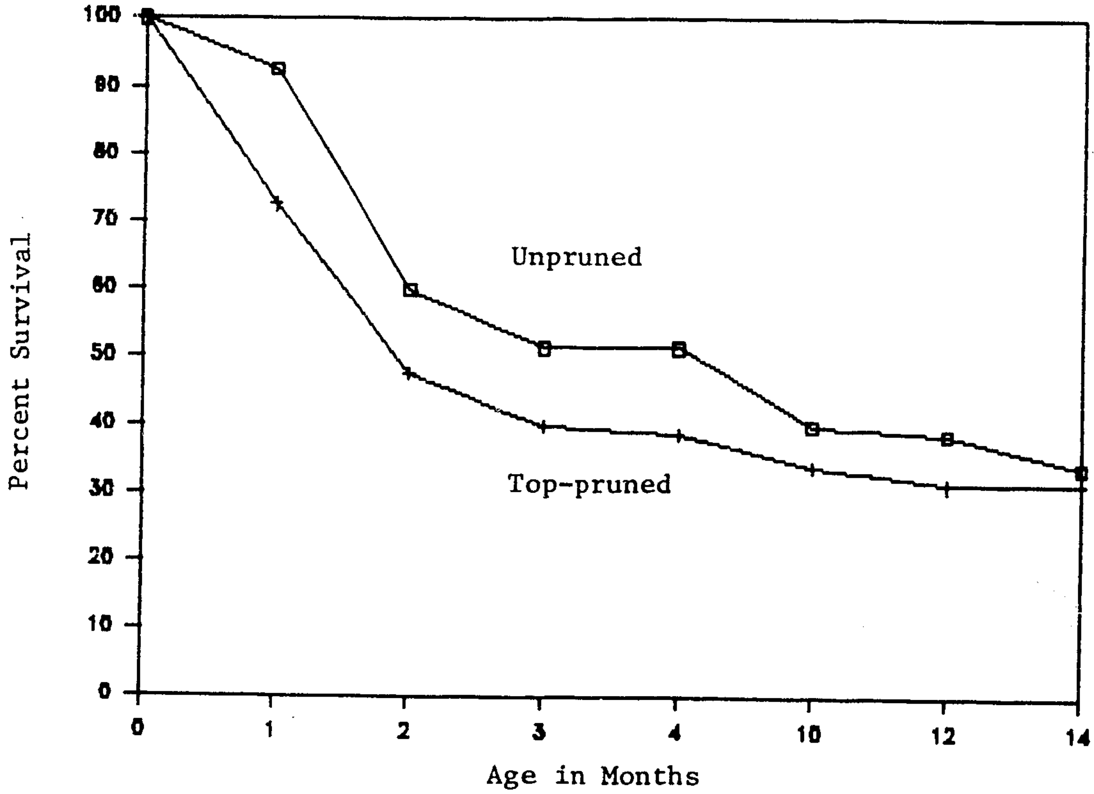

Figure 3 Survival of Colubrina at Cabaret

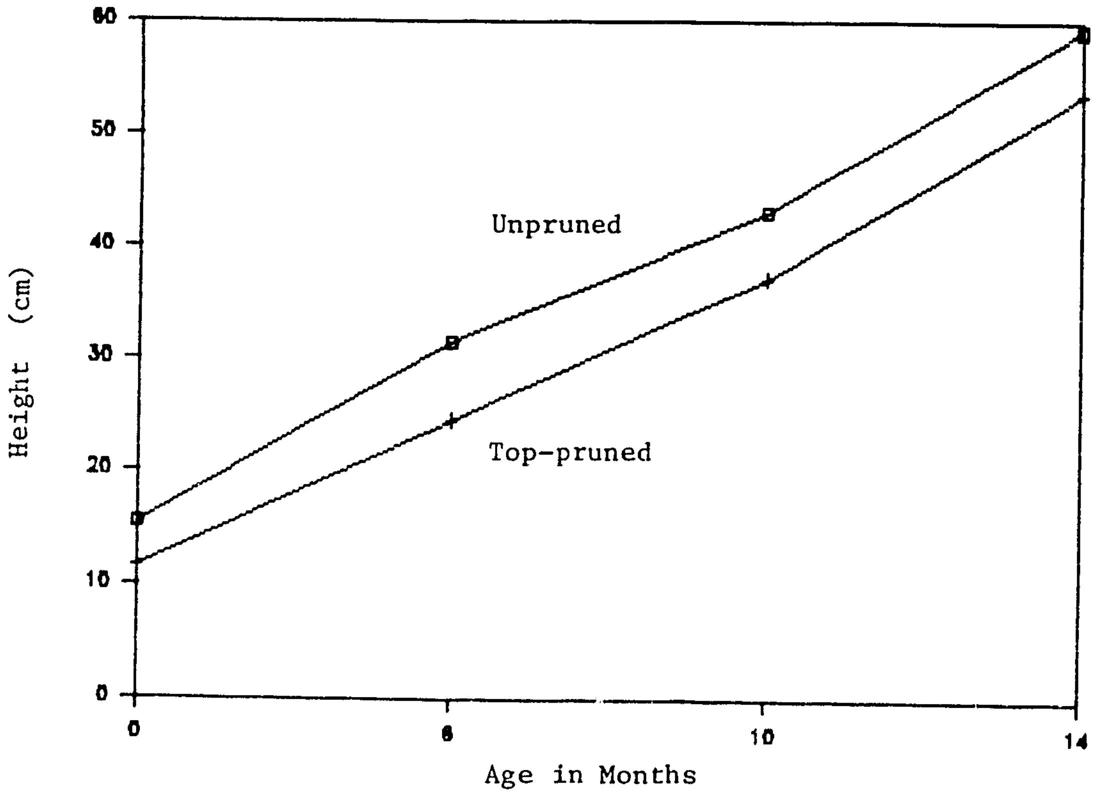

Figure 3A Height Growth of Colubrina at Cabaret

Saut d'Eau

Survival

There were no significant survival differences between the treatments for any species (Figures 4, 5, 6 and 7). After 14 months the unpruned seedlings for all species except Casuarina showed better survival than the pruned seedlings. Survival differences ranged from 2.5% for cassia to 16.2% for Catalpa. Casuarina showed an 11.8% survival difference between the two treatments, but its overall survival is about the best ever recorded in the AOP. The high survival of Casuarina is attributable to the following factors: well hardened seedlings were planted in the trial; the rainfall was adequate for the first six months after outplanting and the seedlings were weeded on a regular basis. There is also a possibility that the seedlings were inoculated with *Frankia* because the soil used in the Haitian mix was taken from the edge of a Casuarina stand.

Height

Significant height differences were found between the treatments for all species at outplanting and at four months. In all cases, the unpruned seedlings were taller than the pruned seedlings. This was a direct result of the pruning operation. Significant height differences between treatments were not found at ten and fourteen months for all species except Cassia, which had significant height differences between treatments (Figures 4A, 5A, 6A and 7A).

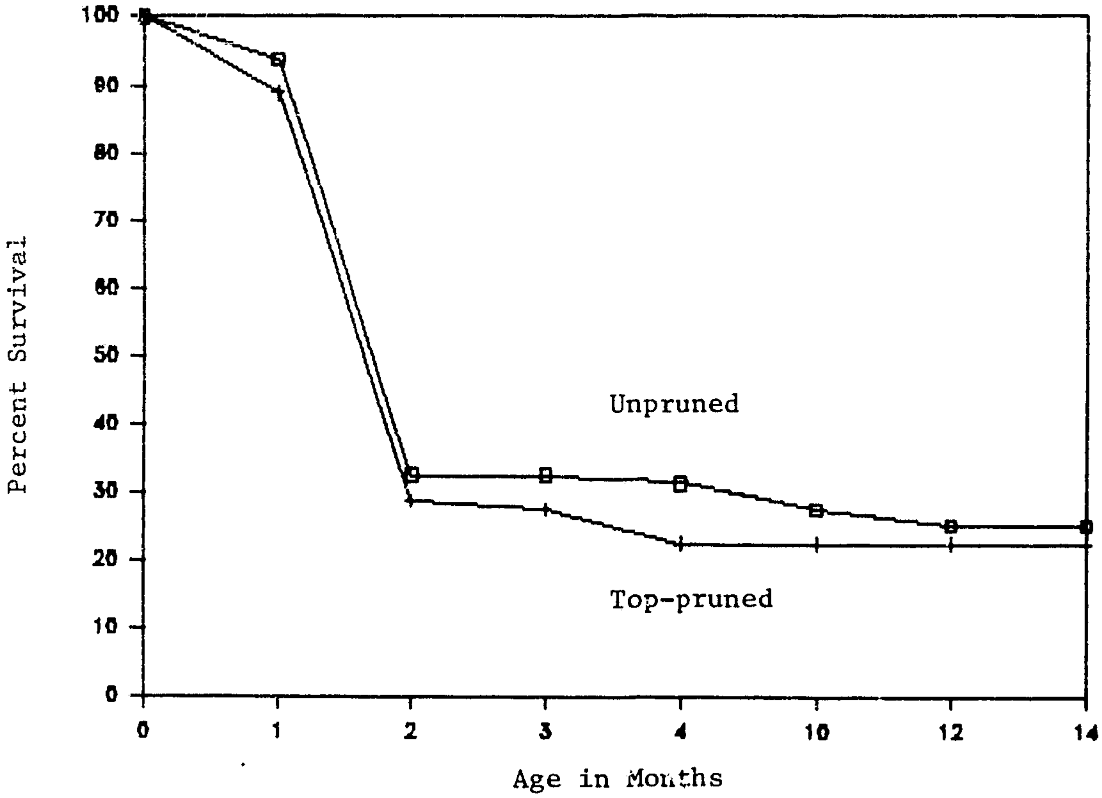

Figure 4 Survival of Cassia at Saut d'Eau

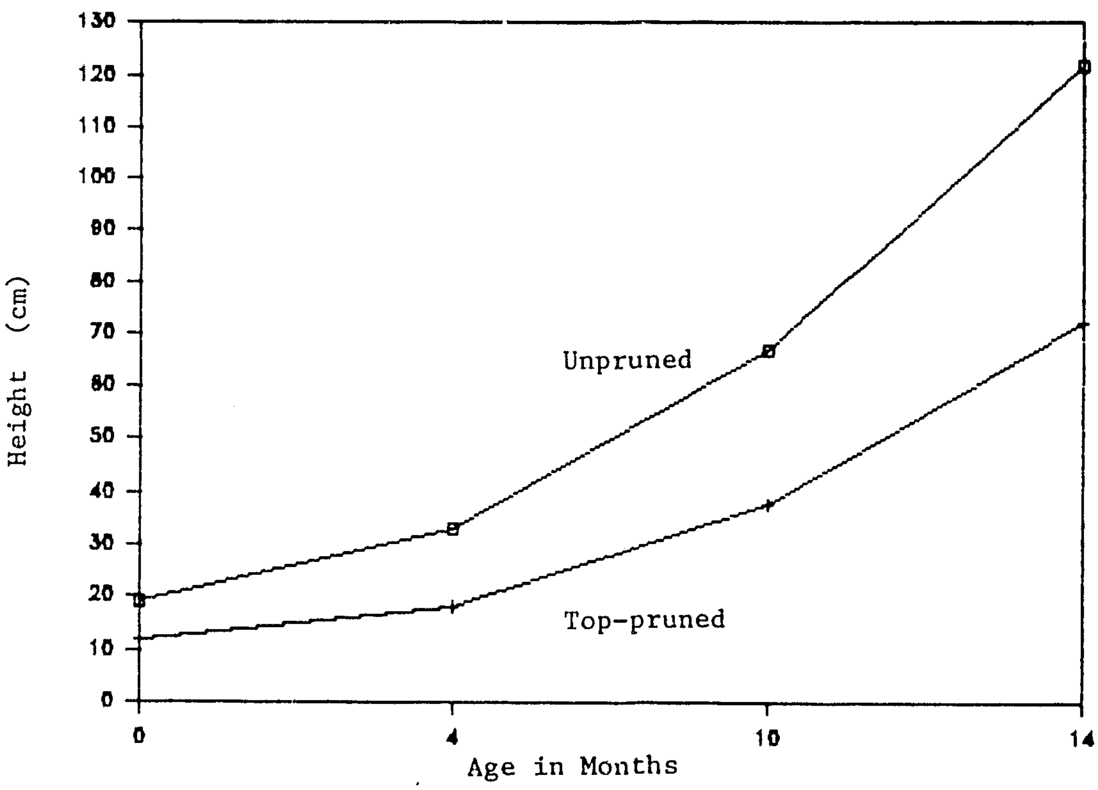

Figure 4A Height Growth of Cassia at Saut d'Eau

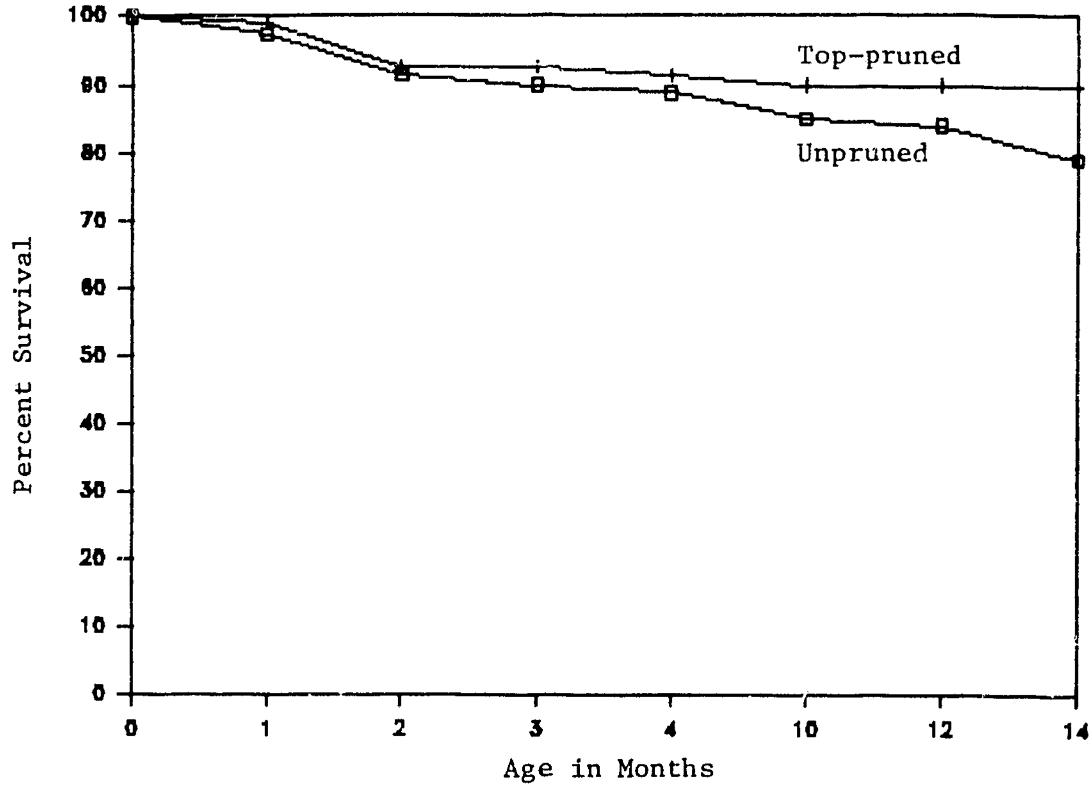

Figure 5 Survival of Casuarina at Saut d'Eau

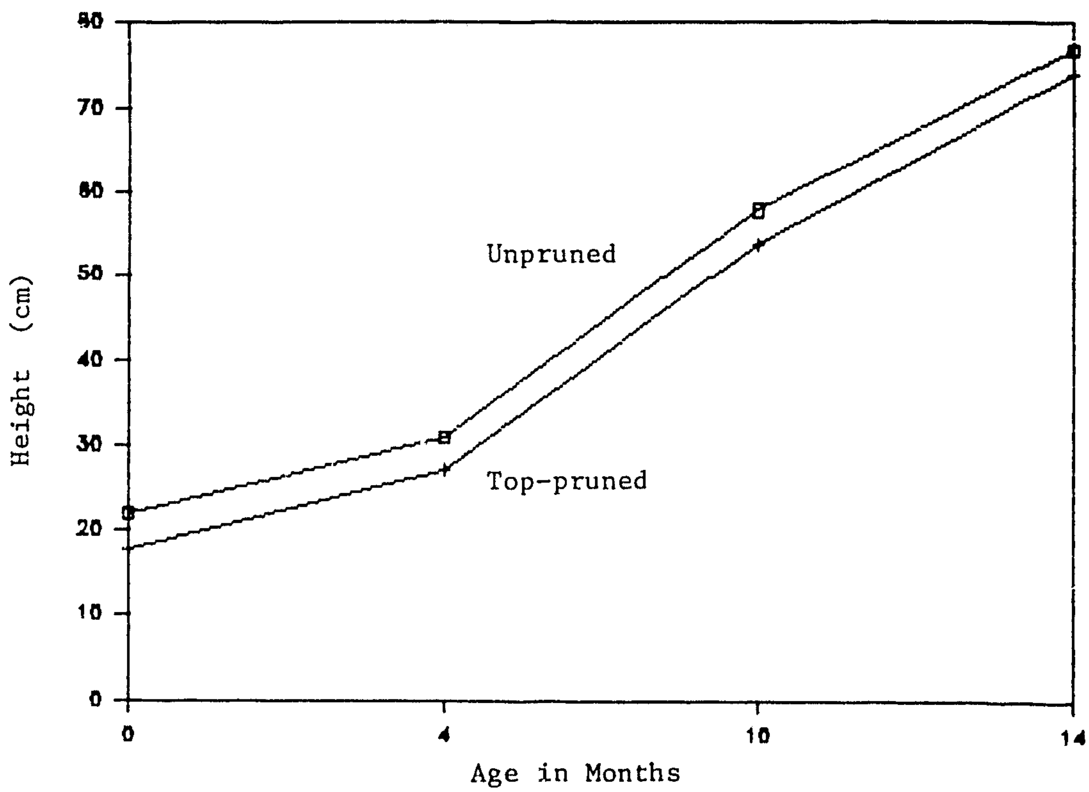

Figure 5A Height Growth of Casuarina at Saut d'Eau

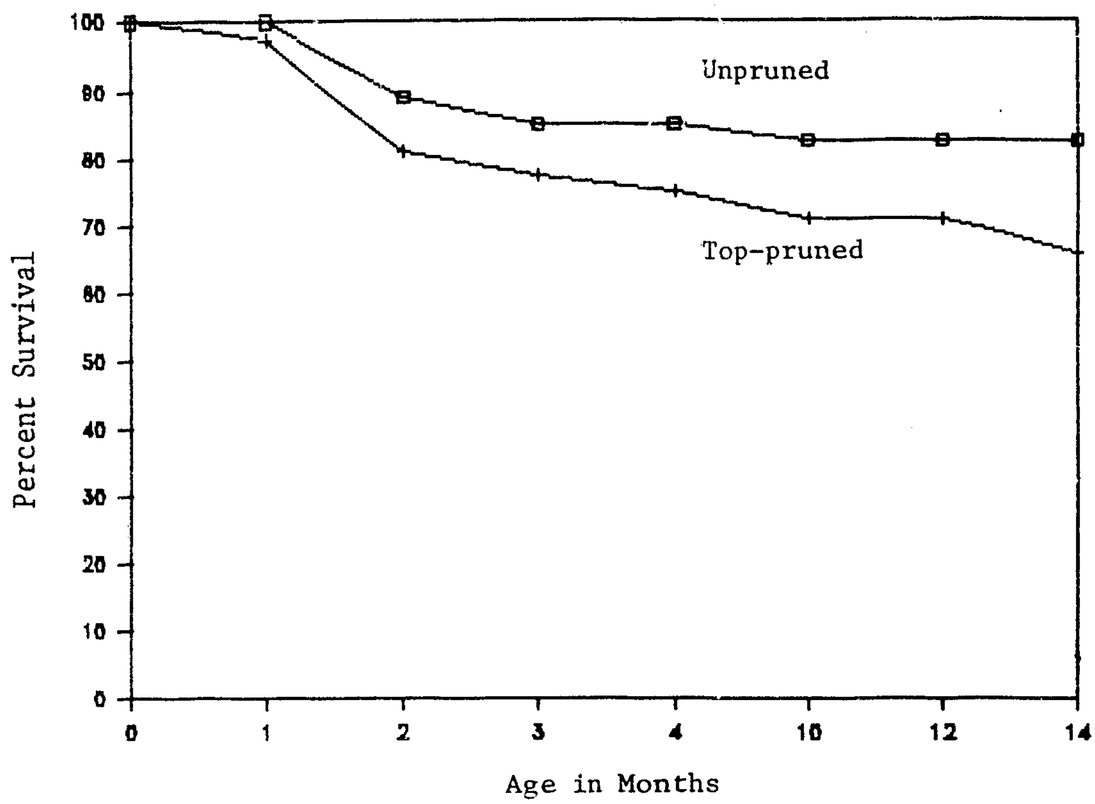

Figure 6 Survival of Catalpa at Saut d'Eau

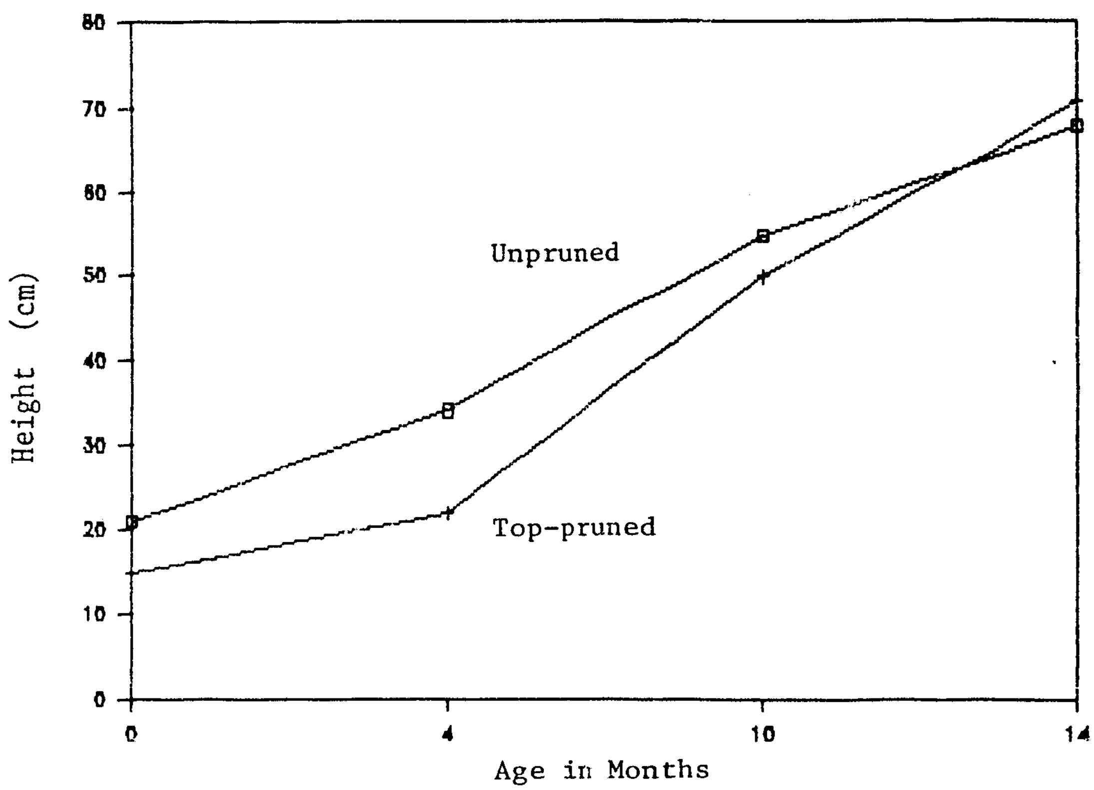

Figure 6A Height Growth of Catalpa at saut d'Eau

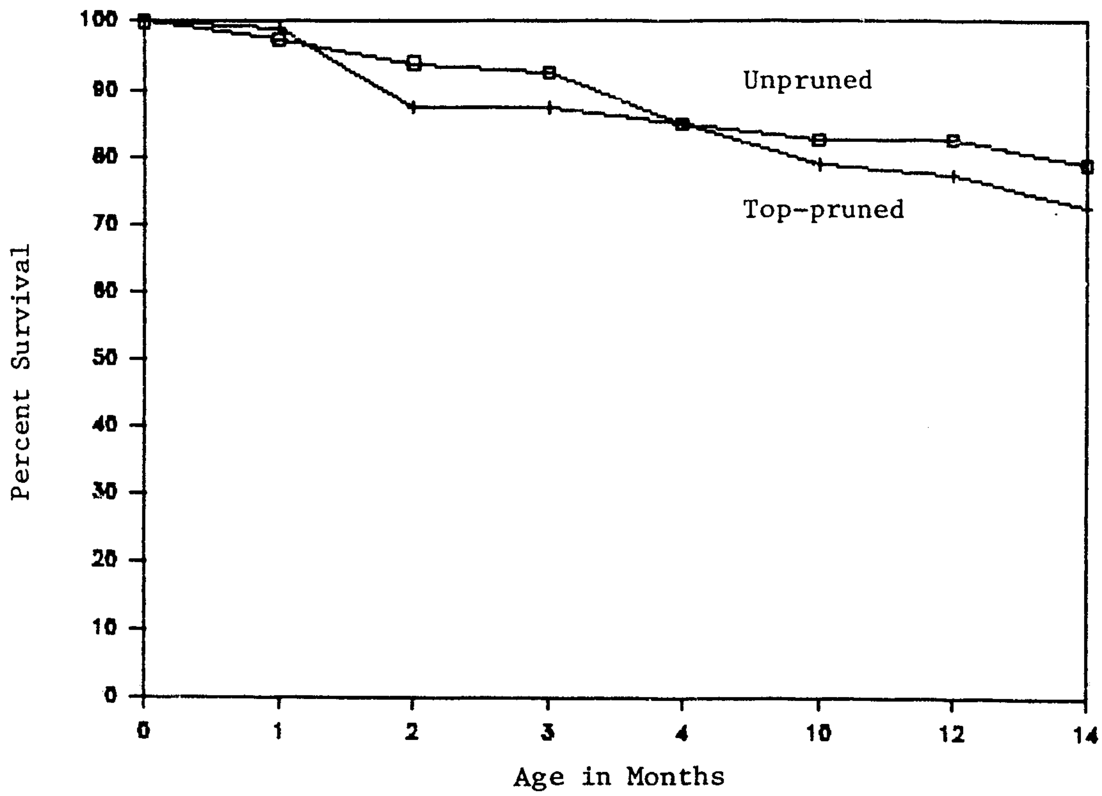

Figure 7 Survival of Eucalyptus at Saut d'Eau

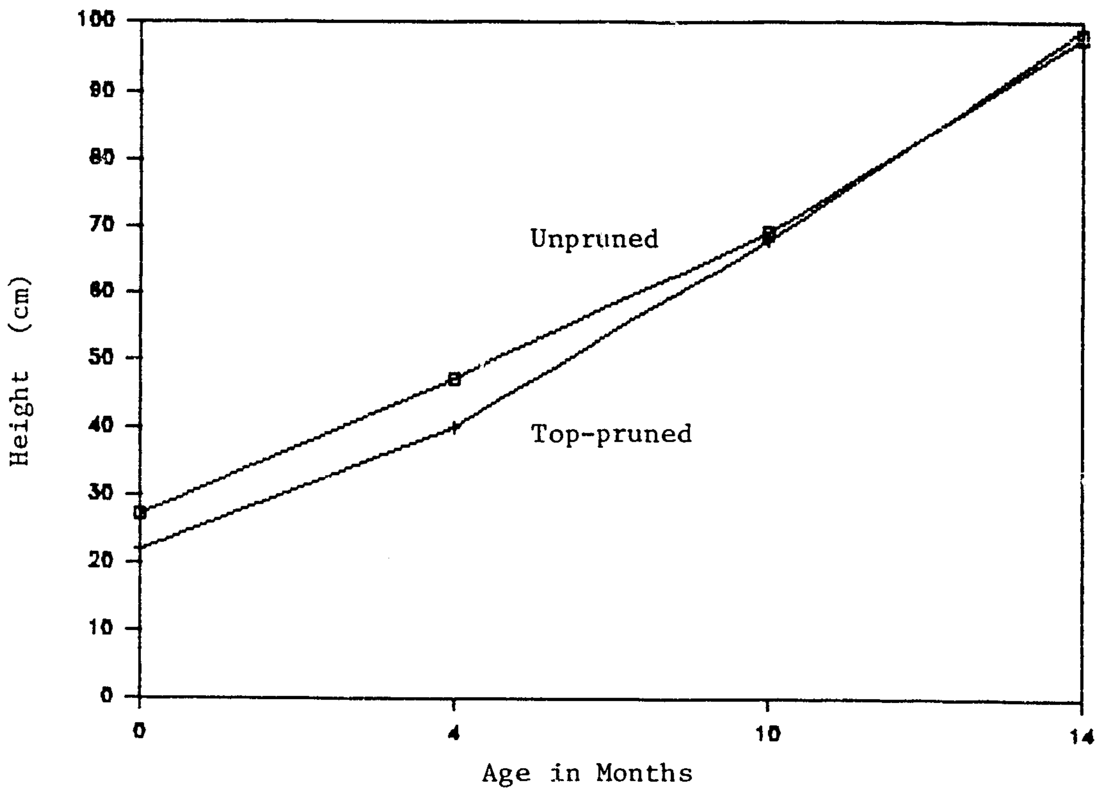

Figure 7A Height Growth of Eucalyptus at Saut d'Eau

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Top-pruning does not appear to increase survival or height growth after planting, in fact, the height growth of Cassia and neem are negatively affected by top-pruning. Though there were no statistically significant survival differences found, the unpruned seedlings generally had better survival than the pruned seedlings. In several cases, the difference in survival rates was as much as 15 percent.

Recommendations

Discontinue top-pruning seedlings before planting except where the seedlings are tall and have large height shoot/root ratios.

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THE EFFECTS OF EXTENDING THE NURSERY GROWTH PERIOD FOR OUTPLANTED SEEDLINGS IN HAITI

By

Roland A. Dupuis

The author is a research forester for the University of Maine Agroforestry Outreach Research Project. The work reported here was sponsored under USAID Project No. 521-0122.

December, 1986

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CHAPTER 1

INTRODUCTION

The Agroforestry Outreach Project (AOP) has been planting trees in Haiti for five years. During this period, more than 25,000,000 seedlings have been planted with a survival rate of about 50 percent. According to the mid-project evaluation, this survival rate is not satisfactory and could be increased (USAID, 1983).

Several approaches can be taken in dealing with the issue of increasing survival. Two of these are the technological approach, which emphasizes species selection and nursery management practices, and the sociological approach, which emphasizes better training and motivation of farmers in outplanting and maintenance techniques.

The purpose of this study was to compare the survival and height growth of growing seedlings with the recommended standard nursery growth period and a 25% extension of that nursery growth period, and determine whether the extended growth schedule should be applied in the AOP.

Due to a change of site and a lack of rain, the seedlings were held in the nursery for an overextended period of time, therefore, the recommended nursery growth period was never tested. Nursery periods referred to as standard and extended are actually extended and overextended, respectively.

CHAPTER 2

METHODS AND MATERIALS

The study site was originally located in Ganthier, but was relocated in Bon Repos before planting. The site relocation was due to better land availability in Bon Repos and the occasional flooding of the Ganthier site during heavy rains.

The study site in Bon Repos was located approximately 17 km Northeast of Port-au-Prince in the Cul-de-Sac Plain (Lat. 18° 38'N, Long. 72° 14'W). The site is generally flat and the altitude is 30 m above mean sea level.

The climatic conditions only exhibit minor fluctuations throughout the year. Mean monthly temperatures range from 24°C in January to 28°C in July (OAS, 1972). Annual rainfall is about 850 mm which falls in two distinct rainy seasons; a very brief April/May season and a longer season from August to October.

The trial is located on a deep, tan to light brown alluvial soil which ranges from clay to sandy silt. Composite soil samples were taken at a depth of 0-10 and 50-60 centimeters. The samples were analyzed at Agricultural Services Inc., Bon Repos, Haiti. The 0-10 cm results showed that the conductivity was 8.4 mmhos/cm, pH was 7.4, phosphorus was 44.5 ppm and potassium was 275 ppm. The 50-60 cm results showed that the conductivity was 18.4 mmhos/cm, pH was 7.6, phosphorus was 34 ppm and potassium was 75 ppm.

The site was covered mainly with *Prosopis juliflora* and *Acacia* species and was prepared during the months of August and September with a 80cm ripper pulled by a John Deere 6040 tractor. One pass was made on contour at three meter intervals. Each pass "ripped" a furrow in the soil 60 cm deep and 30 cm wide. During this operation, the vegetation on the furrow, including the roots were removed. In addition, any hardpan or clay layer was broken up to a depth of 60 centimeters. The vegetation between the rows was cleared by local farmers during the following week.

Four tree species were selected for this trial. These were *Casuarina equisetifolia*, *Colubrina arborescens*, *Leucaena leucocephala* and *Prosopis juliflora*. All of the seed was obtained from ODH except *Colubrina* which was collected near Jean Rabel by CARE. The seed of each species was sown in the ODH winstrip in Fafard No. 2 growing mix at two different times to reflect the standard nursery growing time and a 25 percent increase in nursery growing time for that species. The standard time in the nursery for Casuarina, Colubrina, Leucaena and Prosopis is 17, 13, 9 and 13 weeks respectively. The seed was originally sown so that the seedlings could be planted in Ganthier on September

20th, however, because the site was subsequently changed to Bon Repos where the rainy season is about three weeks later, the actual time in the nursery was increased by three weeks over the recommended standard nursery time. In addition, the seedlings were held in the nursery for an additional three weeks because of a lack of rain during the months of September and October. Table 1 describes the planned and actual standard and extended times in the nursery for each species planted in this study. The percent difference in the nursery growing times were less than 25 percent because of the aforementioned delays.

Table 1 Extended and Overextended Times in the Nursery by Species

Species	Recommended Standard (Weeks)	Actual Extended	Actual Overextended (Weeks)	Percent Extended
Casuarina	17	20	25	20
Colubrina	13	17	19	12
Leucaena	9	13	15	15
Prosopis	13	17	19	12

On the day before the seedlings were planted, they were measured to the nearest centimeter with a 30 cm ruler and marked with flagging which indentified the replications. The seedlings were also watered heavily, removed from the containers and placed in plastic lined boxes which were placed in the shade and left open for the evening.

On the following morning (October 25), the seedlings were transported to the site and planted at a 2.5 m x 3.0 m spacing. Each seedling was planted in a water catchment basin and watered with a gallon of water because it had not rained during the three previous weeks. The trial was weeded at five, seven and nine months.

The survival was recorded monthly and height was recorded at planting, six (after the first rainy season) and ten months (after the second rainy season). The survival data was transformed using an arcsine square root function and analyzed with t-tests, to test the hypothesis that there were no significant differences between survival of seedlings of different age. The height data was analyzed using t-tests, to test the hypothesis that there were no significant differences between heights of seedlings of different age.

CHAPTER 3

RESULTS AND DISCUSSION

Comparison of Extended and Overextended Seedlings

The results show that seedlings which experienced the extended nursery growth period had significantly greater heights at outplanting than seedlings with the usually recommended growth periods. Leucaena however, showed no significant height differences between the standard and extended seedlings. Prosopis had significantly greater height growth for the standard seedlings because during the hardening-off phase, these seedlings were not watered for two days and consequently, died back several centimeters.

At six and ten months the standard seedlings of all species except Casua..ina were significantly taller than the extended seedlings (Figures 1, 2, 3 and 4). Because of extremely high mortality, Casuarina was not analyzed. There are two possible explanations for the fact that the standard seedlings grew taller than the extended seedlings, as was originally hypothesized at the beginning of this study. First, the experimental design (randomized complete block) placed a greater number of standard seedling plots on clayey soil, whereas many of the extended seedling plots were located on sandy clay silt which was the predominant soil type. At the time of planting, these differences in soil type were not evident even though six soil samples were taken at the site. The samples revealed that replication number four at the eastern end of the trial was quite clayey, but failed to show that the clay extended in a narrow band along the entire northern edge of the trial. Since clay has a better water holding capacity than sandy silt clay, all plots located on the clay soil had better height growth than plots on the sandy silt clay. Soil type differences could have also been detected by examining the homogeneity of the vegetative cover and the visible plant/water relationships during the dry season, but the site had been cleared before the decision to switch sites was made.

Secondly, the seedlings may have been held too long in the nursery, thus producing an overabundance of lateral roots at the container/plug interface. This barrier of older lateral roots inhibited new lateral root egress and forced all new roots to exit the bottom of the plug after planting. This is a common ocurrence with containerized conifer seedlings in North America (Burdett, 1981). Therefore, if this is the case, standard seedlings would have accumulated less of a barrier for lateral root egress and thus would exhibit greater early height growth than extended seedlings. Root pruning is the easiest and most accepted way to stimulate lateral root initiation, thus facilitating lateral root egress.

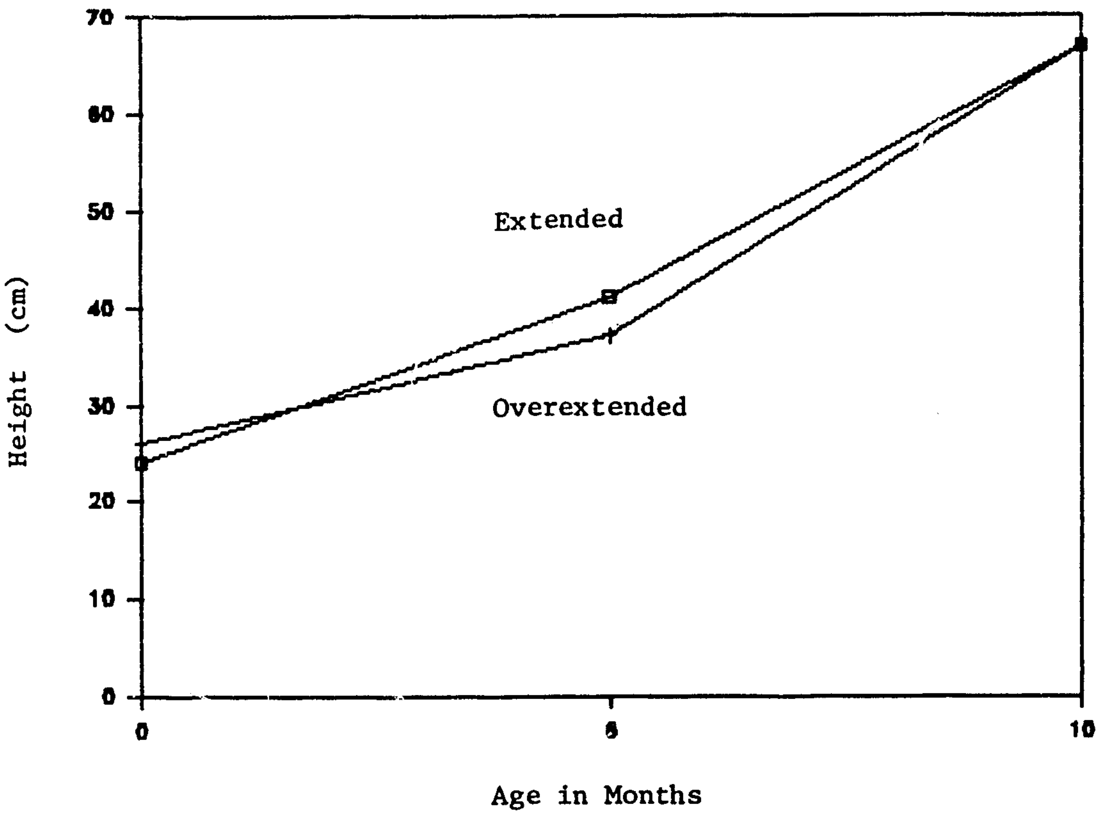

Figure 1. Height of Extended and Overextended Casuarina Seedlings

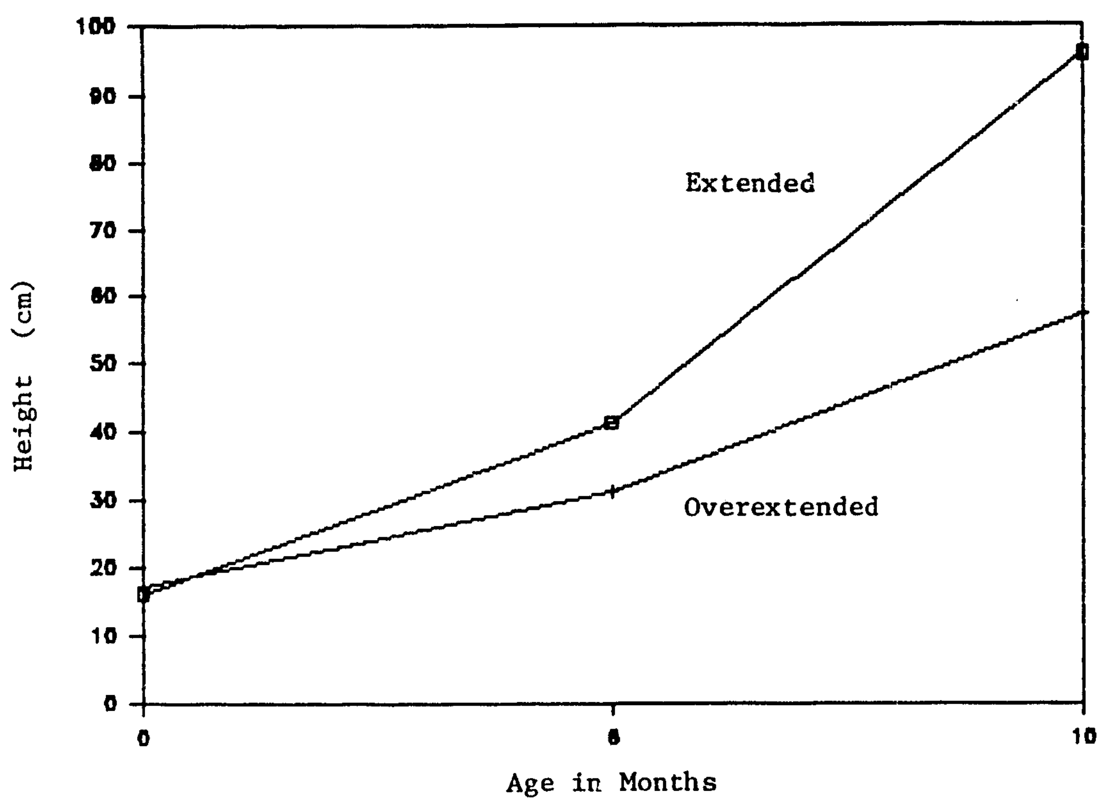

Figure 2. Height of Extended and Overextended Colubrina Seedlings

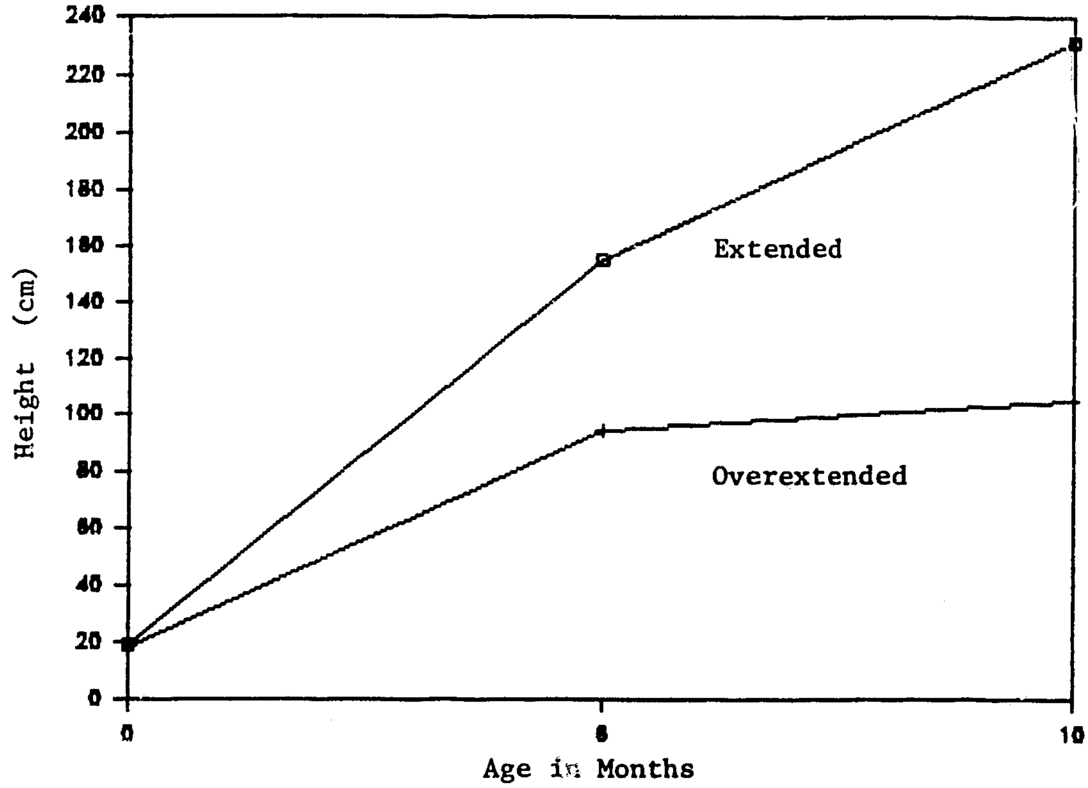

Figure 3. Height of Extended and Overextended Leucaena Seedlings

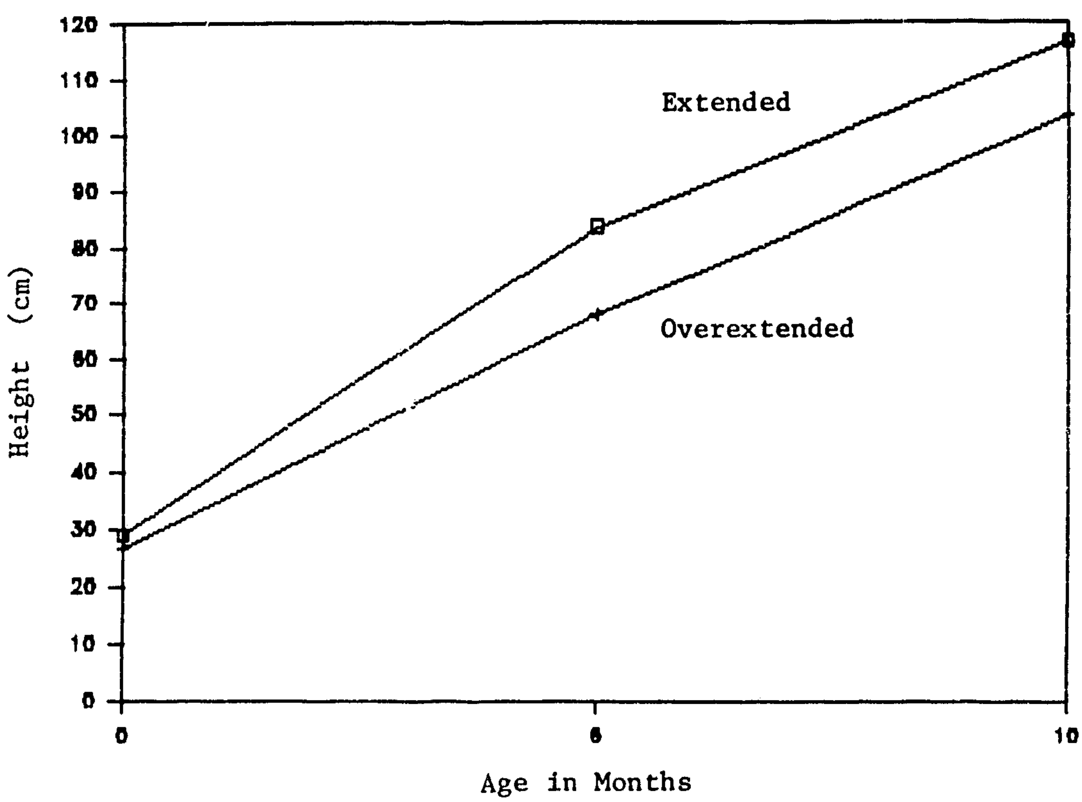

Figure 4. Height of Extended and Overextended Prosopis Seedlings

Survival of standard and extended seedlings of a particular species were not significantly different throughout the trial (Figures 5 and 6). Leucaena and Prosopis are not represented by graphs because each species only had four percent mortality after ten months.

Comparisons Between Species

The overall seedling height at outplanting and six months was significantly different between all species. Seedling height at outplanting was 27.8, 24.6, 18.7 and 16.7cm for Prosopis, Casuarina, Leucaena and Colubrina, respectively (Figure 7). Seedling height at six months was 125.7, 75.9 and 36.0cm for Leucaena, Prosopis and Colubrina, respectively. Casuarina was not included in the analysis at six and ten months because of severe mortality. Seedling height at ten months found that Leucaena was significantly taller than Prosopis and Colubrina. No significant height differences were found between Prosopis and Colubrina, though Colubrina had good survival only on the clayey sites, which gave it above average height growth.

No significant survival differences were found between Leucaena and Prosopis, but both of these species had significantly greater survival than Colubrina. Ten month survival for Leucaena, Prosopis and Colubrina was 95.6, 93.1 and 20.0 percent, respectively (Figure 8).

It is important to note that the percentage of Leucaena, Prosopis and Colubrina trees which experienced die back between May and August was 38, 2 and 15.6 percent respectively. Because Leucaena and Prosopis had roughly the same survival for this period, this indicates that prosopis is more adapted to the site conditions than Leucaena. This reaffirms the fact that Prosopis, although a slow grower initially, is likely the best species for dry lowland sites.

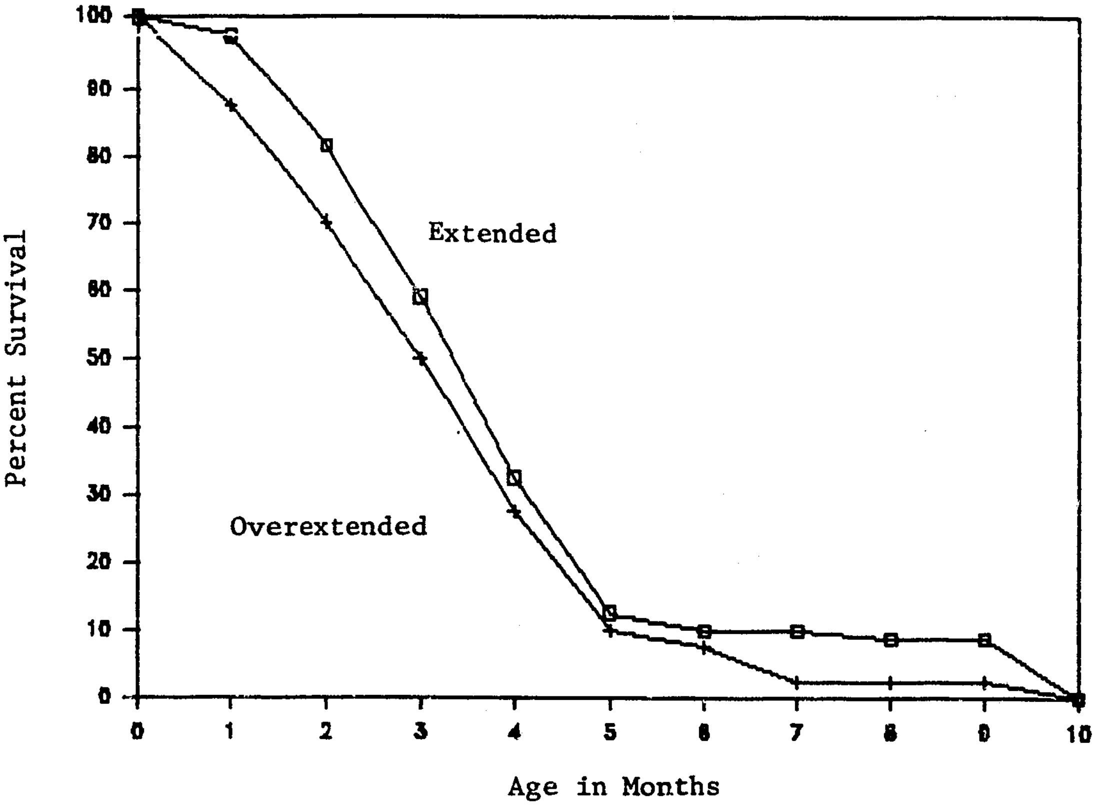

Figure 5. Survival of Extended and Overextended Casuarina Seedlings

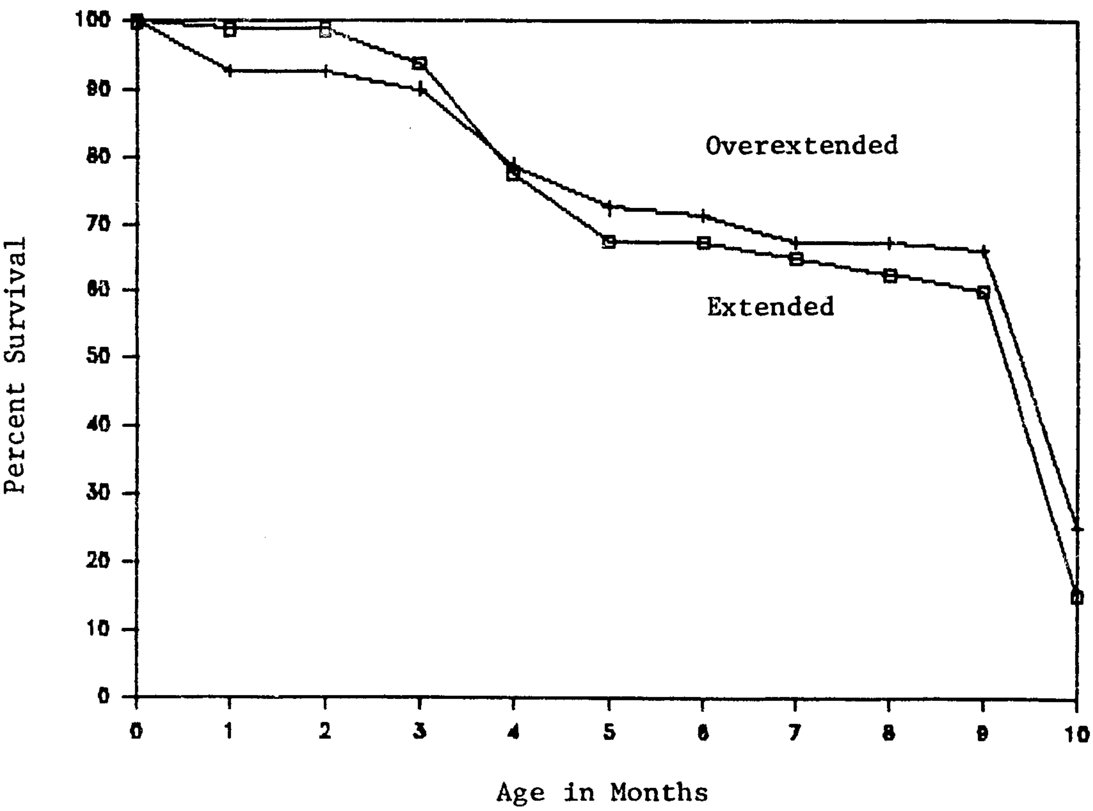

Figure 6. Survival of Extended and Overextended Colubrina Seedlings

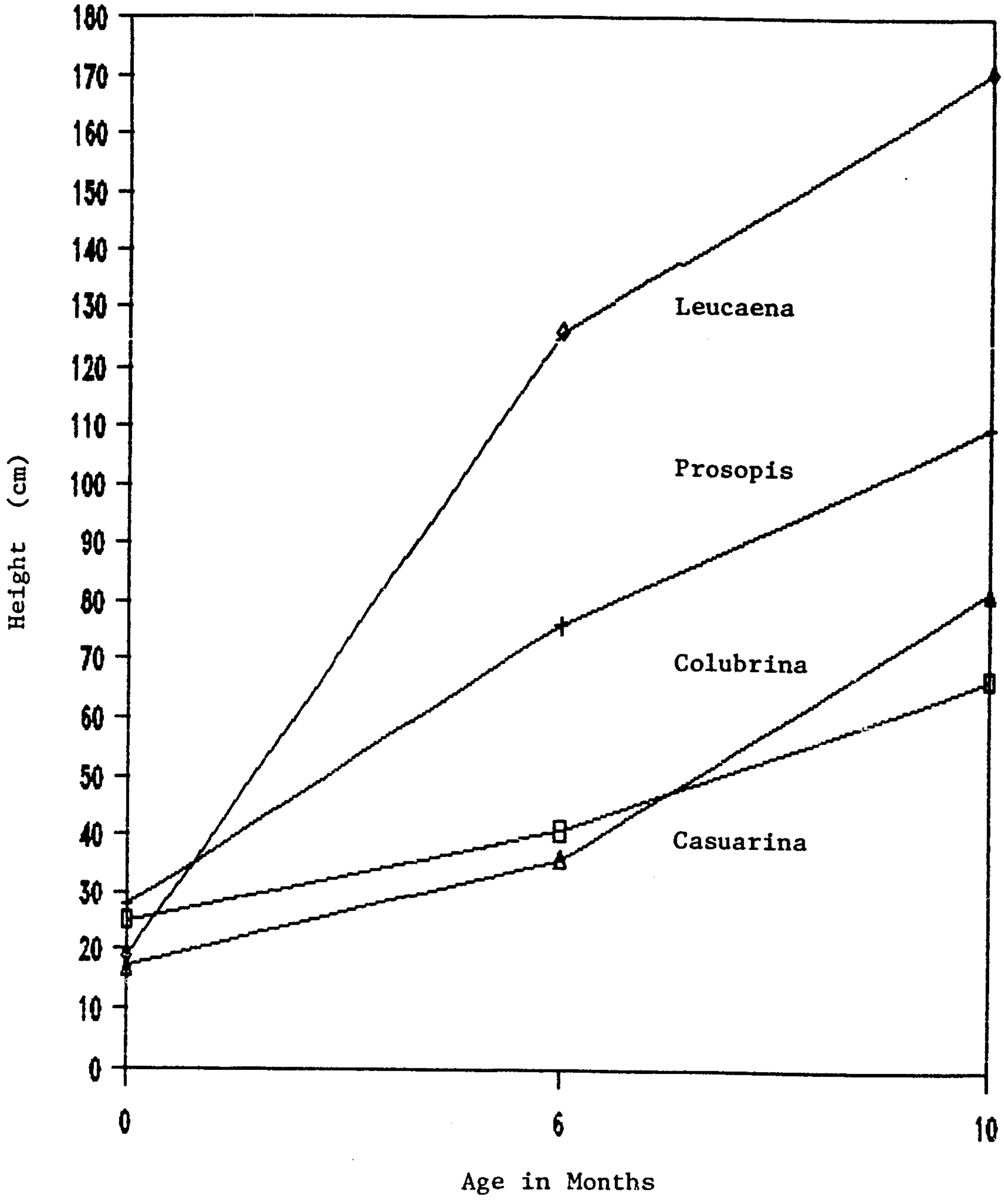

Figure 7. Height by Species

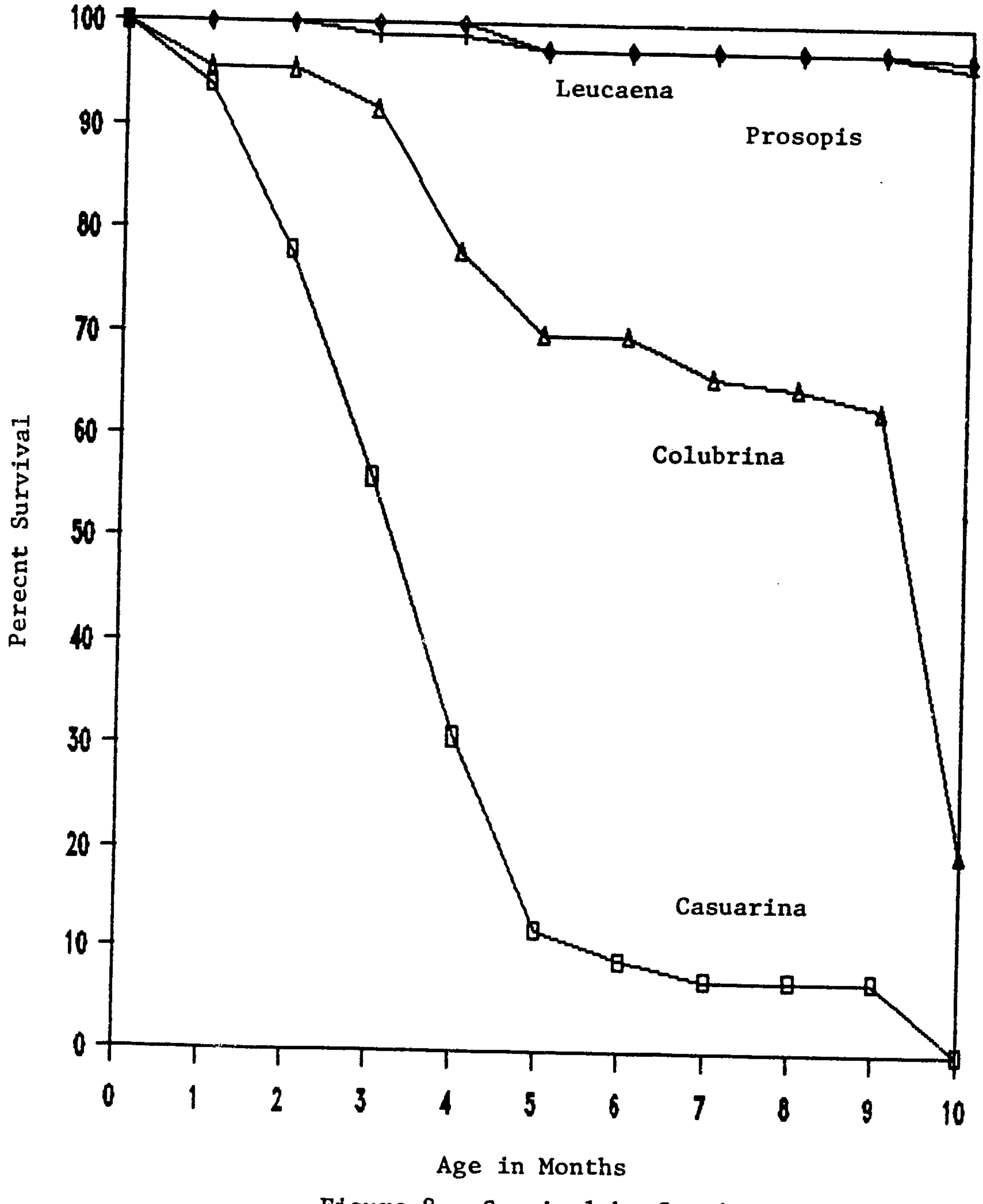

Figure 8. Survival by Species

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Seedlings grown with an extended nursery growth period produce significantly taller seedlings after planting than those grown with an overextended nursery growth period. The currently recommended standard nursery growth period was not tested for any species, because the seedlings were held in the nursery for an overextended period of time.

2. *Prosopis juliflora* is an excellent species to plant in dry lowland areas because of its growth performance in this and other dryland trials.

Recommendations

1. Research on this specific topic should continue with both nursery and field trials, using a wider range of nursery growth ages, including the recommended age. 2. Seedlings that are held in the nursery for an extended period may need to be root pruned before they are planted so that lateral roots will be stimulated to egress through the sidewalls of the plug. This technique should be tested.

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COPPICING TRIALS INVOLVING *LEUCAENA LEUCOCEPHALA* AND *CASSIA SIAMEA*

by

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CHAPTER 1

INTRODUCTION

Coppicing is one of the oldest and simplest silvicultural methods used by man. It is also one of the gentlest on resources and the land. The stumps of a coppiced tree do not die. Instead the living roots continue to bind the soil and a new canopy rapidly forms to shield the soil from wind and rain and helps to suppress weeds. The new shoots grow vigorously because they are supported by roots big enough to feed the former tree. Today, eucalyptus pulpwood plantations in Brazil and elsewhere harvest a first crop after seven to eight years and subsequent harvests are on a five to six year rotation. Certain forests in England have been coppiced for fuelwood on a continual basis for over 500 years (NAS, 1980). Clearly, this method has great promise for the rapid growing tropical hardwood species currently used by the AOP.

Although this is a project final report, it is an interim report for this coppicing experiment. For this reason, readers should not attempt to form any final conclusions about coppicing on the basis of the interim results presented here.

This report outlines the ecological setting, experimental design, and one-year results of a coppicing trial involving *Leucaena leucocephala* and *Cassia siamea* in Perdi Midi (Cap-Haïtien). Secondly, it discusses the establishment of a new trial involving *Leucaena leucocephala* near Mirebalais.

Two distinct hypotheses are being tested here:

1. all thinning regimes are equal in height growth, diameter, and biomass production.

2. a coppiced stand produces the same biomass as an uncoppiced stand

Consequently, the objectives of these silvicultural experiments are to:

1. assess the relative productivity of different coppicing treatments
2. assess the productivity of coppice growth relative to tree growth in an untreated stand of trees

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CHAPTER 2

METHODS AND MATERIALS

Perdi Midi

Site Description

The first experiment was set up on two adjacent tree plantations near Perdi Midi. The plantations were established in October, 1980 on alluvial soils, pockets of which are poorly drained and show obvious signs of salinization. Of the approximately two hectares originally planted, presently about half that area is covered by a thick stand of leucaena and cassia. Plantation density is high with spacing between trees often less than two meters.

The plantation extends north from a gravel road connecting Perdi Midi to Quartier Morin, 15km south of Cap Haïtien. Tree growth is optimal near the road where the soil is deeper and well drained. As the plantation nears the salt pockets about 200m north of the road, both tree height and diameter at breast height (dbh) diminish gradually. The ground on and around the salt flats is covered by bunch grasses and dispersed trees of *Haematoxylum campechianum (campeche)* and *Prosopis juliflora (bayahonde)*.

The study site is located at sea level, in an area of relatively high rainfall (1,470mm) and lies within the humid sub-tropical forest of the Holdridge (1963) Life Zone classification and zone 27 of the Buffum/Campbell (Buffum, 1984) classification. Soil pH ranges from about seven near the southern end of the plantation to eight and nine near the salt flats. Generally, the soil is light brown, very rich in clay and has poor drainage. The surrounding land is either planted with sugar cane or has been in the past and is being resettled by *Prosopis juliflora* and *Haematoxylum campechianum*. Worth noting is a thick, nearly pure stand of *campeche* just to the west of the plantation.

No thinning, pruning, or other silvicultural treatment has been applied to the plantation in the past. This coppice growth experiment represents the first intervention on the plantation since its establishment six years ago.

Experimental Design

This coppicing experiment involves two tree species, *Leucaena leucocephala* and *Cassia siamea*. The experiments were laid out along two parallel strips, six meters wide and more than 140m long. Each experimental plot measures 60m². The length of each plot (ten meters) extends in a north-south direction. The width (six meters) includes three rows of planted trees. Each plot has been separated by a similar size buffer plot. All plots have been replicated twice except for the coppice to all treatment for leucaena, which had to be limited to a single plot because of lack of space (Figure 1).

Between the two experimental strips there are at least four rows of trees of both species. For each experimental plot one seed tree was left standing. All other trees were removed after being measured for dbh, ground and base (10cm) diameter and cut at 10cm above the ground. About one-third of all the trees cut were measured for total length. All treatment plots were measured starting from the southeastern corner of the plot, proceeding along one row, and returning along the adjacent one.

Trees in the control plots were measured for dbh, ground and base (10cm) diameters, flagged with yellow ribbon, and left standing.

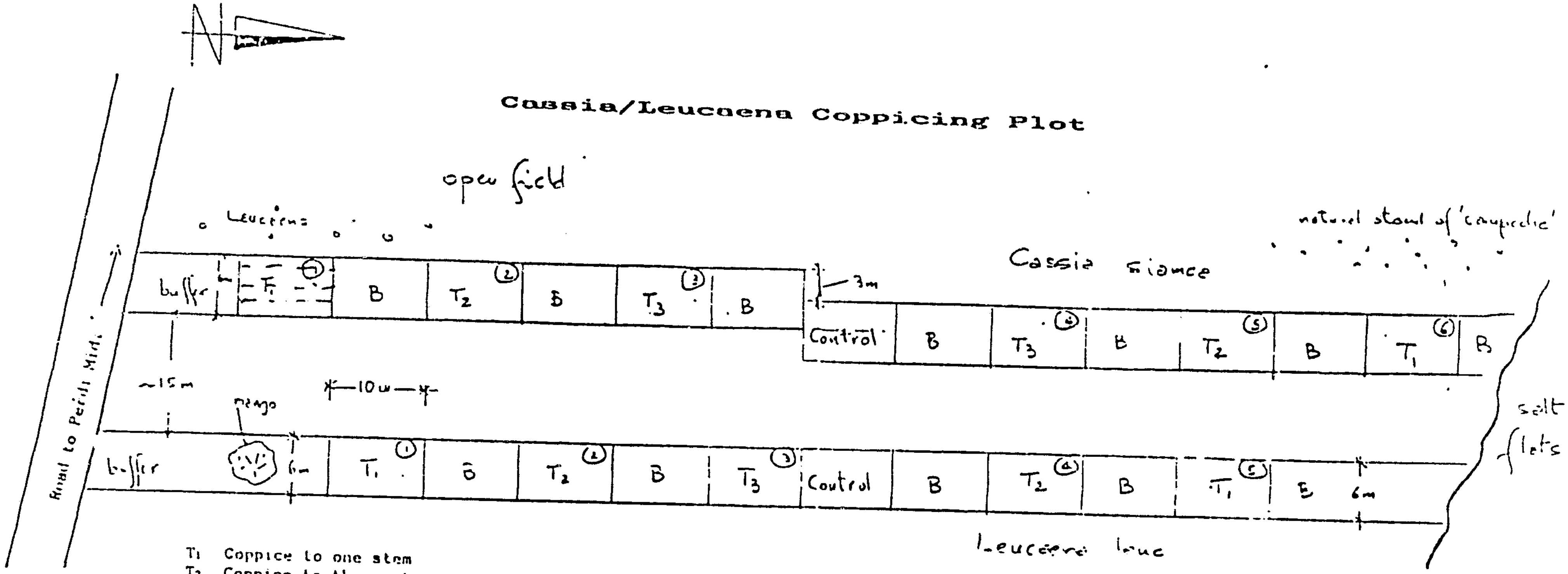
The experimental layout involves three treatments and two replications with one control plot as is shown in Figure 1. The treatments involved are:

1. Coppice to one stem (T1)
2. Coppice to three stems (T2)
3. Coppice to all (no thinning of coppice growth) (T3)

The T3 plot serves as the control plot for Experiment 1, i.e., it will be used to assess the performance of each coppice treatment relative to each other, while the plots labeled as Control on Figure 1 are the control plots for experiment 2 and will be used to assess the productivity of coppiced trees relative to those left standing. There are two replications each of the treatment plots, with the exception of T3 for leucaena. The control plots for Experiment 2 are found at the center of the experimental strips, with the treatment plots replicated in inverse order on each side of the control plot (Figure 1). The treatment plots were not randomly arranged because of a perceived decrease in the height of the original trees as one approached the salt flats. With random distribution, the possibility existed that both replications of a treatment might be exposed to the saline conditions at the northern edge of the site. For this reason the plots were arranged so that only one replication of each treatment would be in the proximity of the salt flats.

Experimental Method

The experimental plots were measured and cut during the last days of August and the first days of September, 1985, coinciding with the beginning of the rainy season. The plots were thinned six months later, in February, 1986. At that time the coppices were thinned to one stem, three stems, or left growing. Coppices were selected on the basis of dominance, diameter, height, form, and in the case of coppice to three stems, on the basis of even distribution around the stump. The following measurements were taken at six months:



T1 Coppice to one stem
T2 Coppice to three stems
T3 All coppices (no thinning)
B Buffer

Average number of trees/plot

24 Cassia
23 Leucaena

Figure 1. The experimental plot layout for the Cassia/Leucaena coppicing experiment near Perdi Midi, Haiti.

Total number of sprouts from each stump
Height of the remaining sprouts
Dbh of trees in the control plots
Dbh of seed trees within each treatment plot

In October, 1986, these measurements were taken:

Total number of sprouts at each stump
Height of the sprouts
Dbh of the sprouts
Dbh of trees in the control plots
Dbh of seed trees in each treatment plot

Similar measurements will be taken at 18 months (February, 1987). After 24 months (September, 1987), the coppices will be harvested and measured for dbh and total height in order to determine the yields of polewood and fuelwood.

Mirebalais

Site Description

The experiment was established on a plantation owned by the Convention Baptiste d'Haïti, approximately four kilometers north of Mirebalais. The area was planted in May, 1983, thus the trees coppiced were over three years of age at the time of the operation.

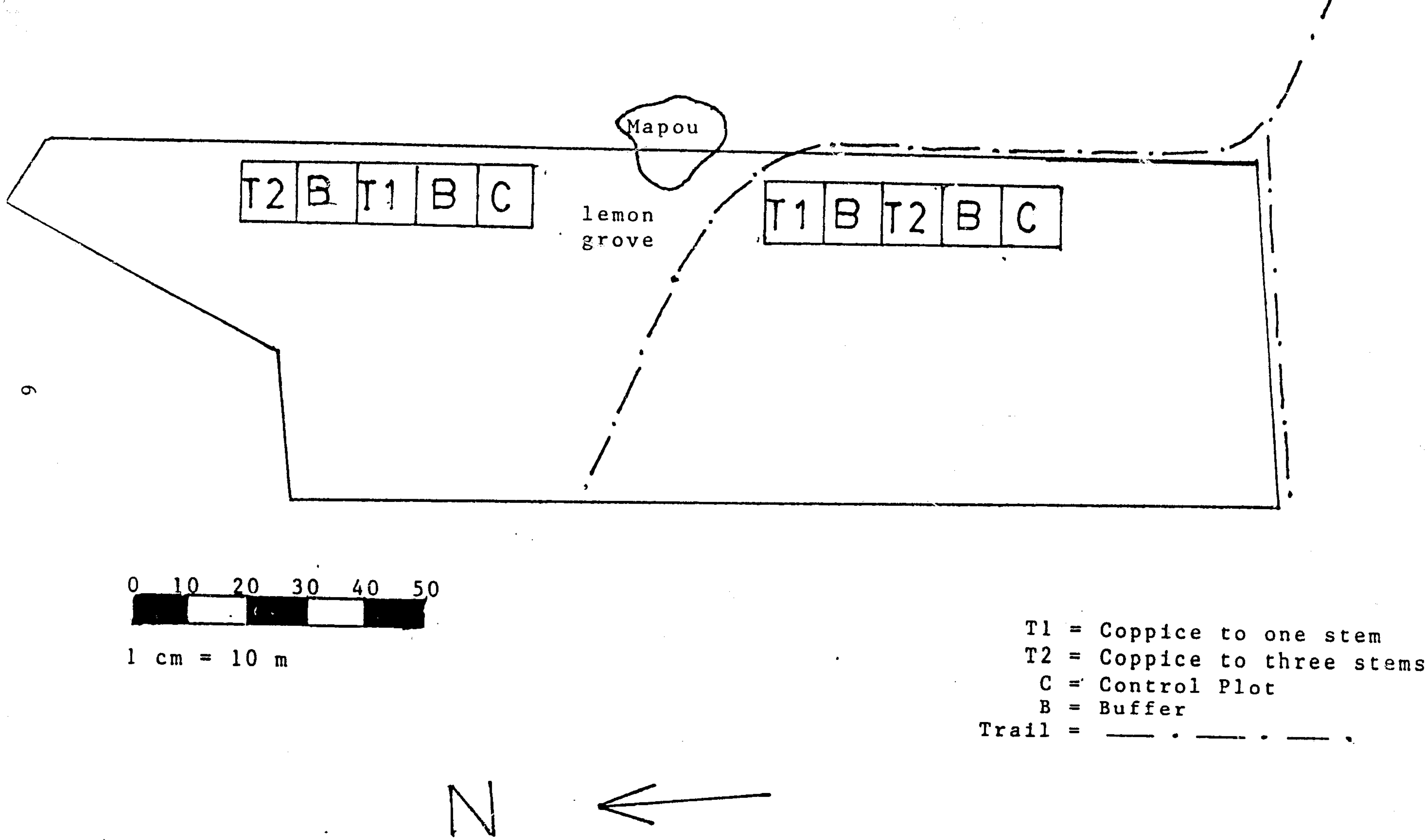
The site was surveyed and soil pits dug in the summer of 1986. The plantation measures approximately 4.8 ha. It is occupied largely by leucaena although several other species are present as part of a species trial established in late 1983. Two areas of better growth were identified at that time, the western third and northeastern corner of the plantation (Dupuis, 1986). This trial is in the northeastern section of the plantation (Figure 2).

The study site is located at an altitude of 244m and lies within the sub-tropical moist forest of the Holdridge (1963) Life Zone classification and zone 37 of the Buffum/Campbell (Buffum, 1984) classification. It receives an average of 1730mm of rainfall per year. The soil has a pH of 7.7 and is a shallow, light brown clay silt underlain by sand and gravel. The slope of the site ranges between five and ten percent.

Experimental Design

The experiment consists of two replications of each treatment and is laid out in a discontinuous strip ten meters wide. The replications are 50m long and are separated by a small grove of lemon trees. Each experimental plot measures $100m^2$ The strip is parallel to the eastern edge of the plantation and is north-south in alignment. Each experimental plot is separated by a similar size buffer zone (Figure 2).

FIGURE 2. Experimental Plot Layout for the Coppicing Study at Mirebalais



For each experimental plot, all trees were measured for dbh, ground diameter, and basal diameter (10cm) and cut at 10cm above ground with a bow saw. Approximately one-fourth of all trees were measured for total length.

Diameter distribution of the trees in the experimental plot is presented in Figure 3. Trees in the control plots were measured for dbh, ground and basal (10cm) diameter, flagged with ribbon and left standing.

The experimental design involves two treatments and two replications with two control plots as shown in Figure 2. The treatments involved are:

1. Coppice to one stem (T1)
2. Coppice to three stems (T2)
3. Control

Experimental Method

The experimental plots were measured and cut on October 7, 1986. The experimental methods will be the same as those applied in the Perdi Midi experiment. The application of the treatments will take place six months from the date of study establishment, and identical measurements will be taken at 12, 18, and 24 months.

CHAPTER 3

INTERIM RESULTS AND DISCUSSION

RESULTS

There are two reasons why the preliminary findings presented here should not be interpreted as the final results of this experiment. First, the experiment is designed to conclude after two years, and the experiment is presently only halfway to that endpoint. Secondly, the seasonal rains were late in falling at Perdi Midi this year and the twelve month measurements were collected before they began. The onset of the rains has undoutedly changed the situation in comparison to when the measurements were taken.

Cassia siamea

Figure 4 shows a comparison of the average heights at 12 months and dbh of the two replications of each treatment. Figure 5 indicates the average heights of the replications combined for each treatment at the time of treatment application and at six months after treatment application. It also shows the average dbh at six months after treatment application. Figure 4 indicates that there are no large differences between the replications for either of the two variables examined. Figure 5 shows that average height and dbh at six months after treatment application are similar for T1 and T3 treatments, while height and diameter are lower for T2. Possible reasons for these results will be examined in the Discussion section.

Leucaena leucocephala

Figures 6 and 7 provide the same information for leucaena as did Figures 4 and 5 respectively, for cassia.

Two things should be noted from Figure 6. First, as previously mentioned, there was only a single replication of the coppice to all treatment due to lack of space. Second, there is a definite, if small, difference between replications for total height in both the T1 and T2 treatments.

Figure 7 shows that at six months after treatment application, the treatments produce extremely homogeneous results where height and dbh are concerned. It also indicates that the T3 treatment showed the greatest increase in height from time of treatment application (February, 1986) to October, 1986.

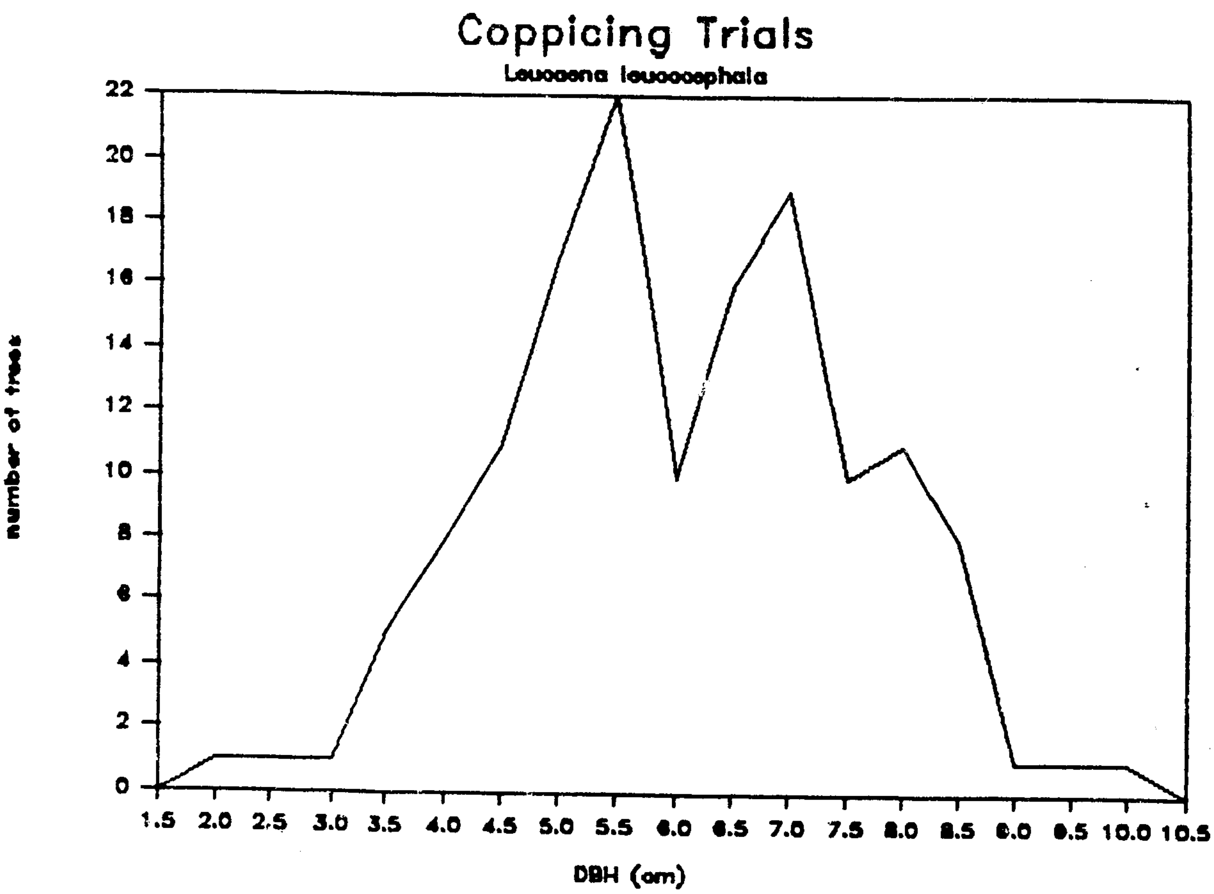


FIGURE 3. Diameter Distribution of Luecaena leucocephala Trees Harvested in Coppicing Study at Mirebalais.

DISCUSSION

Cassia siamea

At this point, approximately half way through the projected course of study, conclusions should not be drawn, but only tendencies discussed. Figure 5 presents an unexpected result. The relationship between the T1 and T2 treatments is as one would expect, since T1 leaves only a single sprout to draw on the resources of a well established root system. The performance of the T3 treatment did not follow this rationale. With an average of nine sprouts per stump (Table 1) one would expect the sprouts in this treatment to be smaller than those of the other treatments because of fewer available resources. Instead, T3 sprouts are similar to those in the T1 treatment, and much larger than those in the T2 treatment.

It is tempting to attribute this to the experimental layout (Figure 1). Both T3 blocks are in the interior of the experimental strip, away from the salt flats, suggesting that these trees had less to contend with in the way of harsh environments. Figure 4, however, shows that replication 1 for both the T1 and T2 treatments did not produce greatly taller sprouts than their counterparts near to the salt flats. Indeed, in the T1 treatment those trees closer to the salt flats are, on the average, taller than those near to the road.

Leucaena leucocephala

The results for *Leucaena leucocephala* are also puzzling. It is quite possible that what appears to be confusing now will become clear in another 12 months. Many uncontrollable variables contribute to the early growth of coppices. Only time (24 months) will tell which are truly significant and in what way they effect coppice treatments.

Figure 6 shows that replication 2 produced a higher average height than replication 1 in both the T1 and T3 treatments. Secondly, Figure 7 shows that the T2 treatment produces sprouts which have, on the average, greater total height and diameter than those in the T1 treatment. Also, Table 2 shows that T3 has a slightly higher average height than either of the other two treatments.

General Discussion

There are several possible explanations for the growth habits described here, including correlation of sprout performance with stump size, possible J-rooting of the original trees, microsite differences in soil and nutrient content, and the effect of animal incursion into the plantation. It is not possible to attribute the results to any single factor. The early stages of shoot growth are extremely rapid and variable, and it is not until crown closure and expression of dominance that the true results of an operation such as this one are seen.

TABLE 1. Measurements at establishment and six months at the Perdi Midi site for *Cassia siamea*

COPPICING STUDY (PERDI MIDI)
Measurements at establishment (Feb. 1986)
Cassia siamea

Trmt.#	Avg. Ht.	Avg. Ht. Trmt.	Avg. #. Stems
T1-R1	2.03	2.13	10.04
T1-R2	2.23		9.46
T2-R1	1.53	1.51	7.96
T2-R2	1.49		6.58
T3-R1	1.76	1.85	7.48
T3-R2	1.95		7.73

COPPICING STUDY (PERDI MIDI)
Measurements at six months (Oct. 1986)
Cassia siamea

Trmt.#	Avg.# Stems	Avg. Stems Trmt	Avg. DBH (cm)	Avg. DBH Trmt.	Avg. Ht. (m)	Avg. Ht. Trmt.
T1-R1	4.48	6.26	1.36	1.59	3.09	3.61
T1-R2	8.05		1.82		4.12	
T2-R1	4.48	4.42	0.96	0.94	2.74	2.67
T2-R2	4.37		0.92		2.60	
T3-R1	8.50	9.01	1.32	1.33	3.83	3.68
T3-R2	9.52		1.33		3.53	

TABLE 2. Measurements at establishment and six months at the Perdi Midi site for *Leucaena leucocephala*

COPPICING STUDY (PERDI MIDI)
Measurements at establishment (Feb.1986)
Leucaena leucocephala

Trmt #	Avg. Stems	Avg.Ht (m)	Avg. Ht Treat.
T1-R1	6.9	1.7	2.0
T1-R2	7.6	2.3	
T2-R1	7.4	1.9	2.0
T2-R2	6.6	2.1	
T3	5.1	1.9	1.9

COPPICING STUDY (PERDI MIDI)
Measurements at six months (Oct. 1986)
Leucaena leucocephala

Trmt #	Avg. Stems	Avg. Stems Trmt.	Avg. DBH (cm)	Avg.DBH Trmt	Avg. Ht. (m)	Avg. Ht Trmt.
T1-R1	5.41	4.63	0.55	0.73	1.89	2.39
T1-R2	3.85		0.90		2.88	
T2-R1	4.13	3.68	0.62	0.80	2.22	2.63
T2-R2	3.24		0.98		3.03	
T3	6.00	6.00	0.73	0.73	2.70	2.70

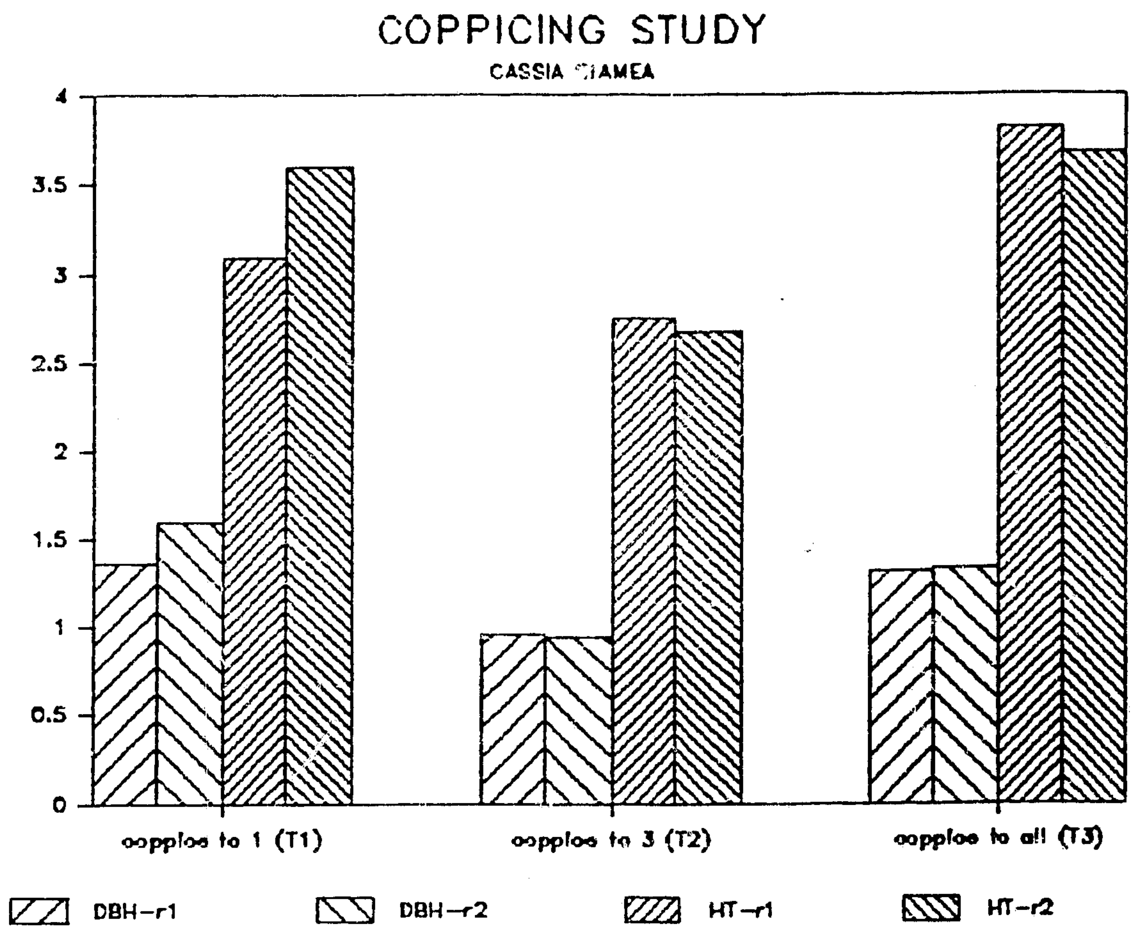


FIGURE 4. Comparison of DBH and Height Between the Two Replications By Treatment For *Cassia siamea* at the Perdi Midi Study

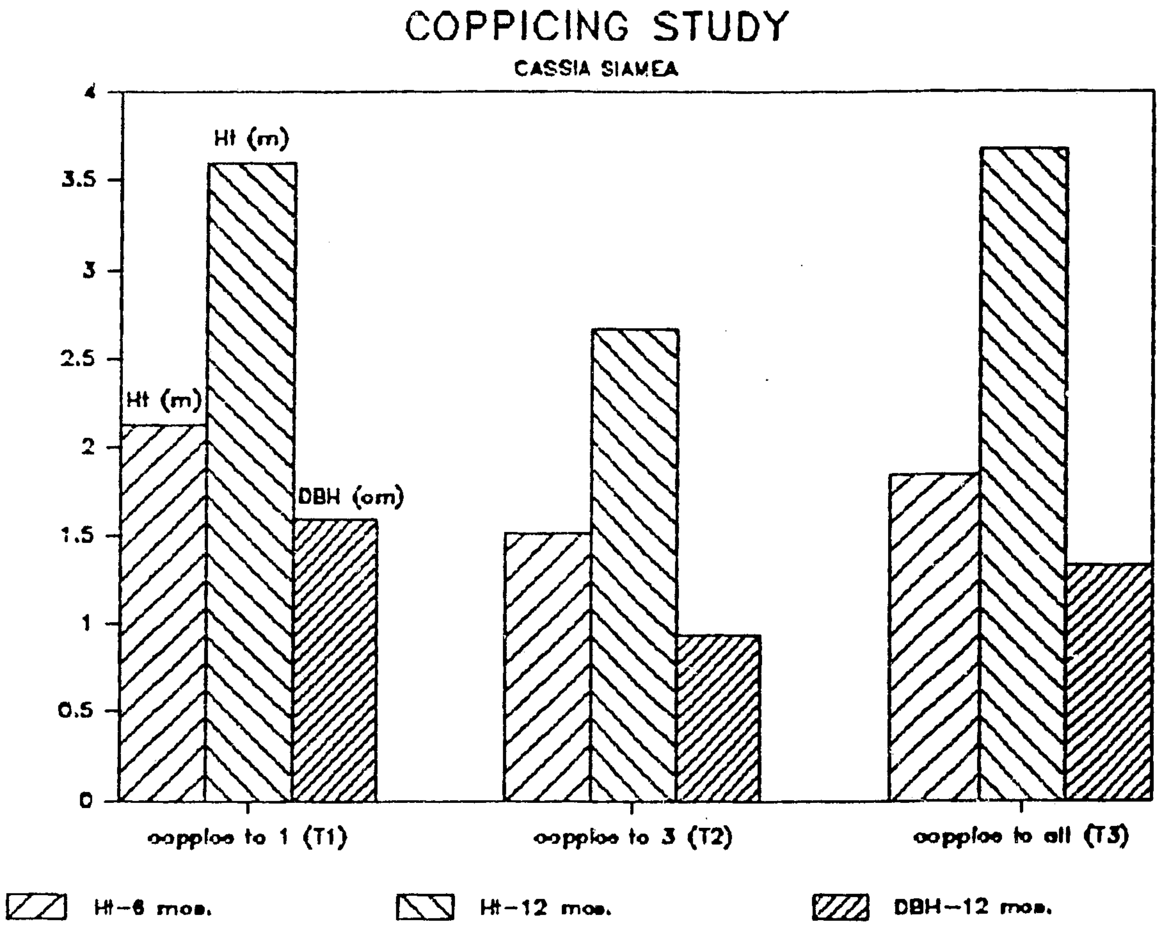


FIGURE 5. Comparison of Height at Six and Twelve Months and DBH at Twelve Months After Treatment Application For <u>Cassia siamea</u> at the Perdi Midi Study.

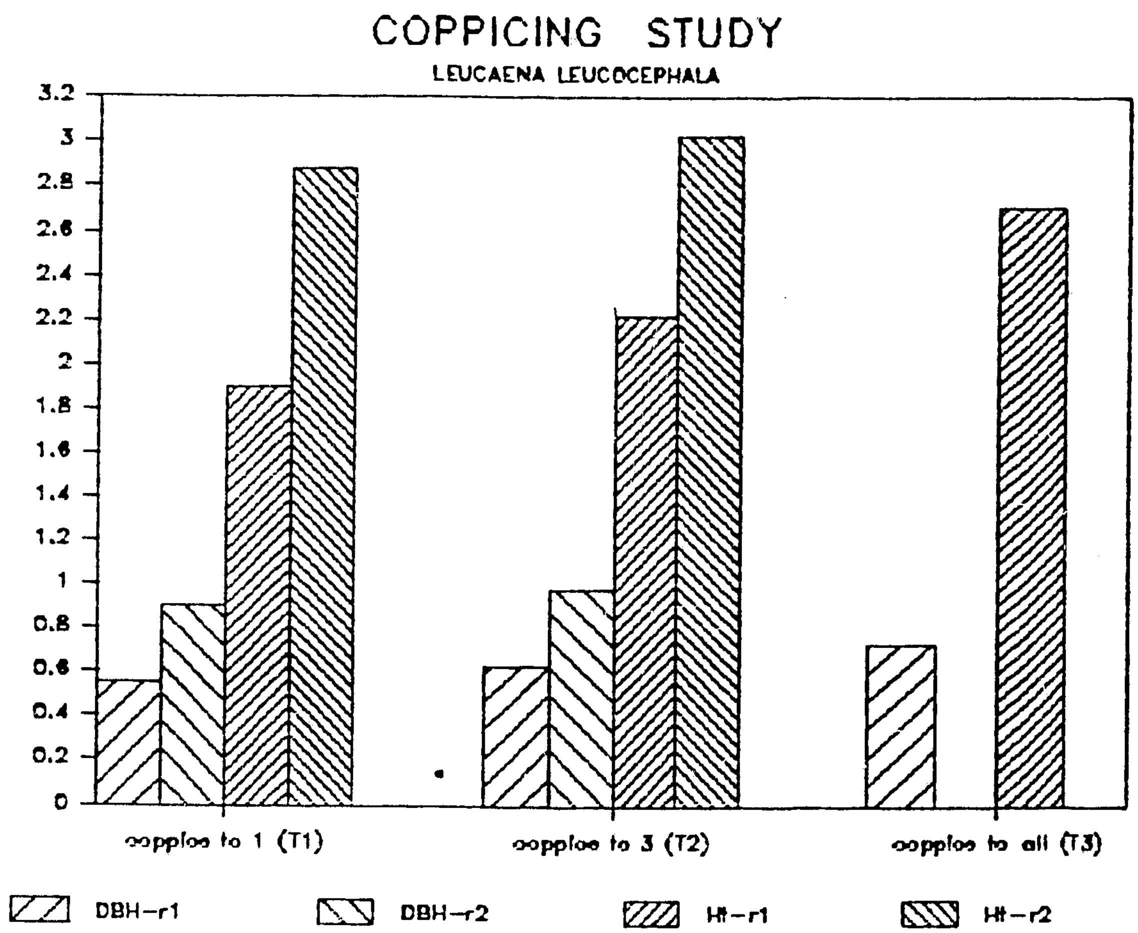


FIGURE 6. Comparison of DBH and Height Between the Two Replications By Treatment for Leucaena leucocephala at the Perdi Midi Study.

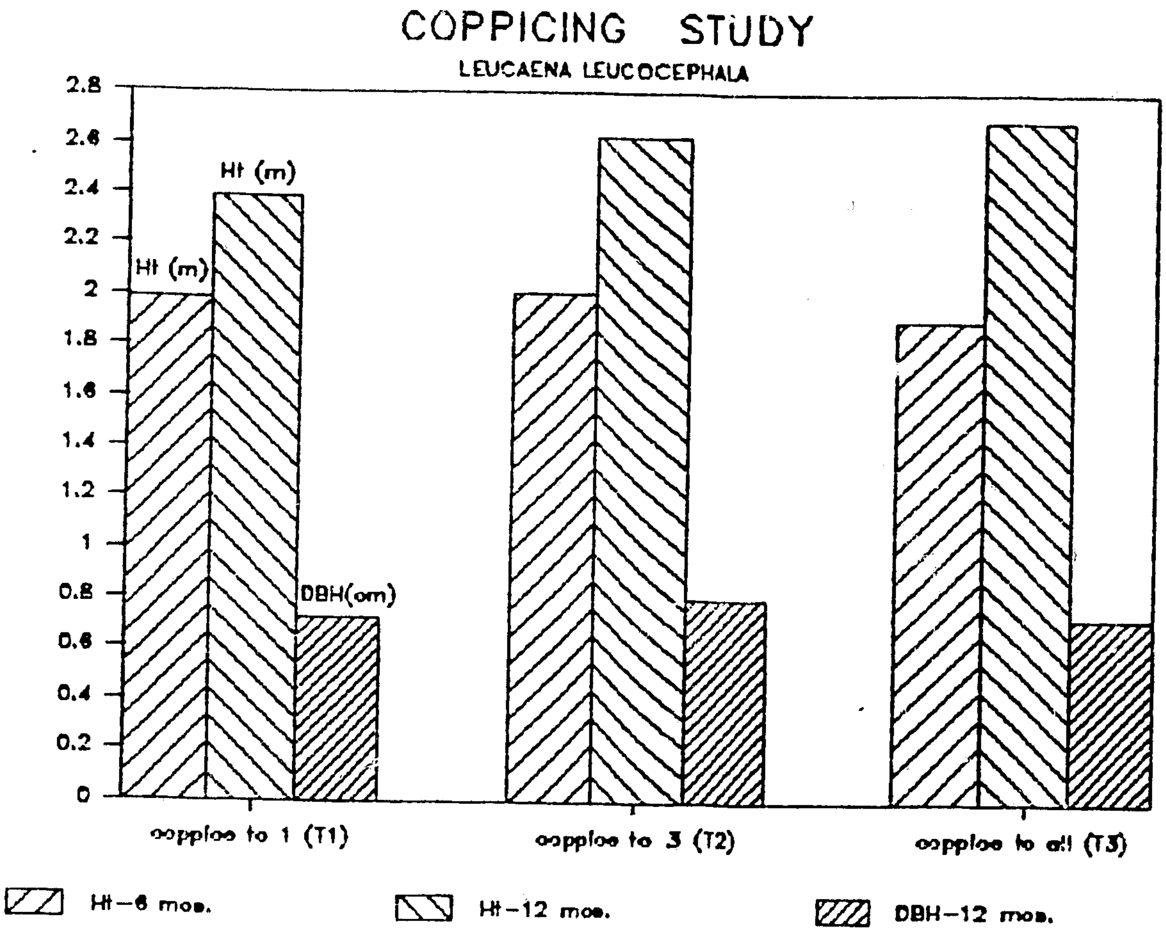


FIGURE 7. Comparison of Height at Six and Twelve Months and DBH at Twelve Months After Treatment Application For Leucaena leucocephala at the Perdi Midi Study.

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CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

These coppicing trials are expected to provide essential information on the appropriate thinning treatment to apply to coppiced plantations of *Leucaena leucocephala* and *Cassia siamea.*

The experiments will provide valuable information on the productivity of coppicing for fuel or polewood production Appropriate analysis of the results will establish whether or not coppicing increases yields of a stand of trees managed for a specific purpose such as fuelwood.

This information will enable the elaboration of fuelwood and polewood yield tables for coppices of the two tree species mentioned.

At this point in the experiment final conclusions should not be drawn. It is imperative that this study reach its completion before trying to extract information from it because of the variability in growth rates inherent in sprout growth.

Recommendations

The length of the coppice cycle (24 months) should be reduced or increased as a function of the specific production objectives.

The thinning treatments to be applied to coppiced plantations should be a function of production objectives.

Soil samples should be taken from each experimental plot at

determined in order to examine the role of microsite differences in the results obtained to this point.

Careful adherence to the measurement schedule will allow easy comparison of the data from both plantations.

The treatments on the Mirebalais site must be the same as those already applied at the Perdi Midi site.

Similar coppicing experiments should be set up for other tree species commonly used in agroforestry in Haiti such as neem.

This easy to apply method of producing poles and fuelwood should be introduced as quickly as possible to the Haitian peasants. It allows for the continued use of the same plot of land while simultaneously protecting the land and its resources.

The use of nitrogen-fixing trees (leucaena) will further enhance the system by adding vital nutrients to the soil.

Experiments should be designed and implemented involving the coppicing method of fuel production and the production of agricultural crops in an intercropping system. Crops could be grown in tandem with the trees until the point of canopy closure.

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FORAGE QUALITY AND BIOMASS PRODUCTIVITY
OF *LEUCAENA LEUCOCEPHALA*
CONTOUR HEDGEROWS

by

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Mike Bannister from PADF helped us to obtain the samples in the southwestern region of Haiti and made the necessary contacts that enabled us ot collect the field data.

Finally, the data could not have been analysed without the professional care and attention given to our forage samples by Annie Pierre from the Biochemistry Lab at the Faculté d'Agriculture et Médicine Vétérinaire. The quality of the results obtained demonstrates the potential of that institution and of its personnel to reliably conduct laboratory analyses of considerable complexity.

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CHAPTER 1

INTRODUCTION

The Agroforestry Outreach Project (AOP) has recognized the potential of *Leucaena leucocephala* hedgerows for soil conservation and stabilization. Both CARE and the Pan American Development Foundation (PADF) have established numerous contour hedgerows in various areas of the country. Procedures for the establishment and harvesting of hedgerows are still experimental and vary as a function of the intended use (soil conservation, green manure, or animal fodder). In Haiti, the use of leuceana hedgerows planted along contour lines offers great possibilities as a biological measure to control erosion, sustain and eventually increase agricultural productivity and provide a source of animal fodder when grown on many low to medium altitude hillsides across the country.

Other species such as *Leucaena diversifolia* and *Calliandra calothyrsus* also hold great promise for farmers in the establishment of biological measures for soil ammelioration and erosion control.

Leucaena leucocephala is an excellent soil improver and stabilizer. Its fast-growing root system breaks up compacted soil layers, thereby improving moisture penetration and decreasing run-off and the chances of soil slippage (NAS, 1977). It increases soil fertility by means of its nitrogen fixing bacteria (*Rhizobium*), and by its nitrogen rich leaf litter which often rivals animal manure for nitrogen content. (NAS, 1980). It is also a favored browse for both cattle and goats due to its high protein content.

All of the above considerations combined with leucaena's ability to thrive on the steep slopes and alkaline soils common in Haiti make leucaena hedgerows an attractive possibility for use in agroforestry systems.

This report summarizes the results of the first phase of research on leucaena contour hedgerows. Its main emphasis was to develop appropriate methodologies and lay the groundwork for future research. Results of this phase of the research are therefore preliminary and must be interpreted with caution, due to reduced sample size and limited site coverage.

The methodology used to select and study the hedgerow samples, as well as a description of the sites chosen, are presented in Chapter 2. Chapter 3 presents, in separate sections, a preliminary interpretation of soil analysis, forage quality analysis, and hedgerow productivity. Implications of the study for future research are presented in Chapter 4.

CHAPTER 2

MATERIALS AND METHODS

The study sites were located in the northwest and the southwest of Haiti. In the northwest the hedgerows were selected from plots established by CARE on peasant land in the vicinity of Passe Catabois. In the southwest, they were selected established by PADF near Les Cayes.

Sample Selection

The total number of samples taken at a given site was subjectively determined on the basis of total hedgerow length, condition of the hedgerows, and the willingness of farmers to have the hedgerows cut. The center of the five meter samples was randomly selected from the total length of the hedgerow. From this center point, the sample plot extended 2.5m to either side. Sample selection specifically avoided portions of hedgerows that were browsed or otherwise damaged. The sample constituted approximately 10% of the total hedgerow length.

Sample Collection

The sample plots were measured for average height, then cut with a machete as close to the root collar as possible in order to facilitate resprouting. The sorting of the cut material into forage and fuel categories was done by local farmers based on the assumption that they are more aware than project personnel of the size of material being eaten by their livestock or used for firewood and charcoal-making.

The two categories of material were weighed on site by using a 10kg scale. Samples of each were immediately collected and sealed in airtight plastic bags for laboratory analysis.

A total of 25 samples was studied from seven different sites as indicated in Figure 1. All hedgerows sampled represented leucaena first growth and had never been cut before. Soil analysis was performed on one or two soil samples taken from each site depending on the apparent variability of the site, while forage analysis was performed on all 25 samples taken. Laboratory analysis of the soil samples included the results presented in Table 1 in addition to structural and pH data. Forage analysis included the data presented in Table 2 and Table 4. Data on sulphur content and micronutrients was not determined for lack of time and reactive agents. Climatic and other site data were provided by CARE and PADF and verified in the field.

Site Description

Galata I and II

These two sites near Passe Catabois in the Département de Nord-Ouest are similar, as both fall within Zone 12 of the Buffum/Campbell Classification (Buffum, 1984) and the Sub-Tropical Dry Forest of the Holdridge Life Zone Classification (Holdridge, 1963). Both sites lie at an altitude of approximately 200m, receive approximately 990mm of precipitation per year, and have predominantly clayey soils with pH's of 7.6.

Galata I has a northeastern exposure, a 30% slope, and drainage rated as good, while the Galata II site has a northern exposure, an 80% slope, and drainage rated as very good. Hedgerows in these sites varied in height from 1.1 to 1.9 m and were 13 months old.

Nancouteau I and II

The two Nancouteau sites are also in the vicinity of Passe Catabois, and are within Zone 12 of the Buffum/Campbell Classification (Buffum, 1984) and the Sub-Tropical Dry Forest of the Holdridge Life Zone Classification (Holdridge, 1963). Both sites are at an altitude of 300m, receive approximately 990mm of rainfall per year, have clayey soils ranging in pH from 7.6 to 7.75, and have good drainage. Nancouteau I has a western exposure and a 50% slope, while Nancouteau II has a eastern exposure and a 60% slope.

Nancouteau I represented the site with the youngest hedgerows in this study (four months), while Nancouteau II included the oldest hedgerows (more than five years).

Décidé

The Décidé site lies within Zone 12 of the Buffum/Campbell Classification (Buffum, 1984) and is in the Sub-Tropical Dry Forest of the Holdridge Life Zone Classification (Holdridge, 1963). The site is located 25km south of Passe Catabois at an altitude of 600m and receives on the average more than 1000mm of precipitation per year. The 90% slope has a western exposure and predominantly clayey soil with a pH of 7.5. The drainage is rated as very good. Hedgerows on this site were slightly taller than two meters and were approximately three years old.

Bergeau

Bergeau, in the vicinity of Les Cayes, is in zone 31 of the Buffum/Campbell Classification (Buffum, 1984) and lies within the Sub-Tropical Moist Forest of the Holdridge Life Zone Classification (Holdridge, 1963). At an altitude of 100m, the site receives an average of over 2000mm of rainfall per year. The southern exposed site has a slope of 20% and clayey soils with a pH of 7.4 and of poor drainage. The hedgerows are used as a demonstration plot for peasants in the area and were 2.3 m tall and 10 months old. They had the highest (0.2) height versus age ratio of all samples in this study (average 0.1).

<u>Arniquet</u>

Also in the vicinity of Les Cayes, this site lies in zone 31 of the Buffum/Campbell Classification (Buffum, 1984) and lies within the Sub-Tropical Moist Forest of the Holdridge Life Zone Classification (Holdridge, 1963). The site, at 100m, receives over 2000mm of rainfall per year. This site has a 50% slope, northern exposure, and clayey soils with a pH of 7.55 and good drainage. Hedgerows have been partially browsed by cattle, are 2.1 meters tall and 14 months old.

The location of all sites may be found on Figure 1.

CHAPTER 3

RESULTS AND DISCUSSION

Interpretation of Soil Analysis

The analysis of soil for each location was carried out by the Faculté d' Agronomie et Médecine Vétérinaire (FAMV). The results are shown in Table 1.

Table 1. Leucaena Contour Hedgerows
Nutrients in Soil
October 1986

SITE	pH	NITROGEN (%)	PHOSPHORUS (%)	POTASSIUM (%)	SODIUM (%)	CALCIUM (%)	MAGNESIUM (%)	Ca/Mg	C/N
Galata I	7.6	0.16	0.01	0.39	0.25	51.70	4.74	11.65	6.4
Galata II	7.8	0.21	0.03	0.62	0.17	54.50	2.49	21.90	6.4
Nancouteau I	7.6	0.34	0.04	0.39	0.09	46.75	1.24	37.70	9.9
Nancouteau II	7.5	0.22	0.02	0.73	0.13	56.50	2.08	27.20	11.3
Décidé	7.4	0.27	0.02	0.33	0.20	65.00	2.08	31.20	7.9
Bergeau	7.6	0.29	0.04	0.27	0.10	39.75	0.83	47.80	7.9
Arniquet	7.3	0.27	0.01	0.19	0.39	57.25	1.24	46.20	9.4
Average	7.5	0.25	0.03	0.42	0.19	53.06	2.10	31.95	8.5

The results from the soil analysis are inconclusive. Purely on the basis of the soils' physical and chemical properties, the various sites in this study show few striking differences. Soil analysis by itself does not appear to explain the differences of biomass production encountered in the field. Some variation among sites in the percentage of soil nutrients can however be noticed, as described below.

1. The soils at all sites are more or less clayey and moderately alkaline.

2. Nitrogen levels ranged from 0.16 to 0.34 percent. These levels would elsewhere be considered poor, but fall within the average range for Haiti (FAMV, 1986). Because of the low Carbon/Nitrogen ratios found here, it is possible that the levels of available nitrogen are even lower due to immobilization.

3. According to the locally accepted norms for phosphorus levels, the reserves of this essential element are relatively good at all seven locations (FAMV, 1986).

4. The percentages of exchangeable cations varied considerably among sites. Sodium (Na) and potassium (K) are low at all sites, while calcium (Ca) and magnesium (Mg) were found to exist in average to high levels at all locations. This high level of Ca, normal in the limestone based soil in much of Haiti, can, however, lead to other problems such as: obstruction of Phosphorus (P) by Ca^{++}, a reduction of oligo-element absorption (iron (Fe), zinc (Zn), copper (Cu), and solphur (S), and a reduction of K availability relative to Ca.

5. The Nitrogen Fixing Tree Association (NFTA) (1985a) reports that soil pH, exchangeable aluminum (Al) and Ca levels, and available P are very important for *leucaena* growth. It grows best in moderately alkaline soils rich in Ca, Mg, K, and sulphur. Phosphorus and oligo-elements can be limiting. If the percentage of the available mineral reserves shown in Table 3 is adequate as it appears, *leucaena* growth should not be inhibited, but fertilization would still be necessary to reduce the deficiency of K, Na and oligo-elements.

6. Since P and N are not available in large amounts, it is essential that *leucaena* seedlings be inoculated with symbionts for nitrogen fixation (*Rhizobium* bacteria) and with mycorrhizae to improve absorption of phosphorus.

7. Finally, this initial interpretation of the soil analysis complements the forage analysis data. The analysis of forage is normally a better diagnostic of site quality for hedgerow growth and a more reliable growth indicator.

Interpretation of Forage Analysis

Three points are important in this interpretation: the chemical composition of the forage, the comparison between chemical compositions of soil and forage and the nutritional value of the forage compared with standard (NFTA) forage values.

Chemical Composition of the Forage

On the whole, the chemical composition of forage falls within the norms established by NFTA (1985a). Phosphorus, which is moderately lower than the minimum standard (0.14 versus 0.16%), magnesium (0.14 versus 0.15%) as well as sodium and fiber were exceptions. Variation in chemical composition within each site and between sites are considerable. The average results of the forage quality analysis are shown in Table 2, while Table 4 presents the results for each site. Table 3 presents the values reported as average by NFTA.

Within Site Variation in Chemical Compositions

The average percentages of nutrients across all sites are as follows:

Table 2. Chemical Composition of Forage Samples by Percentage of Dry Weight.

Component	Percent of dry weight
Nitrogen	3.53
Protein	22.10
Ash	8.28
Fiber	21.89
Calcium	1.11
Phosphorus	0.14
Magnesium	0.14
Sodium	0.04
Potassium	1.49

The "normal ranges" established by NFTA are:

Table 3. Chemical Composition of Average Forage Samples of *Leucaena leucocephala* as Determined by NFTA (1985a)

Component	Percent of dry weight
Nitrogen	3.5 - 4.2
Crude Protein	21.0 - 26.0
Ash	8.0 - 11.0
Fiber	18.0 - 20.0
Calcium	0.5 - 2.4
Phosphorus	0.16 - 0.23
Sulfur	0.15 - 0.25
Magnesium	0.15 - 0.20
Sodium	0.007- 0.03
Potassium	1.0 - 2.6

There is however, some variation between sites in the ranking order of mineral elements in the forage.

In the sites near Les Cayes, for example, the average percentage of Ca is higher than that of K in contradiction to the results from Passe Catabois and Décidé.

Between Site Variation in Chemical Composition

The results of the forage quality analysis with average results per site are presented in Table 4.

Table 4. Leucaena Contour Hedgerows
Nutrients in Forage
October 1986

SITE	No. samples	ASH (g)	NITROGEN (g)	PROTEIN (g)	FIBER (g)	PHOSPHORUS (g)	CALCIUM (g)	POTASSIUM (g)	MAGNESIUM (g)	SODIUM (g)
Galata I	5	8.95	3.88	24.27	18.93	0.12	1.19	1.64	0.14	0.05
Galata II	5	7.85	3.15	19.70	24.32	0.10	1.01	1.98	0.14	0.05
Nancouteau I	4	7.31	3.09	19.33	31.01	0.07	1.04	1.71	0.14	0.03
Nancouteau II	3	8.10	3.68	23.07	18.38	0.15	1.08	1.73	0.14	0.05
Décidé	2	8.92	4.07	25.48	18.62	0.13	1.18	1.37	0.14	0.02
Bergeau	4	8.32	3.81	23.88	17.87	0.18	1.13	0.75	0.14	0.03
Arniquet	2	8.51	3.03	18.98	24.11	0.21	1.15	1.37	0.14	0.03
Average	4	8.28	3.53	22.10	21.89	0.14	1.11	1.49	0.14	0.04
NFTA-Minimum		8.00	3.50	21.00	16.00	0.16	0.50	1.00	0.15	0.01
NFTA-Maximum		11.00	4.20	26.00	20.00	0.23	2.40	2.60	0.20	0.03

Nitrogen

Four of the seven sites (Galata I, Nancouteau II, Décidé, and Bergeau) have an average percentage of nitrogen falling within the normal range. Décidé has the highest average percentage (4.07). Among the three non-conforming sites (Galata II, Nancouteau I, and Arniquet), Arniquet has the lowest average percentage (3.03). Nitrogen levels of 1.6 to 1.9% are considered adequate for beef as well as dairy cattle (Humphreys, 1978).

Phosphorus

Generally, the average percentage of phosphorus at all sites does not coincide with the established values except for the two sites in the vicinity of Les Cayes. At Passe Catabois, the average percentage of phosphorus is low, but considered acceptable (NFTA, 1985a); in Galata II (0.10) and Nancouteau I (0.07), the values are well below the established norms.

Calcium

The average percentage of calcium falls within the normal range at all sites; variation within sites is not significant, ranging from 1.19% at Galata I to 1.01% at Galata II.

Magnesium

This important element falls in the lower range of NFTA standards. The average percentage for all sites is 0.14% compared with an average norm of 0.17 percent.

Potassium

The percentages of potassium at all sites are within the established ranges except at Bergeau, where the average percentage is only 0.75% compared to the norm of at least one percent.

Sodium

The average percentages from all sites (0.04%) are slightly higher than the Leucaena norm of 0.007 to 0.03 percent. In comparison, *Stylosanthes humilis*, a common forage legume used in the tropics, contains 0.06% and *Panicum maximum*, a grass used in managed pastures, 1.0% (Humphreys, 1978).

Fiber

The averages at all sites are higher than the norms except at Bergeau (17.8% versus 19.0%). The average at Galata II and Arniquet was 24% of dry weight, while at the Nancouteau I and II sites the average was 31%.

Ash

All results are within the established ranges. They are average approximately eight percent except at Nancouteau I where the percentage of ashes is moderately low (7.3%).

This information shows that the quality of forage depends on the site. For purposes of animal nutrition, it is therefore important to consider the site from which the forage has been harvested.

Comparison Between Chemical Composition of Soils and Forage

As mentioned in the last section, it is not easy to determine the actual availability of nutrients in the soil. A comparison between chemical compositions of soil and forage samples is, therefore, complex. This analysis is limited only to general tendencies as no significant correlations were found between soil and forage nutrients.

Nitrogen, Phosphorus, and Potassium in Soil and Forage

The analysis shows that the quantities of N, P, and K in the soil are lower than the levels in the forage on all sites. There is no direct correlation between soil nutrients and forage nutrients as shown in Figures 2, 3, and 4. Nancouteau I, for instance, has the highest nitrogen percentage in the soil, but the nitrogen percentage in its forage is one of the lowest of all the sites. The inverse is true for Galata I (Figures 2). There are several similar examples.

The large differences between soil and forage nutrient compositions suggests that the source of some of these nutrients is not exclusively the soil. Nitrogen, therefore, originates largely from fixation of atmospheric nitrogen, precipitation, and organic matter. Additional P and K originate from organic matter on the soil surface. Phosphorus is also made available from fixation by mycorrhizae. Moreover, the antagonism between some elements and oligo-elements such as Fe, Cu, and Zn impede absorption of nutrients by the root system (Bernier and Camiré, 1982).

Calcium, Magnesium, and Sodium in Soil and Forage

Contrary to the results for other elements (N, P, and K), the soils proved to be richer in Ca, Mg, and Na than the forage as shown in Figures 5, 6, and 7. It appears, however, that quantities of Ca, Mg, and Na in the soil are not directly correlated with those in the forage. The soil at Galata I, for instance, is five to six times richer in Mg than the soil at Bergeau, but forage Mg levels of the two sites are similar. The soil at Arniquet is four to five times richer in Na than the soil at Nancouteau I, but the two sites have the same quantity of Na in their forage samples.

It is not possible in this study to determine the causes of this lack of correlation between composition of soil and forage samples. Only the *available* elements in soil are important, not the *total* quantities of these elements. For lack of time, it was also not feasible to determine what portion of the soil nutrients are actually available to the plants.

Finally, other factors such as the antagonism between different elements have a great influence on absorption of elements from the soil. The ratios of antagonistic elements such as Ca and Mg are, therefore, important. Most sites in this study, show an excessively high Ca/Mg ratio which prevents Mg from being absorbed by the root systems.

Nutritive Value of Forage

The nutritive value of forage is established by appropriate chemical analyses and by comparison with other forages. In this report only the differences between the chemical composition of forage in the samples studied and the norms established by NFTA in 1985(a) will be discussed. Figures 8 - 14 show the nutrient values for the sites studied compared to NFTA standards.

The comparison between these standards and the chemical composition of forage of each site indicates the deficiencies and virtues of each forage.

Forages with High Nutritive Value

The forages of Galata I, Nancouteau II, and Décidé have a high nutritive value. These forages are rich in major elements (N, protein, Fiber, P, Ca, K, Mg, and Na), as shown in Figures 8, 11, and 12. The forage of Bergeau can also be considered as a good forage despite being relatively poor in and K (Fig. 13).

Forages With Limited Nutritive Value

Poor in N, proteins, and P, the forages of Galata II, Nancouteau I, and Arniquet can be considered to be of limited nutritive value in spite of their large amounts of fiber. In these sites only four major elements (Ca, K, Mg, and Na) fall within the optimal range. The level of P at Arniquet also falls within this range.

It is well known that the nutritive value of *leucaena* forage is high, but its use limited because of the presence of mimosine. It is generally recommended not to feed animals leucaena forage exclusively. The maximum percentage of *leucaena* in a forage mix (dry weight) should be between 60 and 75% for ruminants, but only 10% for poultry, horses, and other non-ruminants (NFTA, 1985a).

The sample size precluded the use of appropriate tests of digestibility. It was also not possible to obtain data on elements such as sulphur, due to temporary unavailability of specific reactive agents.

Biomass Production

During this phase of the hedgrow production research, only a limited number of samples could be collected and analysed. Given the growth variability of *Leucaena leucocephala* especially at a young age and the variability of site characteristics in Haiti, it is difficult to draw any definite conclusions on growth patterns. Further data will need to be collected in order to assemble the data base required for an in depth statistical analysis and enable extrapolations and generalisations.

For descriptive purposes only, a limited interpretation of field data shows a positive correlation between hedgerow height and total biomass productivity, fuelwood productivity and forage production (in kilograms green weight). Though measured, spacing of the countour hedgerows did not affect biomass productivity significantly. Spacing was sufficient to minimize interference among hedgerows, but whether the crops being interplanted had an effect on growth was not established within the scope of this phase of the hedgerow research. Similarly, density of seeding appeared constant and thus, it didn't appear to have an effect on hedgerow growth. Whether in-row spacing does have an effect however, needs to be established through specifically designed experiments.

From a preliminary analysis it would appear that hedgerow height is a better indicator of productivity than age in terms of either total biomass, fuelwood or forage.

Figure 15 shows the relationship between green biomass weights as measured in the field and the weights estimated by the regression equation:

Biomass (kg) = Height (m) * 9.93 - 5.46;

with a determination coefficient of 69%.

Figure 16 shows the relationship between fuelwood weights as measured in the field and the fuelwood weights estimated by the regression equation:

Fuelwood (kg) = Height (m) * 4.94 - 4.11;

with a determination coefficient of 60%.

Finally, Figure 17 shows the relationship between forage weights as measured in the field and forage weights estimated by the regression equation:

Forage (kg) = Height (m) * 4.99 - 1.34;

with a determination coefficient of 65%.

These regression equations have proven accurate in both the lower and higher ends of the data range as measured in the field (Figure 17). The relatively low determination coefficients are mostly due to a wider than normal scatter of the data points around the production curve. The production curves do not appear smooth in the Figures 15, 16 and 17 because of the varying height intervals used on the X-axis.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Within the time constraints under which this study was conducted, the developement of a practical methodology for the study of *leuceana* hedgerows and the preliminary results outlined in the previous chapter, constitute a satisfactory achievement. More importantly, this study lays the methodological groundwork for future research, suggests specific questions to be answered in the future and sketches some of the major characteristics of *leucaena* hedgerows as source of fuel and forage.

Conclusions

1. Preliminary data analysis shows that leucaena hedgerows produce approximately 1kg of dry forage for every meter of hedgerow, or on the average, 62% of the total biomass.

2. Fuelwood production averages about 0.39kg (dry weight) per linear meter of hedgerow or approximately 38% of total biomass.

3. Hedgerow height will predict potential fuel and forage productivity with greater accuracy than age. For example, the Bergeau site at 10 months and an average height of 2.3m produces 2.6kg/m (green weight) of biomass, while older hedgerows (13 months) at Galata I and II have an average height of 1.4m and produce only 1.6kg/m of biomass. The determination coefficient of biomass production as a function of height and age are 69% and 52%, respectively.

4. It appears that *leucaena* forage quality is adequate given the availability of nutrients in the soil where the hedgerows are growing. The average protein content is 22%, that of nitrogen is 3.5%, calcium 1.1%, and the fiber content is 22 percent. The NFTA (1985) reports similar values and a digestibility factor of 60 to 75 percent. A study conducted near Port-au-Prince found similar protein, calcium and fiber percentages (Milius, 1984). In comparison, alfalfa (*Medicago sativa*) contains 22.5% protein and *Pennisetum spp.*, only 10%, depending on the fertility of the soil.

5. Nitrogen fixation in general varies between 20 to 40kg per every 1000kg of dry matter grown. It depends on biomass growth which in turn depends on soil nutrients and moisture content. For the the sites studied, the average accumulation of atmospheric nitrogen in the soil equals approximately 1 to 2kg for every 36 meters of leucaena hedgerow. Assuming 1000 m of hedgerows per hectare on a moderate slope, the amount of nitrogen fixed by *Rhizobium* bacteria would amount to approximately, 28 to 56kg per hectare.

Recommendations

1. Future data collection has to be expanded (a) to cover a wider range of sites and (b) to build up the total sample size. Variance in the growth of leucaena and in site characteristics requires that the sample size be as large as possible to enable valid extrapolations and generalisations.

2. Research should be designed to determine the most appropriate harvesting cycles for leucaena hedgerows in order to maximize forage and fuelwood productivity. This research will involve the establishment of trial plots and the monitoring of growth over several harvesting cycles.

3. Data on the nutritive value of leucaena hedgerows should be collected and analyzed as an ongoing and parallel research activity.

4. A study should be established to determine the effect of seed inoculation with mycorrhizae (to improve absorption of P) and with *Rhizobium* (to increase availability of N) on hedgerow growth and productivity.

5. In conjunction with ongoing research efforts conducted by CARE in the Northwest and PADF in the Southwest, experimental plots should be set up there and elsewhere and data collected to test diferences in productivity, as well as farmers' acceptance of: *Leucaena leucocephala* var.K8 versus *Leuceana leucocephala* var.K157, and *Leucaena diversifolia*. Additional species such as *Calliandra callothyrsus* and *Sesbania grandiflora* hold great promise for contour hedgerows and need to be tried experimentally.

6. Experiments should be established to determine simple agri-silvo-pastoral systems using leucaena hedgerows to improve overall farm productivity, complementing research already under way under the auspices of Agricultural Development Services (ADSII), the Ministry of Agriculture (MARDNR), and FAMV.

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FUELWOOD, POLEWOOD AND BIOMASS PRODUCTION POTENTIAL OF *LEUCAENA LEUCOCEPHALA* *CASSIA SIAMEA* *AZADIRACHTA INDICA* *COLUBRINA ARBORESCENS* *EUCALYPTUS CAMALDULENSIS* AND *PROSOPIS JULIFLORA*

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EXECUTIVE SUMMARY

This report presents yield and volume tables for six tree species commonly used in agroforestry applications in Haiti. The species studied include: *Leucaena leucocephala, Cassia siamea, Colubrina arborescens Eucalyptus camaldulensis, Azadirachta indica* and *Prosopis juliflora.*

Productivity of these tree species was estimated as a function of diameter at breast height (dbh) and diameter at the stump (10 cm from the ground). Productivity was expressed in terms of (a) total above ground biomass, (b) fuelwood production, and (c) polewood production. In order to enable comparison across sites and over time, the units of measurement were kg dry weight.

The yield tables presented in this report estimate the productive potential of specific tree species on one or more sites. Topographic, climatic, and edaphic conditions unique to those sites have undoubtedly affected the results of this study. The actual productive potential of the trees thus varies as a function of site conditions. Due to the variability of site conditions within which these trees actually grow in Haiti, these yield tables will probably not prove accurate for all sites in Haiti.

Furthermore, given that the trees used in the sample had relatively small dbh, the regression equations used to estimate the productivity as a function of dbh tend to overestimate the production of trees with a dbh higher than for example, 16 centimeters. Extrapolations of production estimates above this diameter must be considered therefore tentative and used with caution.

Nevertheless, the yield tables represent a significant first step in assessing the tree species' productive potential in terms of both fuelwood and polewood within the Haitian ecological context. Their practical value in terms of predicting specific yields on similar site conditions, could prove extremely useful in the planning and design of agroforestry applications across the Haitian countryside.

Results of the comparative analysis of the production potential of all species studied, though only indicative of possible trends, shows that on the basis of dbh, *Leucaena leucocephala* produces the most fuelwood, followed by *Cassia siamea, Prosopis juliflora* and *Azadirachta indica.* When considering the production of polewood, the analysis indicates that *Cassia siamea* followed by *Eucalyptus camaldulensis* and *Azadirachta indica* produces the most polewood.

The yield tables for leucaena, neem, cassia, eucalyptus and prosopis add scientific insight in tree species known abroad, but never studied in Haiti. The production tables for *Colubrina arborescens* contribute new knowledge relative to a tree species unknown outside of Haiti, yet quite valuable for agroforestry application in most humid tropical areas.

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CHAPTER 1

INTRODUCTION

This report presents the result of five months of silvicultural research designed to study the fuelwood, biomass and polewood production potential of six tree species. The trees studied include four exotic species and two trees indigenous to Haiti. *Leucaena leucocephala*, *Cassia siamea*, *Azadirachta indica (neem)* and *Eucalyptus camaldulensis* comprise the exotic trees, while the indigenous trees are represented by *Colubrina arborescens (kapab)* and *Prosopis juliflora (bayahonde)*.

Each tree species was studied on one or more sites, reflecting some of the typical environmental conditions within which these species are commonly planted in Haiti. The study of each species involved the cutting of a sample of trees of different diameters, the weighing of the entire tree by sections and the sampling of the tree sections for laboratory analysis and determination of moisture content and specific gravity.

This report presents in the form of yield tables and line charts, estimates the production potential of the above mentioned tree species on the basis of the data collected in the field. The results of these estimations are treated separately for each species and included in separate chapters of this report. Each chapter includes a section describing the study site and the research methodology used, followed by a discussion of the major findings and an explanation of the regression equation used to estimate the production of fuelwood, polewood, and biomass.

Each yield table is designed to allow the estimation of yields as a function of either dbh (at 1.3m) or stump diameter (at 10cm). The tables enable the computation of the production potential of any stand of trees of the indicated species, by simply counting the trees of each diameter class. One simple field measure (dbh, stump diameter) can thus provide a reliable estimate of a tree stand's production potential in terms of either fuelwood (kg dry weight), total biomass (kg dry weight), or polewood (m^3/1000).

All the tables were produced using regression models that maximized the determination coefficient (r^2). Biomass yield and polevolume tables used the same regression equation for all species studied. Fuelwood tables were calculated using two different parameters: dbh and stump diameter. Two regression models were used for fuelwood production as a function of dbh and three models for fuelwood yields as a function of stump diameter.

A brief discussion about the results of a comparative analysis of the performance of all species studied is presented in Chapter 8. Those results constitute only an indication of possible trends in productive differences rather than proof of different productive potentials.

This report concludes with a recommendations section, where a number of suggestions are made relative to the research methodology, the need for future research and the implications of the results of this study for agroforestry activities in Haiti.

CHAPTER 2

FUELWOOD AND BIOMASS PRODUCTION OF *LEUCAENA LEUCOCEPHALA*

The Agroforestry Outreach Project (AOP) relies to a large extent upon fast growing tree species for fuelwood production. *Leucaena leucocephala*, has been used since the start of the tree planting effort in 1982 and has proven its worth as a rustic, fast growing, and well received tree species. This species appears well-adjusted to the varied ecological conditions of the Haitian countryside and only in a few extreme cases, do native tree species such as *Prosopis juliflora*, appear better adapted. It is bound to be one of the main tree species used for reforestation in Haiti.

This report analyzes the fuelwood production potential of *Leucaena leucocephala* var.K8 on a hillside plantation near Camp Perrin, north of Les Cayes in the southern peninsula of Haiti. The plantation was established in 1980 on a hillside (57% slope) previously utilized for farming and grazing. Plantation density is approximately 800 trees/ha with spacing ranging from 2.5m to 4.5 meters. On the lower part of the plantation where the hillside meets the plain, the growth of trees is clearly better than on the higher part of the plot. Soil there, is in general shallower and more weathered; trees have both lower height and smaller dbh. Average annual precipitation in this area ranges from 1800 to 2320 milimeters. The area is included in the humid sub-tropical forest of the Holdridge (1963) classification and is located at 150 masl. The soil is 10 to 15cm deep under the tree canopy, dark brown, clayish with little humus formation and a pH ranging between 8 and 9, on limestone parent material. This site is included in the Buffum/Campbell zone 31 (Buffum, 1984).

Methodology

A sample of trees from this plantation was cut at 10cm from the ground to determine fuelwood and biomass production potential. The data collection and sampling techniques followed the methodology developed by the Fuelwood Project in Central America (CATIE, 1984). Three or more trees in each diameter class were cut, measured and weighed in sections, 23 trees in total. Ground diameter, stump diameter (at 10 cm), dbh and total height were measured for each tree in the sample. When poles were cut from the stem, their length and diameter were also measured. Weights of poles, branches of more than 2cm in diameter (fuelwood) and leaves and smaller branches were weighed separately on a 40kg or 10kg scale. Samples from each section of the tree were collected as soon as the tree was felled and stored in airtight bags for laboratory analysis to determine moisture content and specific gravity.

Results

Laboratory analysis of the tree samples revealed a moisture content of the merchantable section of the trees (poles and fuelwood) of 44% and a specific gavity of 0.59 grams per cubic millimeter. The remaining biomass, mainly small branches, twigs and leaves contained 69g of water for every 100g of geen biomass.

Statistical analysis of field data revealed high positive correlations between dbh (diameter at 130cm) or stump diameter (at 10cm) and fuelwood, total biomass, and merchantable volume production. However, when only the volume of poles as defined and cut in the field is taken into account, the correlation between dbh or stump diameter and pole volume becomes less evident. This is due to the fact that tree cutters apply different standards to the definition of a pole as a function of their own needs for construction timber and fuelwood products, rather than as a function of diameter, length, or form. The definition of charcoal wood seemed to be more precise (applying more precise standards). Tree cutters appear to have greater experience and are more familiar cutting a tree for charcoal than for poles and logs.

Nevertheless, approximately 56% of all merchantable wood volume was cut into poles with an average length of 3.2m and an average diameter (at midsection) of 8.2 centimeters. Charcoal wood constituted about 39% of the total merchantable volume, while the remaining 5% was cut into logs (saw-timber). Non-merchantable biomass represented 26% of all green biomass weight. The average tree in the sample had a dbh of 8cm, a total height of 7.5m and weighed approximately 85kg (green weight).

Fuelwood Production

Table 1A presents estimates of fuelwood yields of *Leucaena leucocephala* in this five year old stand. The table assumes that the entire tree was used for fuelwood production. Fuelwood yields are expressed in terms of dry weight kilograms for comparison with other sites and across seasons. Moisture content would probably, vary as a function of seasonal changes, site conditions, and rainfall pattern.

The amount of fuelwood production can be estimated using dbh (cm) as the only field measurement and the number of trees in each diameter class. Assuming a conversion factor of 0.45 (Timyan, 1984), this table can also be used to estimate charcoal production. Figure 1A shows the fuelwood production curve as a function of dbh:

$$\text{Dry fuelwood (kg)} = 0.817 \times \text{Bas.Area (cm}^2\text{)} - 2.707 \times \text{dbh (cm)},$$

which has an r^2 = 98 percent.

Total fuelwood production (kg) is estimated in Table 1B as a function of stump diameter (at 10cm). This table can be used to estimate fuelwood production after the tree has already been cut and only the stump can be measured. Like in the case of Table 1A, a charcoal conversion factor of 0.45 should enable to estimate charcoal production as a function of stump diameter. The equation:

Dry fuelwood (kg) = 0.274 stump diameter squared (cm^2),

defines the fuelwood production function with a 97% determination coefficient.

Finally, Table 1C displays total biomass (dry weight of merchantable + non-merchantable sections of the tree) as a function of dbh. The expression:

Dry biomass (kg) = 0.667 Bas.Area (cm^2),

enables the estimation of biomass production, using dbh as the only field measurement (r^2 = 97%). Total biomass weight provides a standard measure of tree yield for purposes of comparison, independent of seasonal variations or unique definitions for merchantable wood sections.

Conclusions

Leucaena leucocephala generally produces considerable amounts of fuelwood. The form of the tree stem does not however, consistently produce high quality timber (logs or poles). Local demand for construction timber does appear however, to tolerate a greater range of variation in length, diameter, and shape. This tree species has proven to adapt well to difficult edaphic and climatic conditions in every region of Haiti. Its potential as a fuelwood tree is unquestionable. Possibly, provenance studies and careful selection of seed trees could identify tree stock with a better form, thus increasing its usefulness as a producer of timber, while maintaining its characteristics as a fast growing and adaptable tree.

Moreover, a coppicing experiment established in the summer of 1985 near Cap Haïtien, should more clearly outline the potential of leucaena to produce on a short rotation, quality polewood and an abundance of fuelwood. Throughout the analysis, leucaena demonstrated greater variance than any other tree species studied. It is suggested therefore, that more samples of this species be studied to more accurately determine the productive potential of this species in the Haiti's, highly diverse countryside. As a result, the yield tables estimated in this study could be adjusted in order to reliably predict production levels of fuelwood and polewood over the range of environmental conditions in Haiti.

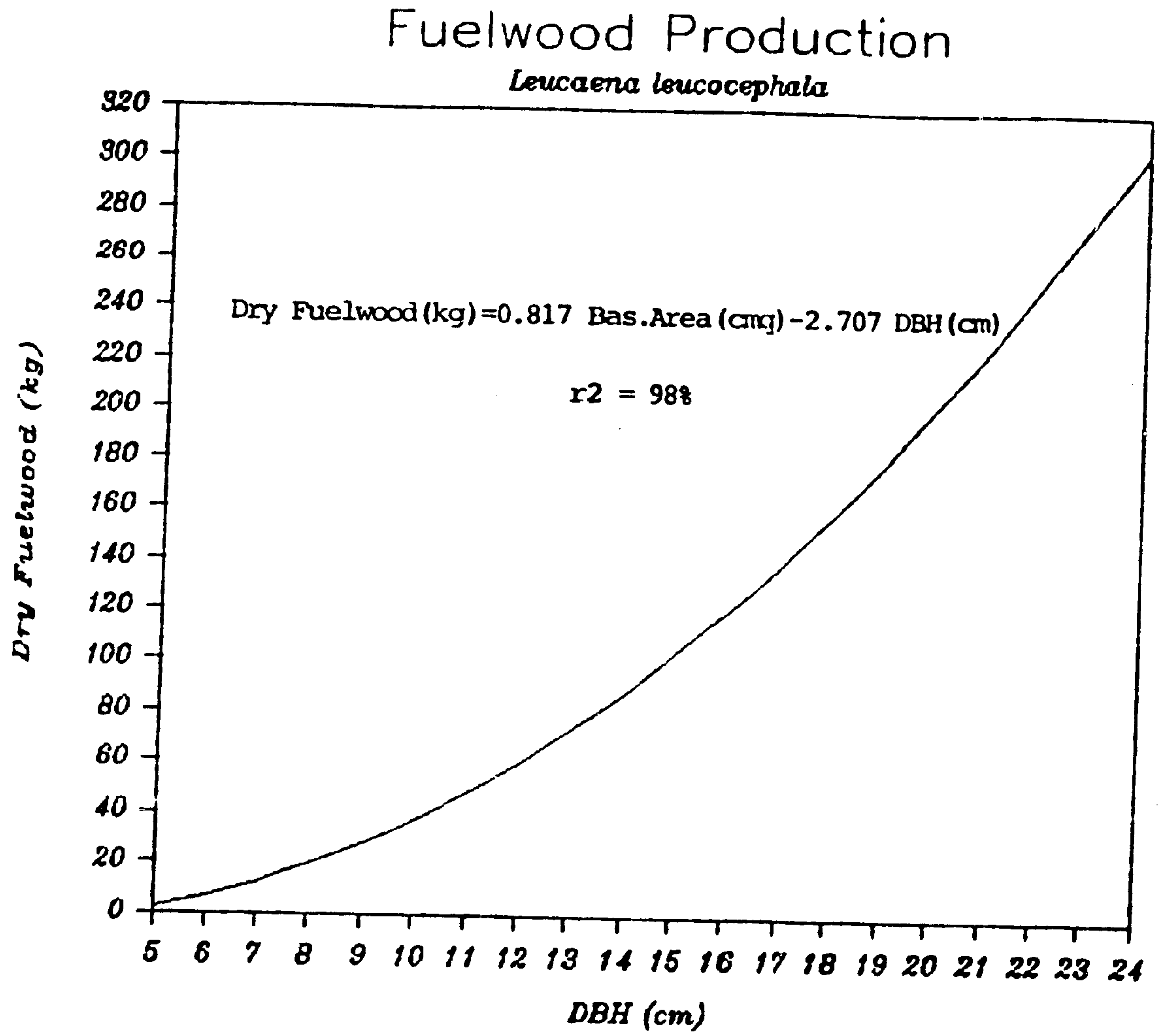

Figure 1A. Fuelwood production for Leucaena leucocephala in Haiti as a function of DBH.

YIELD TABLE

Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Leucaena leucocephala - July 1985.
Dry Fuelwood (kg)=0.817 Bas.Area(cmq) - 2.707 DBH (cm); r2 = 98%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
5	19.64	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.1	22.6	25.1
6	28.27	6.9	13.7	20.6	27.4	34.3	41.1	48.0	54.9	61.7	68.6
7	38.48	12.5	25.0	37.5	50.0	62.5	75.0	87.5	99.9	112.4	124.9
8	50.27	19.4	38.8	58.2	77.6	97.1	116.5	135.9	155.3	174.7	194.1
9	63.62	27.6	55.2	82.8	110.4	138.1	165.7	193.3	220.9	248.5	276.1
10	78.54	37.1	74.2	111.3	148.4	185.5	222.6	259.7	296.8	333.9	371.0
11	95.03	47.9	95.7	143.6	191.5	239.3	287.2	335.1	382.9	430.8	478.7
12	113.10	59.9	119.8	179.8	239.7	299.6	359.5	419.4	479.3	539.3	599.2
13	132.73	73.3	146.5	219.8	293.0	366.3	439.5	512.8	586.0	659.3	732.5
14	153.94	87.9	175.7	263.6	351.5	439.3	527.2	615.1	703.0	790.8	878.7
15	176.72	103.8	207.5	311.3	415.1	518.9	622.6	726.4	830.2	933.9	1037.7
16	201.06	121.0	241.9	362.9	483.8	604.8	725.7	846.7	967.6	1088.6	1209.6
17	226.98	139.4	278.8	418.3	557.7	697.1	836.5	976.0	1115.4	1254.8	1394.2
18	254.47	159.2	318.4	477.5	636.7	795.9	955.1	1114.2	1273.4	1432.6	1591.8
19	283.53	180.2	360.4	540.6	720.8	901.1	1081.3	1261.5	1441.7	1621.9	1802.1
20	314.16	202.5	405.1	607.6	810.1	1012.6	1215.2	1417.7	1620.2	1822.8	2025.3
21	346.36	226.1	452.3	678.4	904.5	1130.7	1356.8	1582.9	1809.0	2035.2	2261.3
22	380.13	251.0	502.0	753.0	1004.1	1255.1	1506.1	1757.1	2008.1	2259.1	2510.2
23	415.48	277.2	554.4	831.6	1108.7	1385.9	1663.1	1940.3	2217.5	2494.7	2771.8
24	452.39	304.6	609.3	913.9	1218.5	1523.2	1827.8	2132.4	2437.1	2741.7	3046.3

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1A Production of Leucaena fuelwood (dry weight) as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Leucaena leucocephala - July 1985.
Dry Fuelwood (kg)=0.2745*Stump sqr.(cmq); r2 = 97%

Stump (cm)	Stump sqr (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	4	1.1	2.2	3.3	4.4	5.5	6.6	7.7	8.8	9.9	11.0
3	9	2.5	4.9	7.4	9.9	12.4	14.8	17.3	19.8	22.2	24.7
4	16	4.4	8.8	13.2	17.6	22.0	26.4	30.7	35.1	39.5	43.9
5	25	6.9	13.7	20.6	27.5	34.3	41.2	48.0	54.9	61.8	68.6
6	36	9.9	19.8	29.6	39.5	49.4	59.3	69.2	79.1	88.9	98.8
7	49	13.5	26.9	40.4	53.8	67.3	80.7	94.2	107.6	121.1	134.5
8	64	17.6	35.1	52.7	70.3	87.8	105.4	123.0	140.5	158.1	175.7
9	81	22.2	44.5	66.7	88.9	111.2	133.4	155.6	177.9	200.1	222.3
10	100	27.5	54.9	82.4	109.8	137.3	164.7	192.2	219.6	247.1	274.5
11	121	33.2	66.4	99.6	132.9	166.1	199.3	232.5	265.7	298.9	332.1
12	144	39.5	79.1	118.6	158.1	197.6	237.2	276.7	316.2	355.8	395.3
13	169	46.4	92.8	139.2	185.6	232.0	278.3	324.7	371.1	417.5	463.9
14	196	53.8	107.6	161.4	215.2	269.0	322.8	376.6	430.4	484.2	538.0
15	225	61.8	123.5	185.3	247.1	308.8	370.6	432.3	494.1	555.9	617.6
16	256	70.3	140.5	210.8	281.1	351.4	421.6	491.9	562.2	632.4	702.7
17	289	79.3	158.7	238.0	317.3	396.7	476.0	555.3	634.6	714.0	793.3
18	324	88.9	177.9	266.8	355.8	444.7	533.6	622.6	711.5	800.4	889.4
19	361	99.1	198.2	297.3	396.4	495.5	594.6	693.7	792.8	891.9	990.9
20	400	109.8	219.6	329.4	439.2	549.0	658.8	768.6	878.4	988.2	1098.0

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2 A Production of Leucaena fuelwood (dry weight) as a function of stump diameter.

YIELD TABLE

Production of total biomass (dry weight in kg)

as a function of DBH (cm).

Leucaena leucocephala - July 1985.

Dry Biomass (kg) = 0.667 Bas.Area (cmq); r2 = 97%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	2.1	4.2	6.3	8.4	10.5	12.6	14.7	16.8	18.9	21.0
3	7.07	4.7	9.4	14.1	18.9	23.6	28.3	33.0	37.7	42.4	47.1
4	12.57	8.4	16.8	25.1	33.5	41.9	50.3	58.7	67.1	75.4	83.8
5	19.64	13.1	26.2	39.3	52.4	65.5	78.6	91.7	104.8	117.9	131.0
6	28.27	18.9	37.7	56.6	75.4	94.3	113.2	132.0	150.9	169.7	188.6
7	38.48	25.7	51.3	77.0	102.7	128.3	154.0	179.7	205.4	231.0	256.7
8	50.27	33.5	67.1	100.6	134.1	167.6	201.2	234.7	268.2	301.7	335.3
9	63.62	42.4	84.9	127.3	169.7	212.2	254.6	297.0	339.5	381.9	424.3
10	78.54	52.4	104.8	157.2	209.5	261.9	314.3	366.7	419.1	471.5	523.9
11	95.03	63.4	126.8	190.2	253.5	316.9	380.3	443.7	507.1	570.5	633.9
12	113.10	75.4	150.9	226.3	301.7	377.2	452.6	528.1	603.5	678.9	754.4
13	132.73	88.5	177.1	265.6	354.1	442.7	531.2	619.7	708.3	796.8	885.3
14	153.94	102.7	205.4	308.0	410.7	513.4	616.1	718.7	821.4	924.1	1026.8
15	176.72	117.9	235.7	353.6	471.5	589.3	707.2	825.1	943.0	1060.8	1178.7
16	201.06	134.1	268.2	402.3	536.4	670.5	804.7	938.8	1072.9	1207.0	1341.1
17	226.98	151.4	302.8	454.2	605.6	757.0	908.4	1059.8	1211.2	1362.6	1514.0
18	254.47	169.7	339.5	509.2	678.9	848.7	1018.4	1188.1	1357.8	1527.6	1697.3
19	283.53	189.1	378.2	567.3	756.5	945.6	1134.7	1323.8	1512.9	1702.0	1891.1
20	314.16	209.5	419.1	628.6	838.2	1047.7	1257.3	1466.8	1676.4	1885.9	2095.4

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3 A Production of total Biomass (dry weight) as a function of DBH.

CHAPTER 3

FUELWOOD AND BIOMASS PRODUCTION OF *CASSIA SIAMEA*

Cassia siamea is a native to Southeast Asia, yet throughout the tropics has appeared to adapt well and is becoming a favorite of fuelwood plantations for its fast growth, the quality of its wood and good stem form. The Agroforestry Outreach Project (AOP) on sites with adequate (more than 1000mm) annual rainfall and good to average soils.

One large plantation of *Cassia siamea* was established on a plain near the Rivière Salée (Limbé), in the northern region of Haiti. The trees were planted in the spring of 1980 at a spacing of 2.5 by 2.5 meters. This same density remains five years later which gives the impression of an overly dense plantation. Although the canopy is not fully closed, trees do have to compete for scarce nutrients in the soil.

Soils at th's site vary greatly. There are pockets of deep rich soils as there are salt flats, where tree growth is clearly stunted. Depth, structure and pH vary accordingly. The soil most commonly represented on the plantation is 15 to 20cm deep, dark brown to black, rich in clay, has poor drainage and a fragmented limestone substrate. The pH ranges from very alcaline (pH from 8 to 9) on the salt flat to slightly alcaline (pH 7 to 8) at the base of a small hill on the northern end of the plantation site. Annual rainfall over this area averages around 2000 millimeters. The area is situated at an elevation of less than 100 masl and falls within the humid/very humid sub-tropical forest (Holdridge, 1963) and Buffum/Campbell Zone 35 (Buffum, 1984).

Methodology

Thirty-one trees ranging in diameter (at 130cm) from 1 to 14cm were cut, measured and weighed. Data collection and sampling techniques reflect the methodology developed for the Regional Fuelwood Project in Central America (CATIE, 1984). Dbh, stump diameter (at 10cm) and ground diameter were measured for each tree sampled. Measures of total tree height as well as pole length and diameter, were also taken. From each tree cut, samples of the merchantable sections of the tree as well as from the leaves and small branches were collected for laboratory analysis to determine moisture content and specific gravity.

Results

The average tree in the sample had a dbh of 7cm, a total height of 8.5m and weighed approximately 42kg (green weight). Non-merchantable portions of the tree (leaves and small branches, less than 2cm in diameter) constituted 21% of all green biomass weight. Almost 60% of all biomass (and 75% of all merchantable volume) was cut into either poles or logs. Sixty percent of all trees sampled produced at least one pole. About half produced a second pole, and those with a dbh greater than 13cm, produced a small butt log, with lumber potential. Only 19% of the total weight was separated as having only fuelwood potential.

Statistical analysis of the field data indicated that the average tree in the sample produced a considerable amount of merchantable volume consisting of one part fuelwood for every three parts of construction timber. As in the case of *Leucaena leucocephala*, the size standards which defined poles and logs in the field varied greatly, with pole form being the least important of all considerations. Charcoal wood, on the other hand, was easily separated from non-merchantable wood. Familiarity with charcoal-making as opposed to cutting trees for timber, could explain the significant variance in pole size standards. Most peasants cut trees for their own construction needs rather than for the pole market.

Laboratory analysis of the tree samples taken determined a dry versus green weight ratio of 0.50 (50% moisture content) for the merchantable sections of the tree and 0.42 for the leafy parts. Specific gravity of the wood samples was calculated at 0.57 g/mm^3. The leaves, pods, and seeds of this species contain a substance toxic to pigs, but not to cattle and goats (NAS, 1980). Sawdust from wood cutting is also an irritant to the human skin.

Fuelwood Production

In the site conditions described above, Cassia produces about one third less dry fuelwood (weight) than *Leucaena leucocephala* (growing on a hillside in the southwest of Haiti). Table 2A shows fuelwood production (kg) as a function of dbh. This table enables one to estimate fuelwood production by only measuring dbh and counting the number of trees in each diameter class. The function that predicts fuelwood production is:

$$\text{Dry fuelwood (kg)} = 0.55 \times \text{Bas. Area (cmq)} - 1.5 \times \text{dbh (cm)},$$

with a determination coefficient of 97 percent. Figure 2A graphically displays this expression.

Table 2D displays estimates of pole volume production in cubic decimeters, as a function of dbh. Its squared value (Basal Area) is used for better approximation. The function used to produce the volume table is:

$$\text{Pole volume } (m^3/1000) = 0.43 \times \text{Bas.Area } (cm^2);$$

the r^2 is 94 percent. Figure 2B shows polewood production in graphic form as a function of dbh.

Table 2B enables the estimation of fuelwood yield for any given tree, when only the stump can be measured in the field. The equation:

$$\text{Dry fuelwood (kg)} = 4.0 \times \text{stump diameter (cm)} - 9.5 \times \text{square root of stump diameter (cm)}$$

was used to prepare Table 2B, with an r^2 of 86 percent.

In order to permit comparisons across sites and seasons, Table 2C provides an estimate of total biomass production according to the function:

$$\text{Dry biomass (kg)} = 0.5 \times \text{Bas. Area } (cm^2),$$

with a determination coefficient of 96 percent.

Conclusions

Cassia siamea displays far less variance than leucaena in the distribution of dbh, height and fuelwood production. Generally, the stems are more regular, although often multiple. Pole production is therefore, more consistent as a function dbh and height. Correlation coefficients among these parameters are consistently high. Variation in dbh and height of cassia can be attributed to varying site conditions, primarily soil quality and drainage. On average sites in Haiti with good rainfall, (above 1000mm) *Cassia siamea* could prove to be a good fuelwood tree, with good to very good potential for producing construction timber.

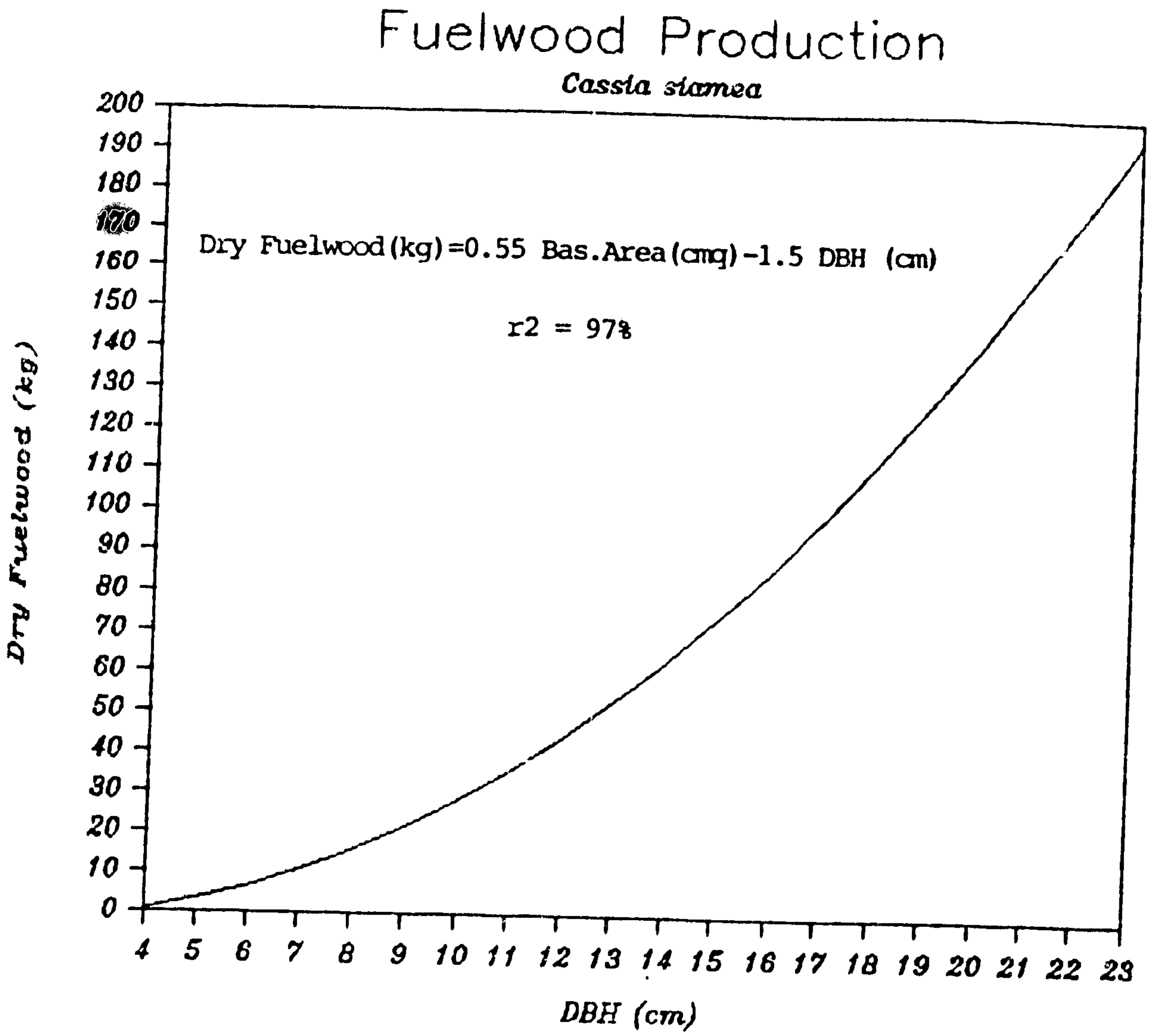

Figure 1B. Fuelwood production of Cassia siamea (dry weight) in Haiti as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Cassia siamea - July 1985.
Dry Fuelwood (kg)=0.551 Bas.Area (cmq) - 1.5 DBH (cm); r2 = 97%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
4	12.57	0.9	1.8	2.8	3.7	4.6	5.5	6.5	7.4	8.3	9.2
5	19.64	3.3	6.6	10.0	13.3	16.6	19.9	23.2	26.6	29.9	33.2
6	28.27	6.6	13.2	19.7	26.3	32.9	39.5	46.1	52.6	59.2	65.8
7	38.48	10.7	21.4	32.1	42.8	53.5	64.2	74.9	85.6	96.3	107.1
8	50.27	15.7	31.4	47.1	62.8	78.5	94.2	109.9	125.6	141.3	157.0
9	63.62	21.6	43.1	64.7	86.2	107.8	129.3	150.9	172.4	194.0	215.5
10	78.54	28.3	56.6	84.8	113.1	141.4	169.7	197.9	226.2	254.5	282.8
11	95.03	35.9	71.7	107.6	143.5	179.3	215.2	251.0	286.9	322.8	358.6
12	113.10	44.3	88.6	133.0	177.3	221.6	265.9	310.2	354.5	398.9	443.2
13	132.73	53.6	107.3	160.9	214.5	268.2	321.8	375.4	429.1	482.7	536.4
14	153.94	63.8	127.6	191.5	255.3	319.1	382.9	446.7	510.6	574.4	638.2
15	176.72	74.9	149.7	224.6	299.5	374.3	449.2	524.1	599.0	673.8	748.7
16	201.06	86.8	173.6	260.4	347.1	433.9	520.7	607.5	694.3	781.1	867.9
17	226.98	99.6	199.1	298.7	398.3	497.8	597.4	697.0	796.5	896.1	995.7
18	254.47	113.2	226.4	339.6	452.9	566.1	679.3	792.5	905.7	1018.9	1132.1
19	283.53	127.7	255.4	383.2	510.9	638.6	766.3	894.1	1021.8	1149.5	1277.2
20	314.16	143.1	286.2	429.3	572.4	715.5	858.6	1001.7	1144.8	1287.9	1431.0
21	346.36	159.3	318.7	478.0	637.4	796.7	956.1	1115.4	1274.8	1434.1	1593.5
22	380.13	176.5	352.9	529.4	705.8	882.3	1058.7	1235.2	1411.6	1588.1	1764.5
23	415.48	194.4	388.9	583.3	777.7	972.1	1166.6	1361.0	1555.4	1749.8	1944.3

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1B. Fuelwood production (dry weight) of Cassia siamea as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Cassia siamea - July 1985.
Dry Fuelwood (kg)=4.001*(stump) - 9.461 sqr.root (stump); r2 = 86%

Stump (cm)	sqr.root Stump	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
6	2.45	0.8	1.7	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3
7	2.65	3.0	6.0	8.9	11.9	14.9	17.9	20.8	23.8	26.8	29.8
8	2.83	5.2	10.5	15.7	21.0	26.2	31.5	36.7	42.0	47.2	52.5
9	3.00	7.6	15.3	22.9	30.5	38.1	45.8	53.4	61.0	68.6	76.3
10	3.16	10.1	20.2	30.3	40.4	50.5	60.6	70.6	80.7	90.8	100.9
11	3.32	12.6	25.3	37.9	50.5	63.2	75.8	88.4	101.1	113.7	126.3
12	3.46	15.2	30.5	45.7	61.0	76.2	91.4	106.7	121.9	137.1	152.4
13	3.61	17.9	35.8	53.7	71.6	89.5	107.4	125.3	143.2	161.1	179.0
14	3.74	20.6	41.2	61.8	82.5	103.1	123.7	144.3	164.9	185.5	206.1
15	3.87	23.4	46.7	70.1	93.5	116.9	140.2	163.6	187.0	210.4	233.7
16	4.00	26.2	52.3	78.5	104.7	130.9	157.0	183.2	209.4	235.5	261.7
17	4.12	29.0	58.0	87.0	116.0	145.0	174.0	203.1	232.1	261.1	290.1
18	4.24	31.9	63.8	95.6	127.5	159.4	191.3	223.1	255.0	286.9	318.8
19	4.36	34.8	69.6	104.3	139.1	173.9	208.7	243.5	278.2	313.0	347.8
20	4.47	37.7	75.4	113.1	150.8	188.5	226.3	264.0	301.7	339.4	377.1
21	4.58	40.7	81.3	122.0	162.7	203.3	244.0	284.7	325.3	366.0	406.7
22	4.69	43.6	87.3	130.9	174.6	218.2	261.9	305.5	349.2	392.8	436.5
23	4.80	46.6	93.3	139.9	186.6	233.2	279.9	326.5	373.2	419.8	466.5
24	4.90	49.7	99.3	149.0	198.7	248.4	298.0	347.7	397.4	447.1	496.7
25	5.00	52.7	105.4	158.2	210.9	263.6	316.3	369.0	421.8	474.5	527.2

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2B. Fuelwood production (dry weight) of Cassia siamea as a function of stump diameter.

YIELD TABLE
Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Cassia siamea - July 1985.
Dry Biomass (kg) = 0.4637 Bas.Area (cmq); r2 = 96%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.5	2.9	4.4	5.8	7.3	8.7	10.2	11.7	13.1	14.6
3	7.07	3.3	6.6	9.8	13.1	16.4	19.7	22.9	26.2	29.5	32.8
4	12.57	5.8	11.7	17.5	23.3	29.1	35.0	40.8	46.6	52.4	58.3
5	19.64	9.1	18.2	27.3	36.4	45.5	54.6	63.7	72.8	81.9	91.0
6	28.27	13.1	26.2	39.3	52.4	65.6	78.7	91.8	104.9	118.0	131.1
7	38.48	17.8	35.7	53.5	71.4	89.2	107.1	124.9	142.8	160.6	178.5
8	50.27	23.3	46.6	69.9	93.2	116.5	139.8	163.2	186.5	209.8	233.1
9	63.62	29.5	59.0	88.5	118.0	147.5	177.0	206.5	236.0	265.5	295.0
10	78.54	36.4	72.8	109.3	145.7	182.1	218.5	254.9	291.4	327.8	364.2
11	95.03	44.1	88.1	132.2	176.3	220.3	264.4	308.5	352.5	396.6	440.7
12	113.10	52.4	104.9	157.3	209.8	262.2	314.7	367.1	419.5	472.0	524.4
13	132.73	61.5	123.1	184.6	246.2	307.7	369.3	430.8	492.4	553.9	615.5
14	153.94	71.4	142.8	214.1	285.5	356.9	428.3	499.7	571.0	642.4	713.8
15	176.72	81.9	163.9	245.8	327.8	409.7	491.7	573.6	655.5	737.5	819.4
16	201.06	93.2	186.5	279.7	372.9	466.2	559.4	652.6	745.9	839.1	932.3
17	226.98	105.3	210.5	315.8	421.0	526.3	631.5	736.8	842.0	947.3	1052.5
18	254.47	118.0	236.0	354.0	472.0	590.0	708.0	826.0	944.0	1062.0	1180.0
19	283.53	131.5	262.9	394.4	525.9	657.4	788.8	920.3	1051.8	1183.3	1314.7
20	314.16	145.7	291.4	437.0	582.7	728.4	874.1	1019.7	1165.4	1311.1	1456.8

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3B. Production of total Biomass (dry weight) of Cassia Siamea as a function of DBH.

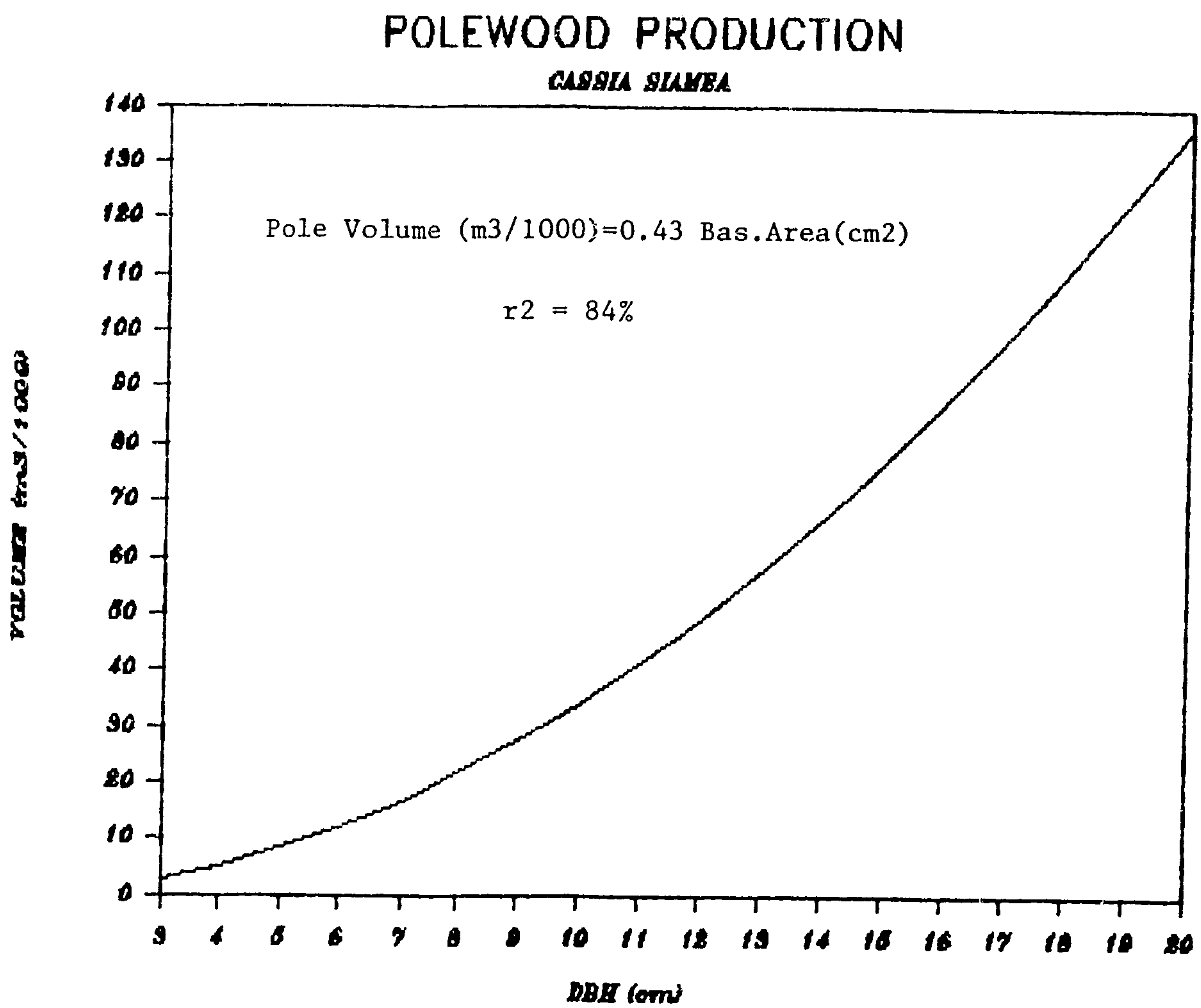

Figure 2B. Polewood Production of Cassia siamea in Haiti as a function of DBH

YIELD TABLE

Production of polewood (volume in m3/1000)

as a function of DBH (cm).

Cassia siamea - July 1985.

Polewood volume (m3/1000) = 0.434 Bas.Area(cm2); r2 = 84%

DBH (cm)	Bas.Area (cm2)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	3.1	6.1	9.2	12.3	15.4	18.4	21.5	24.6	27.6	30.7
4	12.57	5.5	10.9	16.4	21.8	27.3	32.8	38.2	43.7	49.1	54.6
5	19.64	8.5	17.1	25.6	34.1	42.7	51.2	59.7	68.3	76.8	85.3
6	28.27	12.3	24.6	36.9	49.1	61.4	73.7	86.0	98.3	110.6	122.9
7	38.48	16.7	33.4	50.2	66.9	83.6	100.3	117.1	133.8	150.5	167.2
8	50.27	21.8	43.7	65.5	87.4	109.2	131.1	152.9	174.7	196.6	218.4
9	63.62	27.6	55.3	82.9	110.6	138.2	165.9	193.5	221.2	248.8	276.4
10	78.54	34.1	68.3	102.4	136.5	170.6	204.8	238.9	273.0	307.2	341.3
11	95.03	41.3	82.6	123.9	165.2	206.5	247.8	289.1	330.4	371.7	413.0
12	113.10	49.1	98.3	147.4	196.6	245.7	294.9	344.0	393.2	442.3	491.5
13	132.73	57.7	115.4	173.0	230.7	288.4	346.1	403.7	461.4	519.1	576.8
14	153.94	66.9	133.8	200.7	267.6	334.5	401.4	468.3	535.1	602.0	668.9
15	176.72	76.8	153.6	230.4	307.2	384.0	460.7	537.5	614.3	691.1	767.9
16	201.06	87.4	174.7	262.1	349.5	436.9	524.2	611.6	699.0	786.3	873.7
17	226.98	98.6	197.3	295.9	394.5	493.2	591.8	690.4	789.1	887.7	986.3
18	254.47	110.6	221.2	331.7	442.3	552.9	663.5	774.1	884.6	995.2	1105.8
19	283.53	123.2	246.4	369.6	492.8	616.0	739.2	862.4	985.7	1108.9	1232.1
20	314.16	136.5	273.0	409.6	546.1	682.6	819.1	955.6	1092.1	1228.7	1365.2

USAID/AFORP/UMO/Ehrlich, 1985.

Table 4B. Polewood Production of Cassia siamea as a function of DBH

CHAPTER 4

FUELWOOD AND BIOMASS PRODUCTION OF *AZADIRACHTA INDICA* (NEEM)

This tree is one of the most popular exotic tree species in Haiti. It is commonly planted as an ornamental tree in courtyards and alongside roads. Neem is also widely used in reforestation for its adaptability and considerable tolerance for poor soils and droughts. Where moist and well-drained soils prevail, *Azadirachta indica* is definitively one of the better fuelwood trees available. Its foliage is non-edible even to goats, which makes it an especially attractive tree species to be planted in open range areas. Used as green manure it is effective in restoring nutrients to the soil. Its seeds produce a chemical coumpound (*azadirachtin*) used as an insect repellent and an oil used in burning lamps (NAS, 1980).

The sample of trees used in this study was obtained from an arid area in the Cul-de-Sac, in the southern region of Haiti. Much of this plantation, established in the fall of 1982 by Operation Double Harvest (ODH) has failed due to poor soils, poor drainage, and extremely low rainfall (600-700mm). Soils in this area are shallow, light brown with a hard layer of clay found at less than 60 centimeters. The pH has been found to vary between 8 and 9, with some areas extremely saline, impeding any kind of growth .The area is included in the dry sub-tropical forest zone (Holdridge, 1963) and in the Buffum/Campbell Zone 17 (Buffum, 1984). Only a portion of the entire plantation, located in an area previously farmed and irrigated, has survived. There, neem and leucaena trees have grown into a thin stand from which 22 trees were cut, measured, and weighed.

Methodology

Following the methodology developed by the CATIE (1984), the trees were measured at dbh (at 130cm), ground and stump diameter (10cm) and for total height. Once felled, the tree was sectioned in polewood, charcoal wood and non-merchantable biomass. Local tree cutters (peasants) separated the polewood from the charcoal wood, and the leaves. Samples were taken from each section for subsequent determination of moisture content and specific gravity in the laboratory. The entire tree biomass was weighed (except for a 10cm stump and the root system) as soon as the tree was cut, using a 10kg and a 40 kg scale. Each section of the tree was weighed separately. Poles were measured for length, as well as top and bottom diameters.

Results

Laboratory analysis of the tree samples determined that pole and charcoal wood contained moisture equivalent to 46% of their green weight. The specific gravity of wood was calculated at 0.58 grams per cubic millimeter. Leaves and small branches contained greater amounts of water (dry/green weight ratio = 0.35), losing two thirds of their water when placed in an oven at 80°C for 24 to 36 hours.

Statistical analysis of the data collected in the field shows that dbh and stump diameter significantly correlated ($p < .001$) with the tree's fuelwood yields, pole volume, and total biomass production. Tree height on the other hand, though positively correlated, is a less reliable indicator of fuelwood, biomass production, and pole volume. It should be noted that, the local peasant hired to cut the trees in this sample, spontaneously decided to cut poles (from suitable trees) of a uniform length (3.1 meters). This decision was aided by the straight form of most trees in the plantation and possibly, by the tree cutter's familiarity with the requirements of the pole market in the urban area nearby. This is a contrast to other regions of Haiti where secondary markets for polewood do not exist and standards for construction timber are dictated by the peasant's personal needs.

The average neem tree in this sample, had a dbh of 6.8cm, a stump diameter of almost 10cm, a total length (entire tree) of 5.9m and weighed approximately 37 kilograms. Every tree having a dbh greater than 6cm produced one pole, 3.1m long, with an average midpoint diameter of 9.1cm (volume = 0.006 m^3) About 36% of all biomass weight is represented by poles, 23% by charcoal wood, and 41% by leaves and small branches.

Further analysis of field data revealed that neem produces between 40 and 50% less fuelwood than Leucaena for any given diameter (dbh) class. Poles produced from trees of diameter (at 1.30m) greater than 6cm, were generally straight, though tapered significantly. More than 50% of all trees (13) produced one pole each. Variance across the entire sample was small for merchantable weight and pole volume, even when site conditions varied considerably.

Fuelwood Production

Estimates of fuelwood (the portion of biomass usable for charcoal or firewood production) yields for different size neem trees are presented in Table 3A. Yields are expressed in kilograms dry weight to be comparable across seasons and sites. Fuelwood production can be estimated using the function:

$$\text{Fuelwood (kg)} = 0.36 \times \text{Bas. Area (cm}^2\text{)} - 0.71 \times \text{dbh (cm)},$$

with an almost perfect coefficient of determination (r^2 = 99%). Figure 3A displays the production function graphically.

Fuelwood production estimates for neem as a function of stump diameter are shown in Table 3B and calculated by applying the function:

$$\text{Fuelwood (kg)} = 0.2 \times \text{stump diameter squared (cm}^2\text{)} - 1.02 \times \text{stump diameter (cm)},$$

with a determination coefficient of 98 percent. This table enables the estimation of fuelwood production from trees already harvested, when only the stump (at 10cm) can be measured in the field.

A volume table for poles is presented in Table 3D. The function that estimates pole production:

$$\text{Pole volume (m}^3\text{/1000)} = 0.29 \times \text{Bas.Area (cm}^2\text{)},$$

has an r^2 = 94 percent. Figure 3B displays polewood volume production of neem, graphically.

Finally, total biomass production is reported as a function of dbh in Table 3C. Dry biomass production is estimated by the equation:

$$\text{Dry biomass (kg)} = 0.4 \times \text{Basal Area (cm}^2\text{)},$$

with a determination coefficient of 98 percent.

Conclusions

Azadirachta indica appears to combine many features to make it one of the most attractive reforestation trees in Haiti. Adaptability, tolerance of climatic and edaphic extremes, and especially, good initial growth and excellent stem form are features especially appealing to foresters and to Haitian peasants. If its seeds could find widespread utilization for producing lamp oil or as an insecticide, the usefulness of this species would be extraordinary.

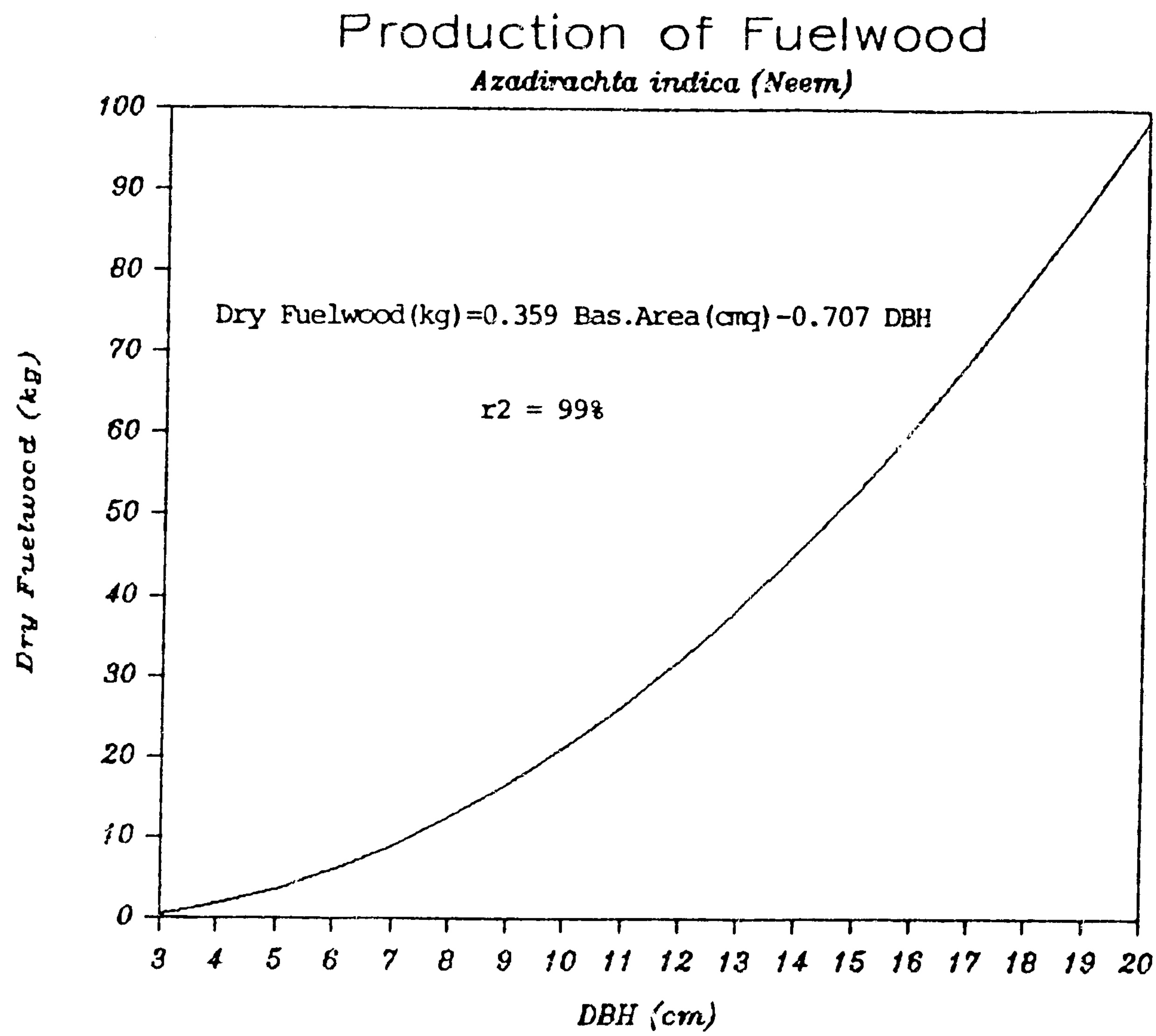

Figure 1C. Fuelwood Production of Azadirachta indica in Haiti as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Azadirachta indica - July 1985.
Dry Fuelwood (kg)= 0.359 Bas.Area(cmq) - 0.707 DBH(cm); r2 = 99%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	0.4	0.8	1.2	1.7	2.1	2.5	2.9	3.3	3.7	4.2
4	12.57	1.7	3.4	5.1	6.7	8.4	10.1	11.8	13.5	15.2	16.8
5	19.64	3.5	7.0	10.5	14.1	17.6	21.1	24.6	28.1	31.6	35.1
6	28.27	5.9	11.8	17.7	23.6	29.5	35.5	41.4	47.3	53.2	59.1
7	38.48	8.9	17.7	26.6	35.5	44.3	53.2	62.1	70.9	79.8	88.7
8	50.27	12.4	24.8	37.2	49.6	61.9	74.3	86.7	99.1	111.5	123 9
9	63.62	16.5	33.0	49.4	65.9	82.4	98.9	115.3	131.8	148.3	164.8
10	78.54	21.1	42.3	63.4	84.5	105.6	126.8	147.9	169.0	190.1	211.3
11	95.03	26.3	52.7	79.0	105.4	131.7	158.0	184.4	210.7	237.1	263.4
12	113.10	32.1	64.2	96.4	128.5	160.6	192.7	224.8	256.9	289.1	321.2
13	132.73	38.5	76.9	115.4	153.8	192.3	230.8	269.2	307.7	346.1	384.6
14	153.94	45.4	90.7	136.1	181.5	226.8	272.2	317.6	362.9	408.3	453.7
15	176.72	52.8	105.7	158.5	211.3	264.2	317.0	369.8	422.7	475.5	528.4
16	201.06	60.9	121.7	182.6	243.5	304.3	365.2	426.1	487.0	547.8	608.7
17	226.98	69.5	138.9	208.4	277.9	347.3	416.8	486.3	555.7	625.2	694.7
18	254.47	78.6	157.3	235.9	314.5	393.1	471.8	550.4	629.0	707.7	786.3
19	283.53	88.4	176.7	265.1	353.4	441.8	530.1	618.5	706.8	795.2	883.5
20	314.16	98.6	197.3	295.9	394.6	493.2	591.9	690.5	789.1	887.8	986.4

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1C. Fuelwood production (dry weight) of Azadirachta indica as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Azadirachta indica - July 1985.
Dry Fuelwood (kg)= 0.2025 Stump sqr.(cmq) - 1.02 Stump (cm); r2 = 98%

Stump (cm)	Stump sqr (cmq)	1	2	3	4	5	6	7	8	9	10
		NUMBER OF TREES									
6	36	1.2	2.3	3.5	4.7	5.9	7.0	8.2	9.4	10.5	11.7
7	49	2.8	5.6	8.3	11.1	13.9	16.7	19.5	22.3	25.0	27.8
8	64	4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2	48.0
9	81	7.2	14.4	21.7	28.9	36.1	43.3	50.6	57.8	65.0	72.2
10	100	10.1	20.1	30.2	40.2	50.3	60.3	70.4	80.4	90.5	100.5
11	121	13.3	26.6	39.8	53.1	66.4	79.7	93.0	106.3	119.5	132.8
12	144	16.9	33.8	50.8	67.7	84.6	101.5	118.4	135.4	152.3	169.2
13	169	21.0	41.9	62.9	83.9	104.8	125.8	146.7	167.7	188.7	209.6
14	196	25.4	50.8	76.2	101.6	127.1	152.5	177.9	203.3	228.7	254.1
15	225	30.3	60.5	90.8	121.1	151.3	181.6	211.8	242.1	272.4	302.6
16	256	35.5	71.0	106.6	142.1	177.6	213.1	248.6	284.2	319.7	355.2
17	289	41.2	82.4	123.5	164.7	205.9	247.1	288.3	329.5	370.6	411.8
18	324	47.3	94.5	141.8	189.0	236.3	283.5	330.8	378.0	425.3	472.5
19	361	53.7	107.4	161.2	214.9	268.6	322.3	376.1	429.8	483.5	537.2
20	400	60.6	121.2	181.8	242.4	303.0	363.6	424.2	484.8	545.4	606.0
21	441	67.9	135.8	203.6	271.5	339.4	407.3	475.2	543.1	610.9	678.8
22	484	75.6	151.1	226.7	302.3	377.9	453.4	529.0	604.6	680.1	755.7
23	529	83.7	167.3	251.0	334.7	418.3	502.0	585.6	669.3	753.0	836.6
24	576	92.2	184.3	276.5	368.6	460.8	553.0	645.1	737.3	829.4	921.6
25	625	101.1	202.1	303.2	404.3	505.3	606.4	707.4	808.5	909.6	1010.6

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2C. Fuelwood production (dry weight) of Azadirachta indica as a function of stump diameter.

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YIELD TABLE
Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Azadirachta indica - July 1985.
Dry Biomass (kg) = 0.399 Bas.Area (cmq); r2 = 98%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.3	2.5	3.8	5.0	6.3	7.5	8.8	10.0	11.3	12.5
3	7.07	2.8	5.6	8.5	11.3	14.1	16.9	19.7	22.6	25.4	28.2
4	12.57	5.0	10.0	15.0	20.1	25.1	30.1	35.1	40.1	45.1	50.1
5	19.64	7.8	15.7	23.5	31.3	39.2	47.0	54.8	62.7	70.5	78.3
6	28.27	11.3	22.6	33.8	45.1	56.4	67.7	79.0	90.3	101.5	112.8
7	38.48	15.4	30.7	46.1	61.4	76.8	92.1	107.5	122.8	138.2	153.6
8	50.27	20.1	40.1	60.2	80.2	100.3	120.3	140.4	160.4	180.5	200.6
9	63.62	25.4	50.8	76.2	101.5	126.9	152.3	177.7	203.1	228.5	253.8
10	78.54	31.3	62.7	94.0	125.3	156.7	188.0	219.4	250.7	282.0	313.4
11	95.03	37.9	75.8	113.8	151.7	189.6	227.5	265.4	303.3	341.3	379.2
12	113.10	45.1	90.3	135.4	180.5	225.6	270.8	315.9	361.0	406.1	451.3
13	132.73	53.0	105.9	158.9	211.8	264.8	317.8	370.7	423.7	476.6	529.6
14	153.94	61.4	122.8	184.3	245.7	307.1	368.5	429.9	491.4	552.8	614.2
15	176.72	70.5	141.0	211.5	282.0	352.5	423.1	493.6	564.1	634.6	705.1
16	201.06	80.2	160.4	240.7	320.9	401.1	481.3	561.6	641.8	722.0	802.2
17	226.98	90.6	181.1	271.7	362.3	452.8	543.4	634.0	724.5	815.1	905.7
18	254.47	101.5	203.1	304.6	406.1	507.7	609.2	710.7	812.3	913.8	1015.3
19	283.53	113.1	226.3	339.4	452.5	565.6	678.8	791.9	905.0	1018.2	1131.3
20	314.16	125.3	250.7	376.0	501.4	626.7	752.1	877.4	1002.8	1128.1	1253.5

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3C. Production of total biomass (dry weight) of Azadirachta indica as a function of DBH.

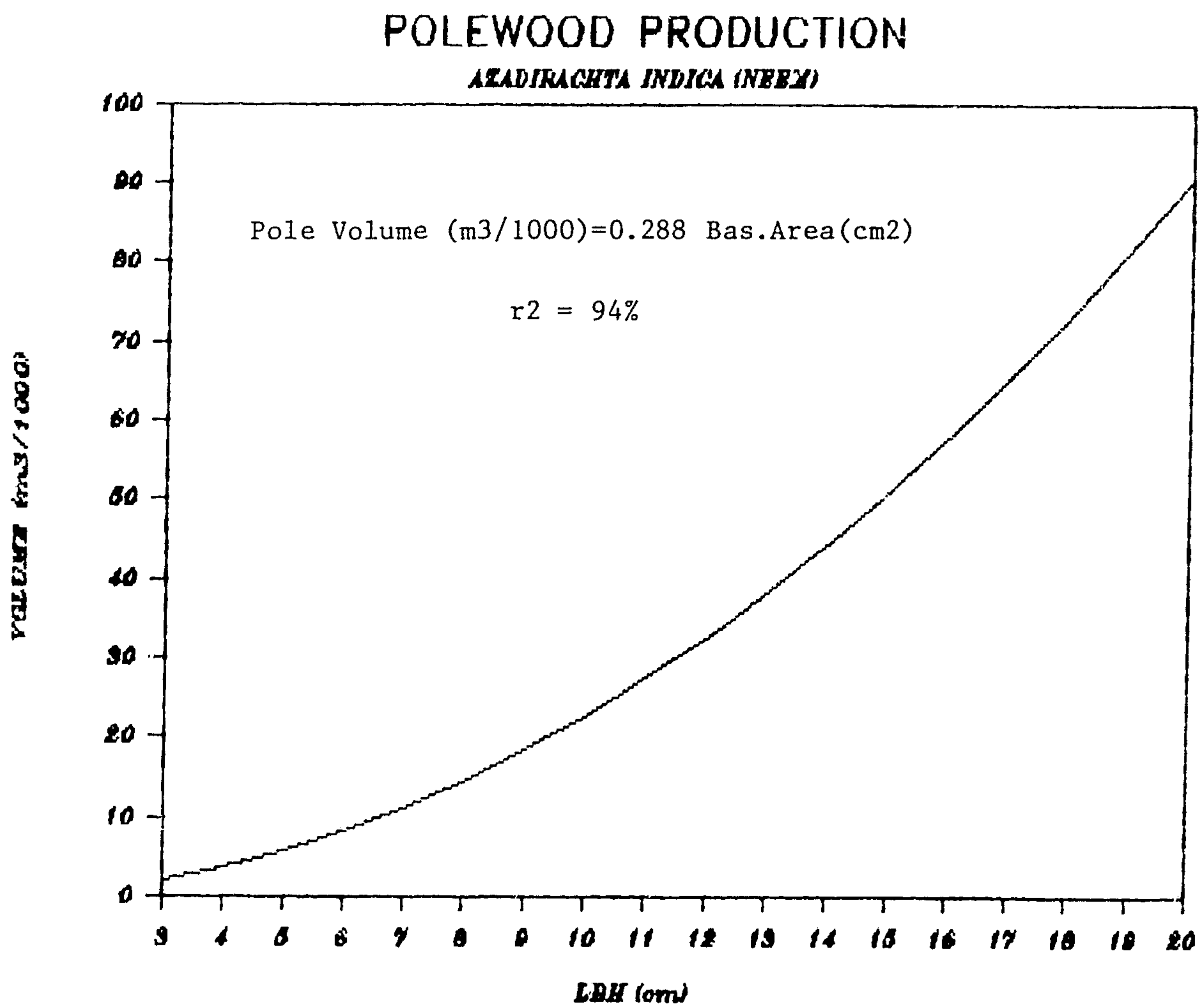

Figure 2C. Polewood Production of Azadirachta indica in Haiti as a function of DBH

YIELD TABLE

Production of polewood (volume in mc/1000)

as a function of DBH (cm).

Azadirachta indica (Neem) - July 1985.

Polewood volume (m3/1000) = 0.288 Bas.Area(cm2); r2 = 94%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	2.03	4.1	6.1	8.1	10.2	12.2	14.2	16.3	18.3	20.3
4	12.57	3.62	7.2	10.8	14.5	18.1	21.7	25.3	28.9	32.5	36.2
5	19.64	5.65	11.3	17.0	22.6	28.3	33.9	39.6	45.2	50.9	56.5
6	28.27	8.14	16.3	24.4	32.5	40.7	48.8	57.0	65.1	73.2	81.4
7	38.48	11.07	22.1	33.2	44.3	55.4	66.4	77.5	88.6	99.7	110.7
8	50.27	14.47	28.9	43.4	57.9	72.3	86.8	101.3	115.7	130.2	144.7
9	63.62	18.31	36.6	54.9	73.2	91.5	109.8	128.2	146.5	164.8	183.1
10	78.54	22.60	45.2	67.8	90.4	113.0	135.6	158.2	180.8	203.4	226.0
11	95.03	27.35	54.7	82.0	109.4	136.7	164.1	191.4	218.8	246.1	273.5
12	113.10	32.55	65.1	97.6	130.2	162.7	195.3	227.8	260.4	292.9	325.5
13	132.73	38.20	76.4	114.6	152.8	191.0	229.2	267.4	305.6	343.8	382.0
14	153.94	44.30	88.6	132.9	177.2	221.5	265.8	310.1	354.4	398.7	443.0
15	176.72	50.85	101.7	152.6	203.4	254.3	305.1	356.0	406.8	457.7	508.5
16	201.06	57.86	115.7	173.6	231.4	289.3	347.2	405.0	462.9	520.7	578.6
17	226.98	65.32	130.6	196.0	261.3	326.6	391.9	457.2	522.5	587.9	653.2
18	254.47	73.23	146.5	219.7	292.9	366.1	439.4	512.6	585.8	659.1	732.3
19	283.53	81.59	163.2	244.8	326.4	408.0	489.6	571.1	652.7	734.3	815.9
20	314.16	90.41	180.8	271.2	361.6	452.0	542.4	632.8	723.3	813.7	904.1

USAID/AFORP/UMO/Ehrlich, 1985.

Table 4C, Polewood Production of Azadirachta indica as a function of DBH

CHAPTER 5

FUELWOOD AND BIOMASS PRODUCTION OF *COLUBRINA ARBORESCENS (Kapab)*

Colubrina arborescens, known locally as *kapab*, is a native tree species commonly used in traditional agroforestry associations on many Haitian mountain slopes. Found mostly at higher elevations (above 400 masl) and in humid areas, this tree grows relatively quickly into a tall tree with a small crown and a straight stem. It can withstand heavy pruning and thus is often found in farm plots among food crops such as beans, maize, sweet potatoes and manioc. This species is not well known outside of the island of Hispaniola and is not listed among the firewood crops by the NAS (1980) and CATIE (1985). Along with *Catalpa longissima (Chêne)*, *kapab* represents one of the most promising agroforestry tree species found growing on the humid hillsides of Haiti.

Methodology

The sample of trees cut for this study was found with the cooperation of the Soil Conservation and Watershed Management Section of the Ministry of Agriculture. Between five and six year ago, agronomists from this section distributed a great number of *Colubrina arborescens* seedlings among the peasants of a farmers' cooperative. All the trees in this sample were growing within planted fields and were pruned to varying degrees. In exchange for other tree seedlings (*Catalpa longissima, Eucalyptus camaldulensis*), the peasants from Morne-à-Cabrit allowed that 18 *kapab* trees of different sizes be cut for this study.

The area from where the sample was taken is located on a mountain range called Chêne des Metheux, at an altitude of 800 to 900 meters above sea level and situated on steep slopes with shallow soils over a calcareous substrate (pH 8 to 9). The area throughout is intensively farmed, mostly with annual food crops. A number of fruit trees (avocado) and coffee plants can be also found. Rainfall varies from 1400 to 1800mm annually. The region is included in the humid to very humid sub-tropical forest of the Life Zone classification (Holdridge, 1963) and in the Buffum/Campbell Zone 51 (Buffum, 1984).

Results

Samples taken from trees cut in the field were processed and analyzed in the laboratory at the Faculté d'Agronomie et Médicine Vétérinaire (FAMV). The wooden sections of the *kapab* show a moisture content ratio (dry over green weight) of 0.53 and a specific gravity of 0.55 grams per cubic millimeter. The non-merchantable biomass (mainly leaves and small branches) contained moisture equivalent to almost twice the dry biomass weight. The wood is characterized by a red heartwood and a pungent odor when cut. Although the wood appears soft, the tree stem is generally straight and is commonly used as polewood.

Correlation coefficients between dbh or stump diameter and fuelweight and total biomass are significant ($p < .001$). The same parameters correlated with pole volume with a correlation coefficient (r) of only 0.75. Half of the trees sampled in the sample produced a pole with an average length of 3.2m and a middle diameter of almost seven centimeters. Seventy-two percent of all biomass weight is represented by either poles or charcoal wood, the remaining 28% being leaves and small branches. The average tree in the sample had a dbh of 5.4cm, is 5m long and weighed in the field only 19kg (about half the weight of leucaena of comparable size). This latter value is however, misleading as most trees sampled were pruned considerably, in the agroforestry tradition of local peasants. The base of the tree is generally, bell-shaped and its perimeter ondulated. As in other species studied, height of the tree is a poor indicator of the yield parameters (fuelwood, polewood and total biomass).

Fuelwood Production

Table 4A displays estimated fuelwood yields for *Colubrina arborescens* as a function of dbh according to the expression:

$$\text{Dry fuelwood (kg)} = 0.26 \times \text{Bas.Area } (cm^2),$$

with an r^2 of 98 percent. In general, *kapab* produces, far less fuelwood than leucaena, yet it is well suited for higher elevations, on poor soils, and produces a good number of poles of excellent form. *Kapab* coppices well and its production potential under this management practice should be evaluated.

In order to estimate fuelwood production as a function of stump diameter (the only measure possible when the tree is already cut), Table 4B presents estimated yields of fuelwood according to the function:

$$\text{Dry fuelwood (kg)} = 0.36 \times \text{stump diameter squared } (cm^2) - 0.43 \times \text{stump diameter (cm)},$$

with a determination coefficient of 97 percent.

Total biomass production potential (dry weight) is presented in Table 4C. These values can be used for comparison of yields across sites and seasons. The expression:

$$\text{Dry fuelwood (kg)} = 0.32 \times \text{Bas.Area } (cm^2),$$

has an r^2 of 98% was used to calculate the yields in the table.

Conclusions

Unfortunately, little is known about this tree species, its ecology, and its potential uses in the context of reforestation and fuelwood production. *Kapab* is especially attractive as a tree to be used in reforestation on the humid highlands of Haiti.

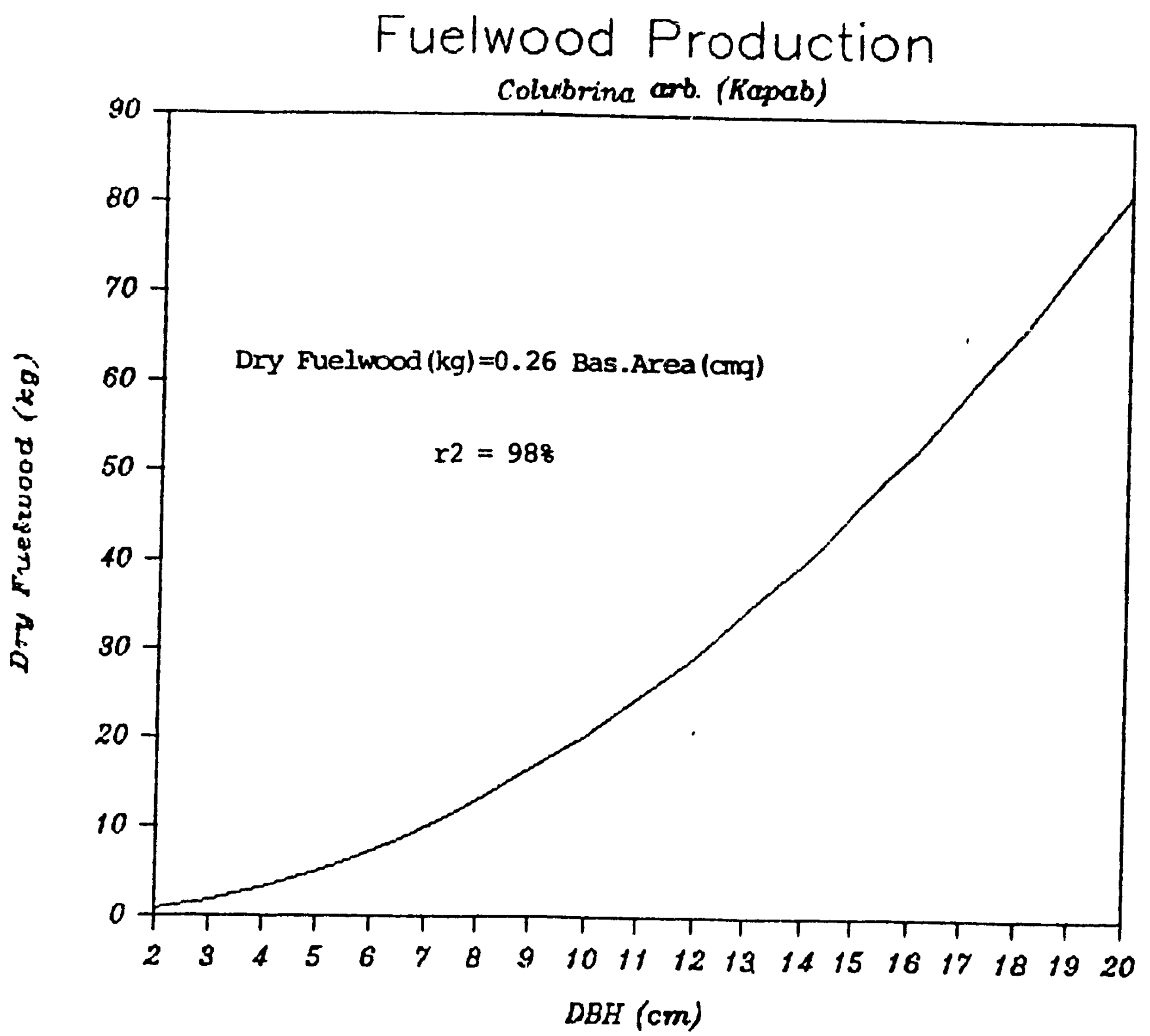

Figure 1D. Fuelwood production of Colubrina arborescens in Haiti as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Colubrina arborescens (Kapab) - Aug. 1985.
Dry Fuelwood (kg) = 0.26 Bas.Area (cmq); r2 = 98%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	0.8	1.6	2.5	3.3	4.1	4.9	5.7	6.5	7.4	8.2
3	7.07	1.8	3.7	5.5	7.4	9.2	11.0	12.9	14.7	16.5	18.4
4	12.57	3.3	6.5	9.8	13.1	16.3	19.6	22.9	26.1	29.4	32.7
5	19.64	5.1	10.2	15.3	20.4	25.5	30.6	35.7	40.8	45.9	51.0
6	28.27	7.4	14.7	22.1	29.4	36.8	44.1	51.5	58.8	66.2	73.5
7	38.48	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.1
8	50.27	13.1	26.1	39.2	52.3	65.3	78.4	91.5	104.5	117.6	130.7
9	63.62	16.5	33.1	49.6	66.2	82.7	99.2	115.8	132.3	148.9	165.4
10	78.54	20.4	40.8	61.3	81.7	102.1	122.5	142.9	163.4	183.8	204.2
11	95.03	24.7	49.4	74.1	98.8	123.5	148.2	172.9	197.7	222.4	247.1
12	113.10	29.4	58.8	88.2	117.6	147.0	176.4	205.8	235.2	264.6	294.0
13	132.73	34.5	69.0	103.5	138.0	172.5	207.0	241.6	276.1	310.6	345.1
14	153.94	40.0	80.0	120.1	160.1	200.1	240.1	280.1	320.2	360.2	400.2
15	176.72	45.9	91.9	137.8	183.8	229.7	275.7	321.6	367.5	413.5	459.4
16	201.06	52.3	104.5	156.8	209.1	261.4	313.6	365.9	418.2	470.4	522.7
17	226.98	59.0	118.0	177.0	236.0	295.1	354.1	413.1	472.1	531.1	590.1
18	254.47	66.2	132.3	198.5	264.6	330.8	396.9	463.1	529.3	595.4	661.6
19	283.53	73.7	147.4	221.1	294.8	368.6	442.3	516.0	589.7	663.4	737.1
20	314.16	81.7	163.4	245.0	326.7	408.4	490.1	571.7	653.4	735.1	816.8

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1D. Fuelwood production (dry weight) of Colubrina arborescens as a function of DBH.

YIELD TABLE

Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Colubrina arborescens (Kapab) - Aug. 1965.
Dry Fuelwood (kg)=0.365 Stump sqr.(cmq) + 0.434 Stump (cm); r2 = 97%

Stump (cm)	Stump sqr (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	4	2.3	4.7	7.0	9.3	11.6	14.0	16.3	18.6	21.0	23.3
3	9	4.6	9.2	13.8	18.3	22.9	27.5	32.1	36.7	41.3	45.9
4	16	7.6	15.2	22.7	30.3	37.9	45.5	53.0	60.6	68.2	75.8
5	25	11.3	22.6	33.9	45.2	56.5	67.8	79.1	90.4	101.7	113.0
6	36	15.7	31.5	47.2	63.0	78.7	94.5	110.2	126.0	141.7	157.4
7	49	20.9	41.8	62.8	83.7	104.6	125.5	146.5	167.4	188.3	209.2
8	64	26.8	53.7	80.5	107.3	134.2	161.0	187.8	214.7	241.5	268.3
9	81	33.5	66.9	100.4	133.9	167.4	200.8	234.3	267.8	301.2	334.7
10	100	40.8	81.7	122.5	163.4	204.2	245.0	285.9	326.7	367.6	408.4
11	121	48.9	97.9	146.8	195.8	244.7	293.6	342.6	391.5	440.5	489.4
12	144	57.8	115.5	173.3	231.1	288.8	346.6	404.4	462.1	519.9	577.7
13	169	67.3	134.7	202.0	269.3	336.6	404.0	471.3	538.6	605.9	673.3
14	196	77.6	155.2	232.8	310.5	388.1	465.7	543.3	620.9	698.5	776.2
15	225	88.6	177.3	265.9	354.5	443.2	531.8	620.4	709.1	797.7	886.4
16	256	100.4	200.8	301.2	401.5	501.9	602.3	702.7	803.1	903.5	1003.8
17	289	112.9	225.7	338.6	451.5	564.3	677.2	790.0	902.9	1015.8	1128.6
18	324	126.1	252.1	378.2	504.3	630.4	756.4	882.5	1008.6	1134.6	1260.7
19	361	140.0	280.0	420.0	560.0	700.1	840.1	980.1	1120.1	1260.1	1400.1
20	400	154.7	309.4	464.0	618.7	773.4	928.1	1082.8	1237.4	1392.1	1546.8

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2D. Fuelwood production (dry weight) of Colubrina arborescens as a function of stump diameter.

YIELD TABLE
Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Colubrina arborescens (Kapab) - Aug. 1985.
Dry Biomass (kg) = 0.318 Bas.Area (cmq); r2 = 98%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
3	7.07	2.2	4.5	6.7	9.0	11.2	13.5	15.7	18.0	20.2	22.5
4	12.57	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
5	19.64	6.2	12.5	18.7	25.0	31.2	37.5	43.7	50.0	56.2	62.4
6	28.27	9.0	18.0	27.0	36.0	45.0	53.9	62.9	71.9	80.9	89.9
7	38.48	12.2	24.5	36.7	49.0	61.2	73.4	85.7	97.9	110.1	122.4
8	50.27	16.0	32.0	48.0	63.9	79.9	95.9	111.9	127.9	143.9	159.8
9	63.62	20.2	40.5	60.7	80.9	101.2	121.4	141.6	161.8	182.1	202.3
10	78.54	25.0	50.0	74.9	99.9	124.9	149.9	174.8	199.8	224.8	249.8
11	95.03	30.2	60.4	90.7	120.9	151.1	181.3	211.5	241.8	272.0	302.2
12	113.10	36.0	71.9	107.9	143.9	179.8	215.8	251.8	287.7	323.7	359.7
13	132.73	42.2	84.4	126.6	168.8	211.0	253.3	295.5	337.7	379.9	422.1
14	153.94	49.0	97.9	146.9	195.8	244.8	293.7	342.7	391.6	440.6	489.5
15	176.72	56.2	112.4	168.6	224.8	281.0	337.2	393.4	449.6	505.8	562.0
16	201.06	63.9	127.9	191.8	255.8	319.7	383.6	447.6	511.5	575.4	639.4
17	226.98	72.2	144.4	216.5	288.7	360.9	433.1	505.3	577.4	649.6	721.8
18	254.47	80.9	161.8	242.8	323.7	404.6	485.5	566.4	647.4	728.3	809.2
19	283.53	90.2	180.3	270.5	360.6	450.8	541.0	631.1	721.3	811.5	901.6
20	314.16	99.9	199.8	299.7	399.6	499.5	599.4	699.3	799.2	899.1	999.0

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3D. Production of total biomass (dry weight) of Colubrina arborescens as a function of DBH.

CHAPTER 6

FUELWOOD AND BIOMASS PRODUCTION OF *EUCALYPTUS CAMALDULENSIS*

This species of *Eucalyptus* is the one most commonly planted in Haiti. It has proven tolerant to prolonged dry seasons and thin topsoil. It grows best however, in deep and moist soils. In optimal conditions, it would appear to share the same habitat requirements as *Catalpa longissima.* Provenance seems to be a key element for successful establishement of this species in any less than ideal environmental conditions (NAS, 1980). It remains a favorite of peasants throughout Haiti and is extensively used by the Agroforestry Outreach Project (AOP).

This Chapter analyzes the fuel and polewood production potential of *Eucalyptus camaldulensis* on a plantation in the vicinity of Port-au-Prince, in the southern region of Haiti. This large plantation (51ha) was established by Operation Double Harvest (ODH) in the fall of 1981. It includes mostly *Leucaena leucocephala* and *Azadirachta indica*, and to a lesser extent, other tree species.

Rainfall in this area averages about 900 to 1000mm per year. The soil is alkaline with a pH ranging from 8 to 9. There are frequent pockets of salt concentration due to excessive irrigation in the past. On the saline site, Eucalyptus as well as other species, grew very little. The area falls within the dry sub-tropical forest zone of the Holdridge life zone classification (1963) and its located on a plain at sea level, previously planted with sugar cane. The study site is located within the Buffum/Campbell Zone 17 (Buffum, 1984).

Methodology

A random sample of 21 trees was selected from different diameter classes, cut, measured and weighed according to the methodology developed for CATIE (1984). Samples were taken from at least two trees in each diameter class for moisture content and specific gravity determination. Each tree was measured for dbh (at 1.3m), ground and stump diameters (at 10cm), and weighed in sections. Poles were cut according to the standards of the local tree cutter. Similarly, charcoal wood was cut from tree sections that were either too small or were too crooked to be made into poles. It must be mentioned that the tree cutter involved in cutting this sample tended to cut long poles (average length of 4.4 meters).

Results

Statistical analysis of the field data revealed that dry fuel weight (kg), total biomass (kg), and pole volume (m^3) correlated significantly ($p < 0.001$) with both dbh and stump diameter. Even tree height, though not as significant, correlated highly with these yield parameters (correlation coeff. = 0.89). Still dbh, and especially basal area, turn out to be the best indicator of tree yields at any given diameter. Fifty-four percent of total biomass weight was cut into poles, 19% into charcoal wood and the remaining 27% were separated as non-merchantable biomass. Two thirds of all trees produced one pole which averaged 8.5cm diameter at the middle and 4.4m in length.

Fuelwood and Polewood Production

Table 5A presents estimated fuelwood production values (dry weight) as a function of dbh (cm), while assuming that the entire merchantable biomass is transformed into fuelwood. The regression function used for this estimation is:

$$\text{Dry fuelwood (kg)} = 0.24 \times \text{Bas.Area } (cm^2),$$

with a determination coefficient (r^2) of 98 percent. The table shows that eucalyptus produces far less fuelwood than leucaena, when site conditions are assumed similar.

Total biomass production (kg) is displayed in Table 5 C. The function:

$$\text{Dry biomass (kg)} = 0.32 \times \text{Bas.Area } (cm^2),$$

is used to estimate biomass as a function of dbh with a determination coefficient of 99 percent. dbh is the only field measure required to estimate fuelwood and biomass production using the above tables. When the tree is already cut, but the stump diameter can still be measured, Table 5B allows the estimation of fuelwood production for previously harvested trees.

Polewood production was also estimated as a function of dbh (cm) using the expression:

$$\text{Polewood volume (mc/1000)} = 0.\ 37 \times \text{Bas.Area } (cm^2),$$

with a determination coefficient of 93 percent. Table 5D constitutes a pole volume table for *Eucalyptus camaldulensis.* The values in the pole volume table are in expressed in cubic decimeters. This unit is used since, tree volume values expressed in cubic meters are naturally extremely small. For example, the average pole in the sample studied had a volume in cubic meters of 0.025. It takes forty poles of similar size to total one cubic meter.

Conclusions

Eucalyptus camaldulensis offers great potential as a producer of construction timber. For fuelwood production, its potential is more limited. Its limitations are obviously aggravated by poor site conditions, where other tree species would out-perform eucalyptus easily. Consideration should be given to compare different provenances of this *Eucalyptus* species to obtain the best results. One provenance of this tree species has done very well in northern Africa (Morocco), possibly in similar ecological conditions as those found in many parts of Haiti. The coppicing potential of this species also need to be explored.

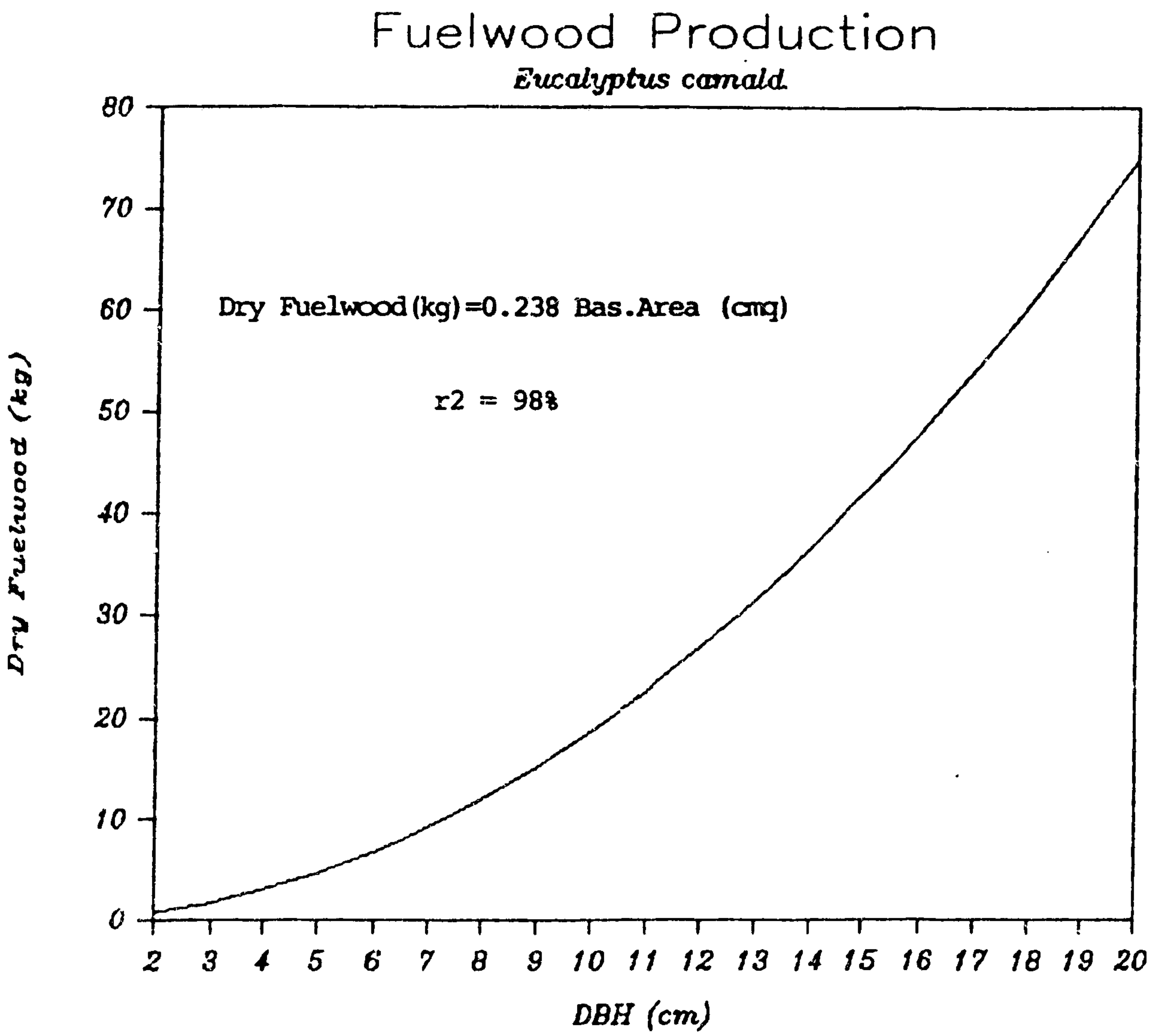

Figure 1E. Fuelwood production of Eucalyptus camadulensis as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Eucalyptus camaldulensis - Aug. 1985.
Dry Fuelwood (kg)=0.238 Bas.Area (cmq); r2 = 98%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	0.7	1.5	2.2	3.0	3.7	4.5	5.2	6.0	6.7	7.5
3	7.07	1.7	3.4	5.1	6.7	8.4	10.1	11.8	13.5	15.2	16.9
4	12.57	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
5	19.64	4.7	9.4	14.0	18.7	23.4	28.1	32.8	37.5	42.1	46.8
6	28.27	6.7	13.5	20.2	27.0	33.7	40.4	47.2	53.9	60.7	67.4
7	38.48	9.2	18.4	27.5	36.7	45.9	55.1	64.2	73.4	82.6	91.8
8	50.27	12.0	24.0	36.0	47.9	59.9	71.9	83.9	95.9	107.9	119.8
9	63.62	15.2	30.3	45.5	60.7	75.8	91.0	106.2	121.3	136.5	151.7
10	78.54	18.7	37.5	56.2	74.9	93.6	112.4	131.1	149.8	168.5	187.3
11	95.03	22.7	45.3	68.0	90.6	113.3	135.9	158.6	181.3	203.9	226.6
12	113.10	27.0	53.9	80.9	107.9	134.8	161.8	188.8	215.7	242.7	269.6
13	132.73	31.6	63.3	94.9	126.6	158.2	189.9	221.5	253.2	284.8	316.3
14	153.94	36.7	73.4	110.1	146.8	183.5	220.2	256.9	293.6	330.3	367.0
15	176.72	42.1	84.3	126.4	168.5	210.7	252.8	294.9	337.1	379.2	421.3
16	201.06	47.9	95.9	143.8	191.7	239.7	287.6	335.6	383.5	431.4	479.4
17	226.98	54.1	108.2	162.4	216.5	270.6	324.7	378.8	432.9	487.1	541.2
18	254.47	60.7	121.3	182.0	242.7	303.4	364.0	424.7	485.4	546.0	606.7
19	283.53	67.6	135.2	202.8	270.4	338.0	405.6	473.2	540.8	608.4	676.0
20	314.16	74.9	149.8	224.7	299.6	374.5	449.4	524.3	599.2	674.1	749.0

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1E. Fuelwood production (dry weight) of Eucalyptus camaldulensis as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Eucalyptus camaldulensis - Aug. 1985.
Dry Fuelwood (kg)= 2.205 (stump) - 1.132 sqr.root (stump); r2 = 91%

Stump (cm)	sqr.root Stump	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	1.41	2.8	5.6	8.4	11.2	14.0	16.8	19.7	22.5	25.3	28.1
3	1.73	4.7	9.3	14.0	18.6	23.3	27.9	32.6	37.2	41.9	46.5
4	2.00	6.6	13.1	19.7	26.2	32.8	39.3	45.9	52.4	59.0	65.5
5	2.24	8.5	17.0	25.5	34.0	42.5	50.9	59.4	67.9	76.4	84.9
6	2.45	10.5	20.9	31.4	41.8	52.3	62.7	73.2	83.6	94.1	104.5
7	2.65	12.4	24.9	37.3	49.7	62.2	74.6	87.1	99.5	111.9	124.4
8	2.83	14.4	28.9	43.3	57.7	72.2	86.6	101.0	115.5	129.9	144.3
9	3.00	16.4	32.9	49.3	65.8	82.2	98.7	115.1	131.6	148.0	164.4
10	3.16	18.5	36.9	55.4	73.9	92.3	110.8	129.3	147.7	166.2	184.7
11	3.32	20.5	41.0	61.5	82.0	102.5	123.0	143.5	164.0	184.5	205.0
12	3.46	22.5	45.1	67.6	90.1	112.7	135.2	157.7	180.3	202.8	225.3
13	3.61	24.6	49.2	73.7	98.3	122.9	147.5	172.0	196.6	221.2	245.8
14	3.74	26.6	53.3	79.9	106.5	133.1	159.8	186.4	213.0	239.6	266.3
15	3.87	28.7	57.4	86.1	114.7	143.4	172.1	200.8	229.5	258.2	286.8
16	4.00	30.7	61.5	92.2	123.0	153.7	184.5	215.2	246.0	276.7	307.4
17	4.12	32.8	65.6	98.4	131.2	164.0	196.9	229.7	262.5	295.3	328.1
18	4.24	34.9	69.8	104.6	139.5	174.4	209.3	244.2	279.0	313.9	348.8
19	4.36	37.0	73.9	110.9	147.8	184.8	221.7	258.7	295.6	332.6	369.5
20	4.47	39.0	78.1	117.1	156.1	195.1	234.2	273.2	312.2	351.3	390.3

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2E. Fuelwood production (dry weight) of Eucalyptus camaldulensis as a function of stump diameter.

YIELD TABLE
Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Eucalyptus camaldulensis - Aug. 1985.
Dry Biomass (kg) = 0.32 Bas.Area (cmq); r2 = 99%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
3	7.07	2.3	4.5	6.8	9.0	11.3	13.6	15.8	18.1	20.3	22.6
4	12.57	4.0	8.0	12.0	16.1	20.1	24.1	28.1	32.1	36.1	40.2
5	19.64	6.3	12.6	18.6	25.1	31.4	37.7	43.9	50.2	56.5	62.8
6	28.27	9.0	18.1	27.1	36.1	45.2	54.2	63.3	72.3	81.3	90.4
7	38.48	12.3	24.6	36.9	49.2	61.5	73.8	86.1	98.4	110.7	123.0
8	50.27	16.1	32.1	48.2	64.3	80.3	96.4	112.5	128.5	144.6	160.7
9	63.62	20.3	40.7	61.0	81.3	101.7	122.0	142.3	162.7	183.0	203.3
10	78.54	25.1	50.2	75.3	100.4	125.5	150.6	175.7	200.8	225.9	251.0
11	95.03	30.4	60.7	91.1	121.5	151.9	182.2	212.6	243.0	273.4	303.7
12	113.10	36.1	72.3	108.4	144.6	180.7	216.9	253.0	289.2	325.3	361.5
13	132.73	42.4	84.8	127.3	169.7	212.1	254.5	297.0	339.4	381.8	424.2
14	153.94	49.2	98.4	147.6	196.8	246.0	295.2	344.4	393.6	442.8	492.0
15	176.72	56.5	113.0	169.4	225.9	282.4	338.9	395.4	451.9	508.3	564.8
16	201.06	64.3	128.5	192.8	257.1	321.3	385.6	449.8	514.1	578.4	642.6
17	226.98	72.5	145.1	217.6	290.2	362.7	435.3	507.8	580.4	652.9	725.5
18	254.47	81.3	162.7	244.0	325.3	406.7	488.0	569.3	650.7	732.0	813.3
19	283.53	90.6	181.2	271.9	362.5	453.1	543.7	634.4	725.0	815.6	906.2
20	314.16	100.4	200.8	301.2	401.6	502.1	602.5	702.9	803.3	903.7	1004.1

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3E. Production of total biomass (dry weight) of Eucalyptus camadulensis as a function of DBH.

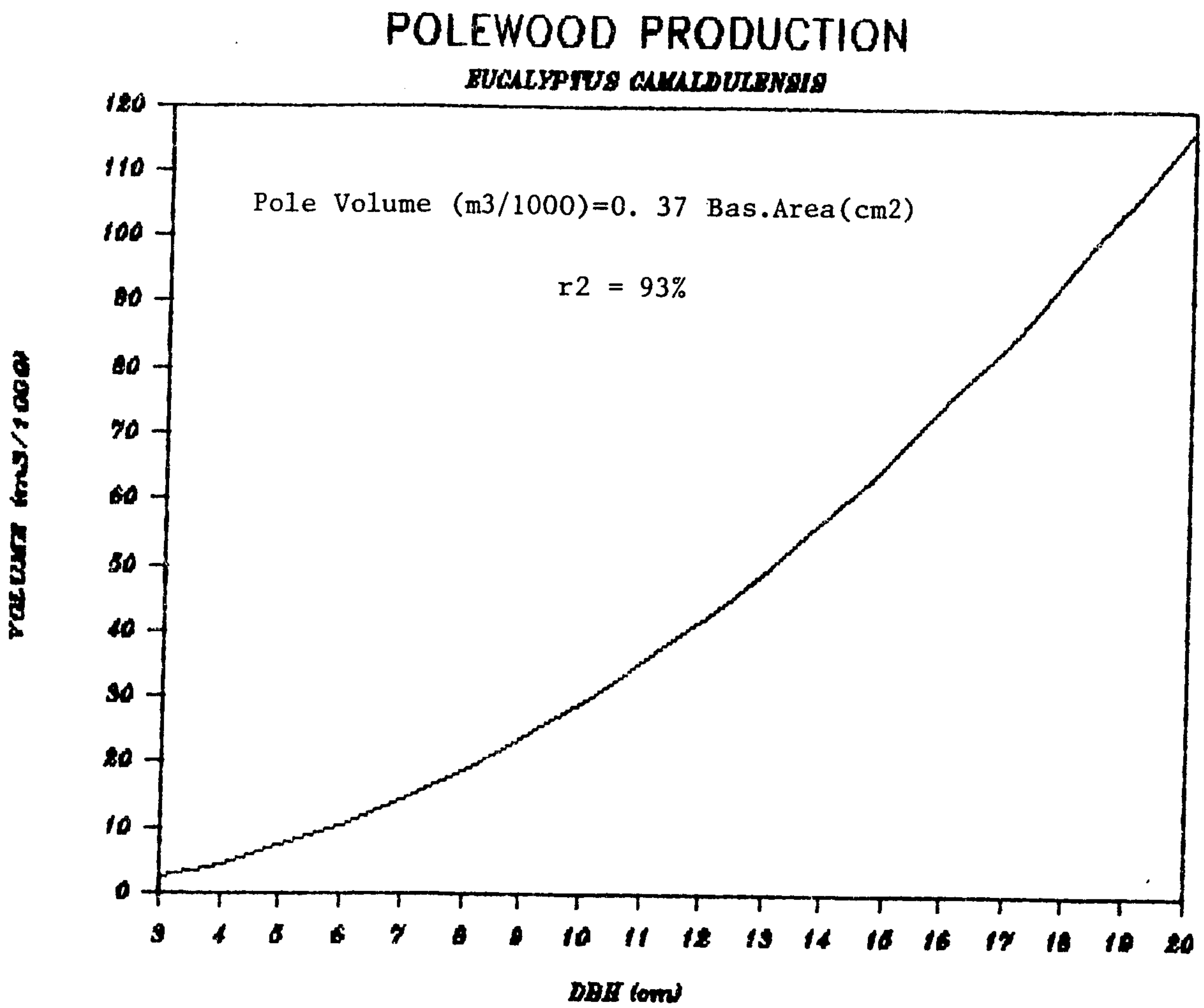

Figure 2E. Polewood Production of Eucalyptus camaldulensis in Haiti as a function of DBH

YIELD TABLE
Production of polewood (volume in mc/1000)
as a function of DBH (cm).
Eucalyptus camaldulensis - July 1985.
Polewood volume (m3/1000) = 0.371 Bas.Area(cm2); r2 = 93%

DBH (cm)	Bas.Area (cm2)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	2.6	5.3	7.9	10.5	13.1	15.8	18.4	21.0	23.6	26.3
4	12.57	4.7	9.3	14.0	18.7	23.4	28.0	32.7	37.4	42.0	46.7
5	19.64	7.3	14.6	21.9	29.2	36.5	43.8	51.1	58.4	65.7	73.0
6	28.27	10.5	21.0	31.5	42.0	52.5	63.1	73.6	84.1	94.6	105.1
7	38.48	14.3	28.6	42.9	57.2	71.5	85.8	100.1	114.4	128.7	143.0
8	50.27	18.7	37.4	56.1	74.7	93.4	112.1	130.8	149.5	168.2	186.8
9	63.62	23.6	47.3	70.9	94.6	118.2	141.9	165.5	189.2	212.8	236.5
10	78.54	29.2	58.4	87.6	116.8	146.0	175.2	204.4	233.6	262.7	291.9
11	95.03	35.3	70.6	106.0	141.3	176.6	211.9	247.3	282.6	317.9	353.2
12	113.10	42.0	84.1	126.1	168.2	210.2	252.2	294.3	336.3	378.4	420.4
13	132.73	49.3	98.7	148.0	197.4	246.7	296.0	345.4	394.7	444.0	493.4
14	153.94	57.2	114.4	171.7	228.9	286.1	343.3	400.5	457.8	515.0	572.2
15	176.72	65.7	131.4	197.1	262.7	328.4	394.1	459.8	525.5	591.2	656.9
16	201.06	74.7	149.5	224.2	298.9	373.7	448.4	523.2	597.9	672.6	747.4
17	226.98	84.4	168.7	253.1	337.5	421.9	506.2	590.6	675.0	759.3	843.7
18	254.47	94.6	189.2	283.8	378.4	472.9	567.5	662.1	756.7	851.3	945.9
19	283.53	105.4	210.8	316.2	421.6	526.9	632.3	737.7	843.1	948.5	1053.9
20	314.16	116.8	233.6	350.3	467.1	583.9	700.7	817.4	934.2	1051.0	1167.8

USAID/AFORP/UMO/Ehrlich, 1985.

Table 4E. Polewood Production of Eucalyptus camaldulensis as a function of DBH

CHAPTER 7

FUELWOOD AND BIOMASS PRODUCTION OF *PROSOPIS JULIFLORA (Bayahonde)*

Prosopis juliflora (bayahonde) is the most common dry area tree species in Haiti. It grows exceptionally well in arid zones, with rainfall of less than 400mm annually. It also tolerates alkaline soils, where other trees cannot adapt. It is a favorite of charcoal makers for the quality of the charcoal it produces. Its green biomass is used for forage, yet in the open range, it is avoided by goats because of its abundant thorns. *Prosopis* coppices well and then produces straight stems used as poles in construction. The wood is durable and used for fence posts and door and window frames. It is the favorite firewood tree in rural areas as it burns slowly and evenly.

The potential of prosopis in reforestation of eroded hillsides has yet to be tapped. Many eroded slopes in the country could recuperate their vegetative cover quickly and cost effectively, if prosopis were allowed to regrow naturally and not be harvested on a short rotation for charcoal production. It reproduces easily by root suckers as well as seed (NAS, 1980).

Methodology

The samples used for preparation of the yield tables were cut from various sites in the Cul-de-Sac (Ganthier) and near Cabaret. Rainfall at Ganthier, an area at sea level, averages about 700mm per year. At Cabaret, north of the capital city, rainfall is about 900mm annually, with extended dry seasons when little or no rainfall occurs. While the trees samples near Ganthier were typical of courtyard trees, coppiced and used frequently for domestic fuel production, the trees cut near Cabaret had been let to grow for several years. The yield tables therefore, reflect some of the environmental variability within which this tree species grows in Haiti.

Twenty trees were cut, measured and weighed in sections according to the methodology developed for CATIE (1984). Each tree was separated in merchantable (more than 2cm minimum diameter) and non-merchantable wood (mostly leaves and small branches). The merchantable wood was divided into polewood (if a pole could be cut from the stem) and charcoal wood and weighed separately. The remaining biomass was also weighed as soon as the tree was felled. Each tree was measured for dbh, stump, and ground diameters, as well as total height. Poles were measured for length and top and bottom diameters.

Results

The analysis of the tree samples in the laboratory determined that the specific gravity of prosopis was 0.72 g/mm³, the moisture content of wood samples represents 36% of total green weight, while that of the leaves and small branches is 51 percent. The heartwood of *Prosopis juliflora* is almost black in color, quite hard, dense, and heavy.

Statistical analysis of the field data determined that dbh and stump diameter correlated highly only with fuel weight and dry biomass production ($p < .001$), while pole volume correlated with these parameters poorly. Total height of the tree turned out to be a poor indicator of all yield parameters, such as fuel and biomass weight and showed no significant correlation with pole volume.

Nine poles were cut from the 20 trees sampled. Their length ranged from 1.8 to 3.7m with an average diameter of 7.6 centimeters. More than two-thirds of the total tree weight was accounted for by either pole or charcoal wood at a ratio of one to two respectively. Leaves, twigs and small branches accounted for 32% of all biomass weight (generally higher than in other species). Although the form of the trees cut was irregular, the peasants involved in cutting the trees, did cut a number of poles to be used on local construction sites, but neither size and form of the poles could meet urban market requirements.

The average tree in the sample was about 6m tall and had a dbh of 6.1cm and weighed 31 kilograms. A number of trees sampled were coppices. Few prosopis trees in Haiti have never been cut before. In fact, relative large stands of prosopis can be found that are intensively, yet rationally managed as coppice stands. Further research in appropriate silvicultural techniques for this promising species are definitively warranted.

Fuelwood Production

Fuelwood production potential of *Prosopis juliflora* is estimated in Table 6A according to the regression equation:

Dry fuelwood(kg) = 0.39 x Bas.Area (cm^2).

The determination coefficient for this function is 99 percent. According to this table, a tree with a dbh of 10cm will produce on the average, 30kg of dry fuelwood. When only the stump diameter (at 10cm) can be measured (the tree has been cut already) Table 6B permits the estimation of fuelwood production as a function of stump diameter. The expression used:

Dry fuelwood (kg) = 0.19 x stump diameter squared (cm^2),

has a determination coefficient of 97 percent.

In order to allow comparisons across sites and seasons, Table 6C enables estimation of total biomass production (dry weight) as a function of dbh. The expression used:

$$\text{Dry biomass (kg)} = 0.52 \times \text{Bas. Area (cm}^2\text{)},$$

has a determination coefficient of 97 percent.

Conclusions

Field observations across Haiti clearly show the tremendous potential of this species in the arid zones of the country. Few other tree species can outperform prosopis in fuelwood production on difficult sites and in semi-desert conditions. Further research in the potential of this tree under different management conditions could indicate ways of maximizing production of fuelwood and ways to utilize this tree in reforestation of marginal areas of the country.

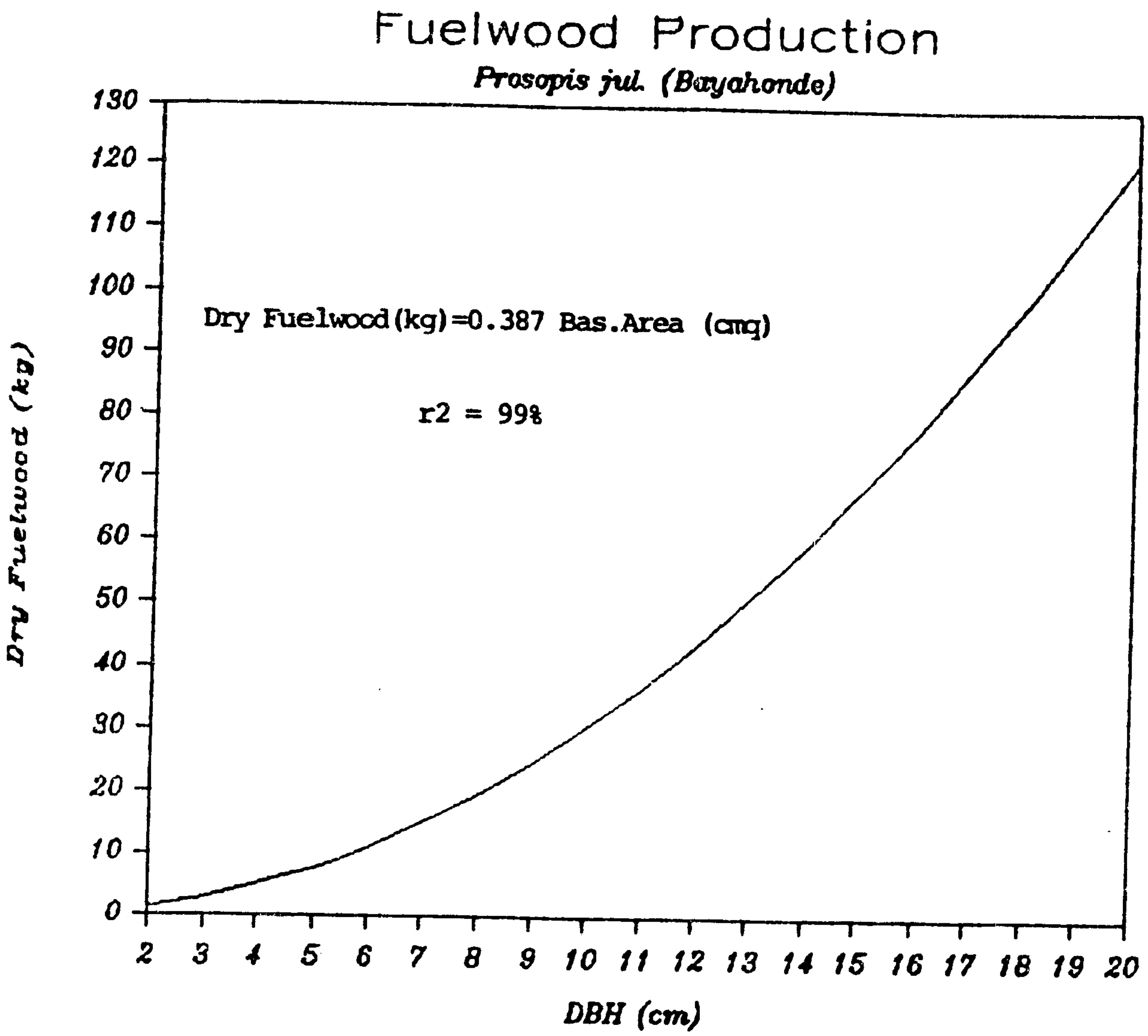

Figure 1F. Fuelwood production (dry weight) of Prosopis juliflora as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Prosopis juliflora (Bayahonde) - Aug. 1985.
Dry Fuelwood (kg)=0.387 Bas.Area (cmq); r2 = 99%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.2	2.4	3.6	4.9	6.1	7.3	8.5	9.7	10.9	12.1
3	7.07	2.7	5.5	8.2	10.9	13.7	16.4	19.1	21.9	24.6	27.3
4	12.57	4.9	9.7	14.6	19.4	24.3	29.1	34.0	38.9	43.7	48.6
5	19.64	7.6	15.2	22.8	30.4	38.0	45.5	53.1	60.7	68.3	75.9
6	28.27	10.9	21.9	32.8	43.7	54.7	65.6	76.5	87.4	98.4	109.3
7	38.48	14.9	29.8	44.6	59.5	74.4	89.3	104.1	119.0	133.9	148.8
8	50.27	19.4	38.9	58.3	77.7	97.2	116.6	136.0	155.5	174.9	194.3
9	63.62	24.6	49.2	73.8	98.4	123.0	147.6	172.2	196.8	221.4	246.0
10	78.54	30.4	60.7	91.1	121.5	151.8	182.2	212.6	242.9	273.3	303.6
11	95.03	36.7	73.5	110.2	147.0	183.7	220.4	257.2	293.9	330.7	367.4
12	113.10	43.7	87.4	131.2	174.9	218.6	262.3	306.1	349.8	393.5	437.2
13	132.73	51.3	102.6	153.9	205.3	256.6	307.9	359.2	410.5	461.8	513.2
14	153.94	59.5	119.0	178.5	238.1	297.6	357.1	416.6	476.1	535.6	595.1
15	176.72	68.3	136.6	205.0	273.3	341.6	409.9	478.2	546.6	614.9	683.2
16	201.06	77.7	155.5	233.2	310.9	388.7	466.4	544.1	621.9	699.6	777.3
17	226.98	87.8	175.5	263.3	351.0	438.8	526.5	614.3	702.0	789.8	877.5
18	254.47	98.4	196.8	295.1	393.5	491.9	590.3	688.7	787.0	885.4	983.8
19	283.53	109.6	219.2	328.8	438.5	548.1	657.7	767.3	876.9	986.5	1096.2
20	314.16	121.5	242.9	364.4	485.8	607.3	728.7	850.2	971.7	1093.1	1214.6

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1F. Fuelwood production (dry weight) of Prosopis juliflora as a function of DBH.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of stump diameter (cm).
Prosopis juliflora (Bayahonde) - Sept. 1985.
Dry Fuelwood (kg)=0.195 Stump diam. sqr.(cmq); r2 = 97%

Stump (cm)	Stump sqr: (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	4	0.8	1.6	2.3	3.1	3.9	4.7	5.5	6.3	7.0	7.8
3	9	1.8	3.5	5.3	7.0	8.8	10.5	12.3	14.1	15.8	17.6
4	16	3.1	6.3	9.4	12.5	15.6	18.8	21.9	25.0	28.1	31.3
5	25	4.9	9.8	14.6	19.5	24.4	29.3	34.2	39.1	43.9	48.8
6	36	7.0	14.1	21.1	28.1	35.2	42.2	49.2	56.3	63.3	70.3
7	49	9.6	19.1	28.7	38.3	47.9	57.4	67.0	76.6	86.1	95.7
8	64	12.5	25.0	37.5	50.0	62.5	75.0	87.5	100.0	112.5	125.0
9	81	15.8	31.6	47.5	63.3	79.1	94.9	110.8	126.6	142.4	158.2
10	100	19.5	39.1	58.6	78.1	97.7	117.2	136.7	156.3	175.8	195.3
11	121	23.6	47.3	70.9	94.5	118.2	141.8	165.4	189.1	212.7	236.3
12	144	28.1	56.3	84.4	112.5	140.6	168.8	196.9	225.0	253.1	281.3
13	169	33.0	66.0	99.0	132.0	165.1	198.1	231.1	264.1	297.1	330.1
14	196	38.3	76.6	114.9	153.1	191.4	229.7	268.0	306.3	344.6	382.8
15	225	43.9	87.9	131.8	175.8	219.7	263.7	307.6	351.6	395.5	439.5
16	256	50.0	100.0	150.0	200.0	250.0	300.0	350.0	400.0	450.0	500.0
17	289	56.5	112.9	169.4	225.8	282.3	338.7	395.2	451.6	508.1	564.5
18	324	63.3	126.6	189.9	253.1	316.4	379.7	443.0	506.3	569.6	632.9
19	361	70.5	141.0	211.5	282.1	352.6	423.1	493.6	564.1	634.6	705.1
20	400	78.1	156.3	234.4	312.5	390.7	468.8	546.9	625.1	703.2	781.3

USAID/AFORP/UMO/Ehrlich, 1985.

Table 2F. Fuelwood production (dry weight) of Prosopis juliflora as a function of stump diameter.

YIELD TABLE

Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Prosopis juliflora (Bayahonde) - Sept.1985
Dry Biomass (kg) = 0.52 Bas.Area (cmq); r2 = 97%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	1.6	3.3	4.9	6.5	8.2	9.8	11.4	13.1	14.7	16.3
3	7.07	3.7	7.3	11.0	14.7	18.4	22.0	25.7	29.4	33.0	36.7
4	12.57	6.5	13.1	19.6	26.1	32.6	39.2	45.7	52.2	58.7	65.3
5	19.64	10.2	20.4	30.6	40.8	51.0	61.2	71.4	81.6	91.8	102.0
6	28.27	14.7	29.4	44.1	58.7	73.4	88.1	102.8	117.5	132.2	146.9
7	38.48	20.0	40.0	60.0	80.0	99.9	119.9	139.9	159.9	179.9	199.9
8	50.27	26.1	52.2	78.3	104.4	130.5	156.6	182.8	208.9	235.0	261.1
9	63.62	33.0	66.1	99.1	132.2	165.2	198.3	231.3	264.3	297.4	330.4
10	78.54	40.8	81.6	122.4	163.2	204.0	244.8	285.6	326.3	367.1	407.9
11	95.03	49.4	98.7	148.1	197.4	246.8	296.2	345.5	394.9	444.2	493.6
12	113.10	58.7	117.5	176.2	235.0	293.7	352.5	411.2	469.9	528.7	587.4
13	132.73	68.9	137.9	206.8	275.8	344.7	413.6	482.6	551.5	620.5	689.4
14	153.94	80.0	159.9	239.9	319.8	399.8	479.7	559.7	639.6	719.6	799.6
15	176.72	91.8	183.6	275.4	367.1	458.9	550.7	642.5	734.3	826.1	917.9
16	201.06	104.4	208.9	313.3	417.7	522.2	626.6	731.0	835.5	939.9	1044.3
17	226.98	117.9	235.8	353.7	471.6	589.5	707.4	825.3	943.1	1061.0	1178.9
18	254.47	132.2	264.3	396.5	528.7	660.9	793.0	925.2	1057.4	1189.5	1321.7
19	283.53	147.3	294.5	441.8	589.1	736.3	883.6	1030.9	1178.1	1325.4	1472.7
20	314.16	163.2	326.3	489.5	652.7	815.9	979.0	1142.2	1305.4	1468.6	1631.7

USAID/AFORP/UMO/Ehrlich, 1985.

Table 3F. Production of total biomass (dry weight) of Prosopis juliflora as a function of DBH.

CHAPTER 8

COMPARISON OF PRODUCTIVE POTENTIAL

A comparison of the six tree species is attempted not to establish the better tree, but to outline patterns of growth and productivity of one species relative to the others. Results of this comparative analysis are presented in graphic as well as in tabular form.

Fuelwood Production

A comparative analysis of fuelwood production for the six tree species studied shows that, on the basis of dbh, leucaena is by far the better producer of fuelwood, at least in the earlier stages of growth. It should be mentioned that the site characteristics for this species, were favorable for tree growth. Thus, indipendent of site characteristics, leucaena produced more fuelwood than (in descending order) cassia, ***bayahonde***, neem, ***kapab*** and eucalyptus. Figure 1G presents these findings in graphic form, while Table 1G presents the results of this analysis in tabular form.

Specifically, leucaena yields about 60kg of dry fuelwood with a dbh of 12cm, while an eucalyptus tree of the same diameter yields only 27 kilograms. This could be partly due to the fact that, while eucalyptus grows primarily along one axis (straight stem), leucaena branches out considerably and has a voluminous crown from which fuelwood can be produced. This consideration is supported by the fact that, while the estimates of pole volume in the case of eucalyptus correlate significantly with dbh, in the case of leucaena, the same correlation is much less significant. A pole volume table for leucaena as not produced due to the far greater variability of this tree species and the unreliability of the resulting prediction equation.

Table 2G shows polewood production potential for cassia, neem and eucalyptus. Figure 2G presents the finding of this comparative analysis in graphic form. The results of the analysis suggest that cassia produces the greatest polewood volume when compared to eucalyptus and neem. Specifically, while a 12 cm tree (at dbh) of neem yields 3.3 cubic dm^3 of polewood, eucalyptus yields 4.2 dm^3 and cassia 4.9 cubic decimeters. In this case too, site conditions are assumed similar and having no differential effect on tree growth for the three species studied for polewood production.

It should be noted that this comparative analysis provides initial baseline estimates of fuelwood and polewood production capabilities. Although data and regression equations for the six species studied are extremely good (r^2 values of 0.86 or better), verification of the accuracy of the yield tables across a wide range of different site conditions is necessary before an actual ranking of productive potential can be established with confidence.

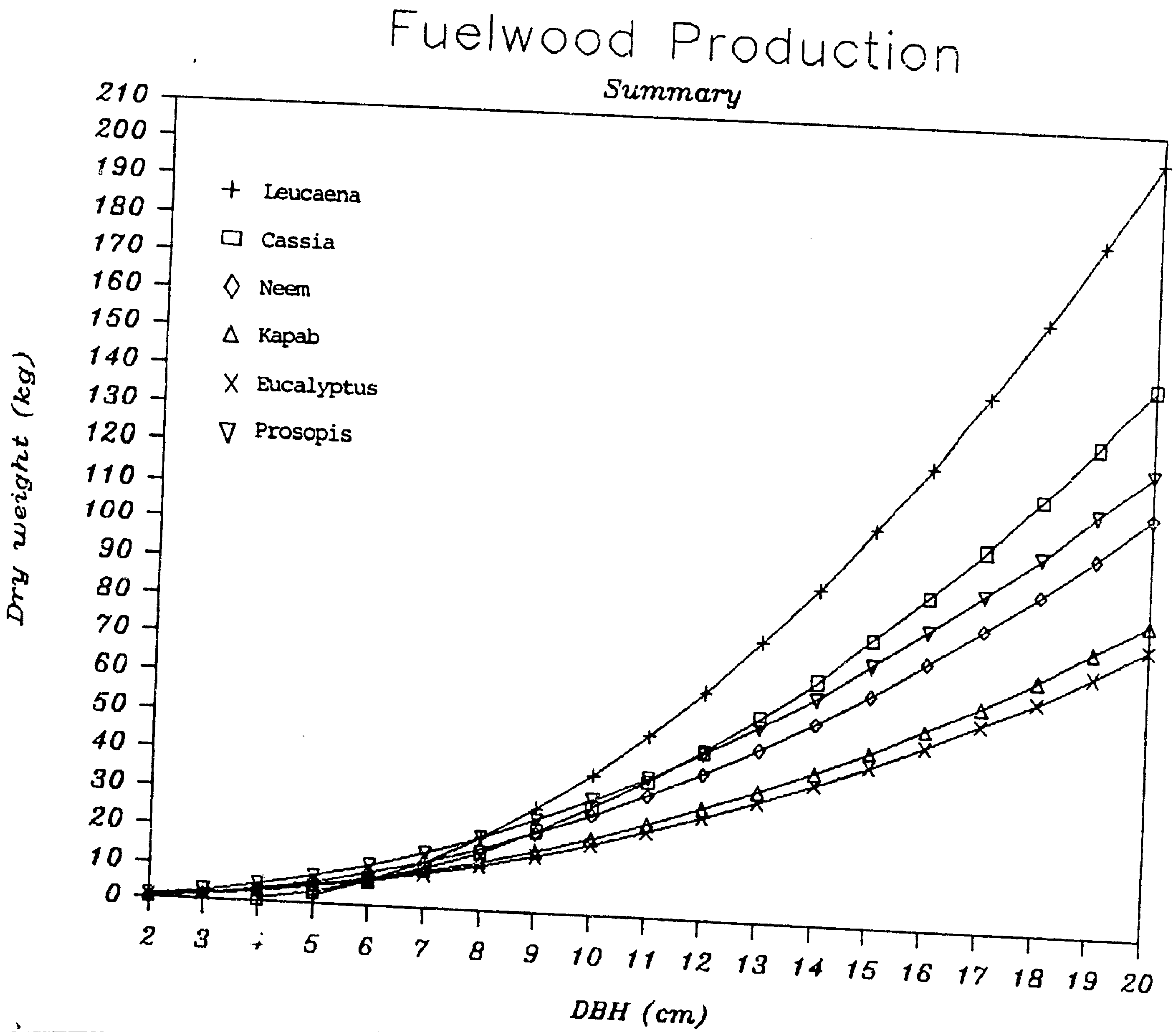

Figure 1 G. Fuelwood production for six species in Haiti as a function of DBH.

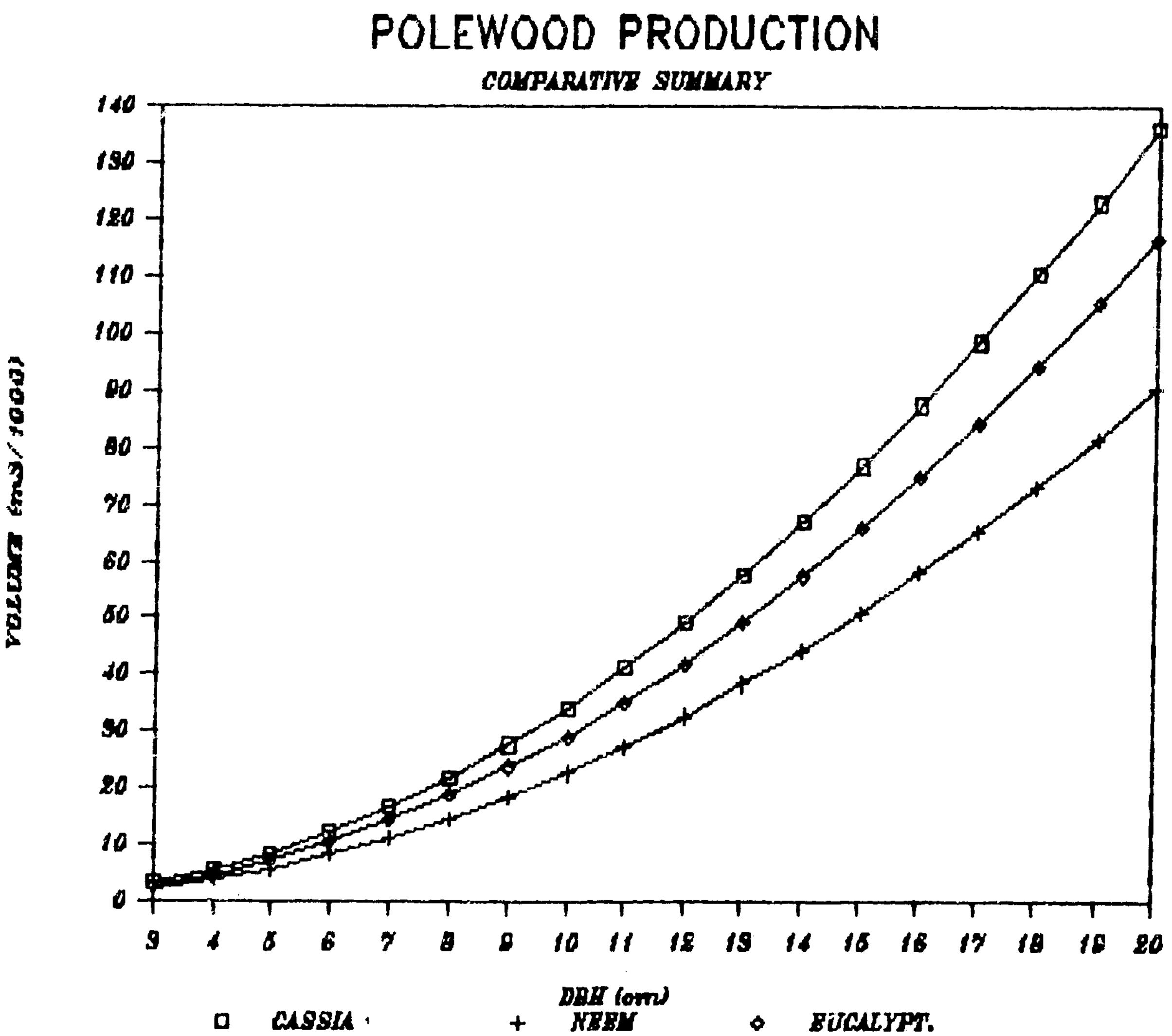

Figure 2G. Polewood Production of Three Species in Haiti as a function of DBH

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Summary results for all species (July-Aug.1985)

DBH (cm)	Bas.Area (cmq)	Cassia	Leucaena	Neem	Kapab	Eucalypt	Prosopis
		TREE SPECIES					
2	3.14			0.4	0.8	0.7	1.2
3	7.07			1.7	1.8	1.7	2.7
4	12.57	0.9		3.5	3.3	3.0	4.9
5	19.64	3.3	2.5	5.9	5.1	4.7	7.6
6	28.27	6.6	6.9	8.9	7.4	6.7	10.9
7	38.48	10.7	12.5	12.4	10.0	9.2	14.9
8	50.27	15.7	19.4	16.5	13.1	12.0	19.4
9	63.62	21.6	27.6	21.1	16.5	15.2	24.6
10	78.54	28.3	37.1	26.3	20.4	18.7	30.4
11	95.03	35.9	47.9	32.1	24.7	22.7	36.7
12	113.10	44.3	59.9	38.5	29.4	27.0	43.7
13	132.73	53.6	73.3	45.4	34.5	31.6	51.3
14	153.94	63.8	87.9	52.8	40.0	36.7	59.5
15	176.72	74.9	103.8	60.9	45.9	42.1	68.3
16	201.06	86.8	121.0	69.5	52.3	47.9	77.7
17	226.98	99.6	139.4	78.6	59.0	54.1	87.8
18	254.47	113.2	159.2	88.4	66.2	60.7	98.4
19	283.53	127.7	180.2	98.6	73.7	67.6	109.6
20	314.16	143.1	202.5	109.5	81.7	74.9	121.5
21	346.36	159.3	226.1				
22	380.13	176.5	251.0				
23	415.48	194.4	277.2				

USAID/AFORP/UMO/Ehrlich, 1985.

Table 1 G. Fuelwood production (dry weight) for all species as a function of DBH.

YIELD TABLE
Production of polewood (cubic meters/1000)
as a function of DBH (cm).
Summary results for all species (Aug.1985)

DBH (cm)	Bas.Area (cmq)	TREE SPECIES Cassia	Neem	Eucalyptus
3	7.07	3.1	2.0	2.6
4	12.57	5.5	3.6	4.7
5	19.64	8.5	5.7	7.3
6	28.27	12.3	8.1	10.5
7	38.48	16.7	11.1	14.3
8	50.27	21.8	14.5	18.7
9	63.62	27.6	18.3	23.6
10	78.54	34.1	22.6	29.2
11	95.03	41.3	27.3	35.3
12	113.10	49.1	32.5	42.0
13	132.73	57.7	38.2	49.3
14	153.94	66.9	44.3	57.2
15	176.72	76.8	50.9	65.7
16	201.06	87.4	57.9	74.7
17	226.98	98.6	65.3	84.4
18	254.47	110.6	73.2	94.6
19	283.53	123.2	81.6	105.4
20	314.16	136.5	90.4	116.8

USAID/AFORP/UNO/Ehrlich, 1985.

Table 2G. Polewood Production for Cassia siamea, Azadirachta indica and Eucalyptus camaldulensis compared

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

Leucaena leucocephala requires additional sampling in order to account not only for site variability, but also for the variance encountered for this species in many of the growth parameters studied (fuelwood weight, polewood volume, height, stem form, etc.).

Similarly, *Eucalyptus camaldulensis* has displayed unusual variability in moisture content and specific gravity, thus justifying additional sampling and laboratory testing.

It is also recommended that similar research be carried out for the study of other native trees of Hispaniola, whose potential in the field of agroforestry appears significant. Specifically, *Catalpa longissima (chêne), Simaruba glauca (frêne)* and *Swietenia mahoganii (acajou)* should be studied for both fuelwood and polewood production potential. In addition, *Casuarina equisetifolia* an exotic tree whose agroforestry applications appear promising, should also be studied for its potential for producing fuel and poles in dry areas of the country.

Finally, the results of this research contribute significantly to the general body of knowledge about tree species used in agroforestry applications across the Central American and Caribbean region. The Center for Research on Tropical Agriculture (CATIE) in Costa Rica has shown interest in both the exchange of scientific data as well as in publication of research findings.

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FINAL REPORT

BIOMASS AND YIELD TABLES FOR *CASUARINA EQUISETIFOLIA* AND *CATALPA LONGISSIMA* IN HAITI

by

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We would like to thank François Severin, Chief of the Soil Conservation and Watershed Management Division of the Ministry of Agriculture, Natural Resources and Rural Developement (MARNDR), for locating a suitable site for the study of *Casuarina equisetifolia* and François Martinau from the same Division for getting the permission to actually fell the trees at Terre Rouge.

We are also very grateful to Parvis Koohafkan, technical advisor at the FAO Watershed Management Training Center at Limbé, for locating the site and allowing the cutting of the sample of *Catalpa longissima.*

Finally, we would like to acknowledge Stuart North from PADF who lent us an essential tool to carry out the experiment and Deborah Levine of the Agroforestry Outreach Research Project for editorial assistance.

CHAPTER 1

INTRODUCTION

This report presents the results of three months of silvicultural research conducted to study the fuelwood, biomass, and polewood production potential of two tree species used in agroforestry applications in Haiti: *Catalpa longissima* (*chêne*) and *Casuarina equisetifolia*. This report complements the Yield Table report prepared by Ehrlich (1985) which covers six tree species, specifically: *Leucaena leucocephala*, *Cassia siamea*, *Azadirachta indica (neem)*, *Colubrina arborescens* (*kapab*), *Eucalyptus camaldulensis*, and *Prosopis juliflora (bayahonde)*.

Chêne is one of the most commonly used native trees in traditional agroforestry applications in Haiti. The Agroforestry Outreach Project has recognized its potential contribution to agroforestry practices in recent years. Most trees found in the countryside are, therefore, planted or retained after regenerating naturally, by the peasants themselves.

Catalpa longissima is planted on moist terrain that is low to medium in altitude and not too steep. It withstands seasonal flooding, grows well on flood plains and rice fields, and is tolerant of pruning. Trees can grow to heights of 20 to 30m and still not shade the crops below them, if properly pruned. Traditionally, however, the *chêne* is pruned excessively and its growth stunted by poor crown to height ratio.

The quality of the wood is generally excellent for lumber and furniture manufacturing and is well regarded by peasants and local craftsmen alike. It is a medium density hardwood that seasons slowly and is sensitive to insect damage. The color of the heartwood is dark brown and the wood grain appealing. This species has not been studied for its technical or silvicultural characteristics.

Casuarina equisetifolia has been extensively distributed to peasants participating in the Agroforestry Outreach Project. Due to lower than expected survival rates in those initial plantings, this species is presently planted with greater care to site and climatic considerations. The Ministry of Agriculture, through its Soil Conservation Division, uses this tree species in the establishment of community woodlots, in windbreaks, and along contour ditches and dry walls. Home owners in urban areas as well as peasants in the countryside favor casuarina trees as a garden tree, near their home or in nearby land. An FAO project at Limbé is experimenting with the use of casuarina in contour hedgerows as animal forage. Preliminary forage quality results from samples of casuarina foliage are presented in this report as well.

Casuarina holds great promise as an agroforestry tree in Haiti as it is appreciated for its fuelwood and polewood quality. Tolerant of dry as well as saline conditions, resistant to wind and adaptable to poor soils, casuarina could certainly find its niche on the Haitian countryside as a producer of fuelwood as well as polewood. It must be noted however, that in extreme climatic and edaphic conditions its growth is far less spectacular than on ideal soils with adequate rainfall. It is this factor that prevents this species from being more widely used and accepted.

The tree species were studied on sites that reflect the environmental conditions within which these species are commonly planted in Haiti. The study of the tree species involved the cutting of a sample of trees of varying diameter classes, the weighing of the entire tree by sections, the sampling of tree portions for laboratory analysis and the determination of moisture content and specific gravity.

This report presents the results of the analysis of the fuelwood, polewood, and biomass production potential of the above mentioned tree species. Each chapter will contain a descriptive section detailing the major findings, a description of the research site, and the methodology of the experiment. The findings on fuelwood, biomass, and polewood production are presented in the form of yield tables as well as in graphic form. Each yield table is designed to allow the estimation of yields as a function of either dbh (tree diameter at 1.3m) or stump diameter (at 10cm). The tables enable the estimation of the production potential of any stand of trees of the indicated species by simply counting the trees of each diameter class. One simple field measure, even if approximate, could provide a reliable estimate of a stand's production potential in terms of fuelwood (kg dry weight), total biomass (kg dry weight), and polewood ($m^3/1000$).

All the tables were produced using regression models that maximized the determination coefficient (r^2). Biomass yield and pole volume tables used similar regression equations in both species studied. Fuelwood tables were calculated using two different parameters: dbh and stump diameter. This enables the estimation of yield potential even when the tree is already cut.

One section of this report is dedicated to the discussion of the productive potential of each species studied and to their significance for agroforestry applications in Haiti. These results are presented in graphic form to enable a simple and clear interpretation of research findings.

Finally, the recommendations section of this report includes a number of suggestions which are made relative to the research methodology, future research objectives and the implications of the results of this study on agroforestry activities in Haiti.

CHAPTER 2

METHODS AND MATERIALS

Limbé - *Catalpa longissima*

Site Description

This chapter analyzes the fuelwood production potential of *Catalpa longissima* on a terraced hillside, just west of the town of Limbé, near Cap-Haïtien, in the northern coastal region of Haiti. The slope had been terraced under the auspices of an FAO soil conservation project and planted with grasses and scattered trees, most commonly *chêne* and mango. Since completion of the project in 1984, the land has been cultivated by individual farmers who presently plant manioc and sweet potato but do not maintain the terraces. As a result, the slope is eroding and gradually recovering its natural profile.

The soils are deep and terra-cotta to light brown, of basaltic origin and clayish structure with little gravel or pebbles in the top horizon. The pH was measured at six. The site is situated at an elevation of less than 100m; it receives an average annual rainfall of approximately 2000mm and falls within the humid/very humid sub-tropical forest (Holdridge, 1963) and Buffum/Campbell Zone 35 (Buffum, 1984).

Experimental Method

A sample of trees from this hillside was cut at ten centimeters from the ground, then measured and weighed, in order to determine the fuelwood and biomass production potential of *Catalpa longissima*. The data collection and sampling techniques followed the methodology developed for the Fuelwood Project in Central America (CATIE, 1984). Three trees in each two centimeter diameter class were cut, measured, and weighed in sections. A total of 17 trees were sampled using this method. Ground diameter, stump diameter (at ten cm), dbh (at 1.3m) and total height were measured for each tree in the sample. When poles were cut from the tree stem, their length and diameter were also measured. In addition, poles, branches of more than one centimeter in diameter (fuelwood), and leaves and twigs were weighed separately on a 40 kg and 10 kg scale. Samples from each section of tree were collected as soon as the tree was felled and stored in airtight bags for laboratory analysis to determine moisture content and specific gravity.

Terre Rouge - *Casuarina equisetifolia*

Site Description

This section of the report analyzes the fuel and polewood production potential of *Casuarina equisetifolia* on the basis of a sample of trees from two nearby sites at Terre Rouge, a ridge-top community on the Chêne de Matheux along the road between Port-au-Prince and Mirebalais. The sites are located at an altitude ranging between 600 and 700m above sea level with an average rainfall varying between 1400 and 1800mm a year. Soils are shallow on limestone parent material. The pH varied between 6.8 and 7.4, texture was lime/clayey with abundant rock outcroppings and loose stones in the top horizons. The sites are found within the Humid Subtropical Forest Zone of the Holdridge (OAS, 1963) classification and Zone 51 of the Buffum/Campbell classification (Buffum, 1984).

The trees sampled were made available for research by the Soil Conservation Division of the Ministry of Agriculture. They were planted on a steep slope in 1982 at a spacing of approximately 2.5 meters. The sample of trees from the larger diameter classes was found on a nearby site which was planted in 1979 by a private landowner.

Experimental Method

A random sample of 17 trees was selected from different diameter classes, cut, measured, and weighed according to the methodology developed for the Fuelwood Project in Central America (CATIE, 1984). Samples from different sections of the trees were collected for moisture content and specific gravity determination. Each tree was measured for total height, dbh (at 1.3m), ground and stump diameter (at 10cm), and weighed in sections. The entire tree biomass was weighed (except for a 10cm stump and the root system) with a 10kg and 40kg scale.

Poles were separated from the fuelwood and from the foliage. They were measured for length as well as top, middle, and bottom diameters. The standards for cutting the poles and separating the fuelwood from the leaves and twigs were those of the peasant hired locally for this purpose. It appeared that, given the quality of the wood cut and the short distance from a major road into Port-au-Prince, the minimum diameter and length of the poles cut might have been less than those usually seen on local markets.

CHAPTER 3

RESULTS AND DISCUSSION

Catalpa longissima

General Results

Laboratory analysis of the tree sampl revealed a moisture content for the merchantable sections o the tree (poles and fuelwood) of 50.5% of green weight and a specific gravity of .549 g/cm³. The remaining biomass, mainly small branches, twigs and leaves contained greater amounts of water, specifically, 62.5g of water for every 100g of green biomass.

Statistical analysis of the data collected in the field shows that dbh and stump diameter correlated significantly ($p < .001$) with the tree's fuelwood and biomass yields, thus providing an excellent indicator of fuelwood and biomass production. Dbh also provides an acceptable indication of polewood yields.

In other species studied such as leucaena, cassia, and prosopis, tree height could not be used as a reliable indicator of biomass productivity. Due to the regular form of the stem of *Catalpa longissima*, total tree height correlates significantly with biomass and fuelwood production and could thus be used as a reliable though not practical, indicator of biomass productivity. Most interestingly, tree height is also significantly correlated with polewood volume.

It must be noted that this tree is particularly valued as a source of polewood and lumber for local consumption. Even when the tree is not pruned, its crown remains small and the stem straight. In the sample studied, every tree with a dbh greater than 3.7cm produced at least a short pole. Trees with a dbh of 10.8cm or more, produced two poles. In terms of dry weight, polewood represented between 50 and 70% of all the biomass produced by the tree, proving the value of this tree as producer of poles and construction timber.

Fuelwood Production

In the yield table for total fuelwood production it is assumed that the entire tree is used for fuelwood. Estimates of fuelwood production for *Catalpa longissima* are presented in Table 1. Yields are expressed in kilograms of dry weight in order to make them comparable with those on other sites and those collected during other times of the year. Fuelwood production can be estimated using the equation:

$$\text{Fuelwood (kg)} = 0.228 * \text{Bas.Area (cm}^2) - 0.83 :$$

with a determination coefficient of 96 percent. Basal Area is a direct function of dbh ($dbh^2 * 3.14/4$). A fuelwood yield curve is presented in Figure 1.

Table 2 shows total biomass production as a function of dbh expressed in kilograms of dry weight for trees having a dbh ranging from 2 to 20 centimeters. Total biomass can be estimated with the equation:

$$\text{Biomass (kg)} = 0.308 * \text{Bas.Area (cm}^2) - 0.54 :$$

with a determination coefficient of 95 percent. Figure 2 presents a comparison of the actual field measurements for total biomass production and those generated using the regression equation.

Table 3 presents fuelwood production yields of *chêne* trees as a function of stump diameter (at ten centimeters from the ground). This table enables the estimation of total fuelwood production even when the tree has already been removed from the land and only the diameter of the stump can be measured. The equation:

$$\text{Fuelwood (kg)} = (\text{Stump Diam.})^2 (\text{cm}^2) * 0.12 - 2.3 :$$

enables estimation of fuelwood productivity as a function of stump diameter with a determination coefficient of 93 percent.

<u>Polewood Production</u>

In the sample studied, the average pole had a diameter (at midpoint) of almost six centimeters and was 3.6m long. The poles were cut according to standards acceptable on the local market and varied greatly. The quality of the wood and the form of the stem appear to outweigh limitations in size. Polewood production can be estimated using the equation:

$$\text{Pole Volume (m}^3/1000) = 352.4 * \text{Bas.Area (cm}^2) - 2030.5 :$$

with a determination coefficient of 95 percent. The polewood production function for *Catalpa longissima* is presented graphically in Figure 3 and a volume table for poles appears in Table 4.

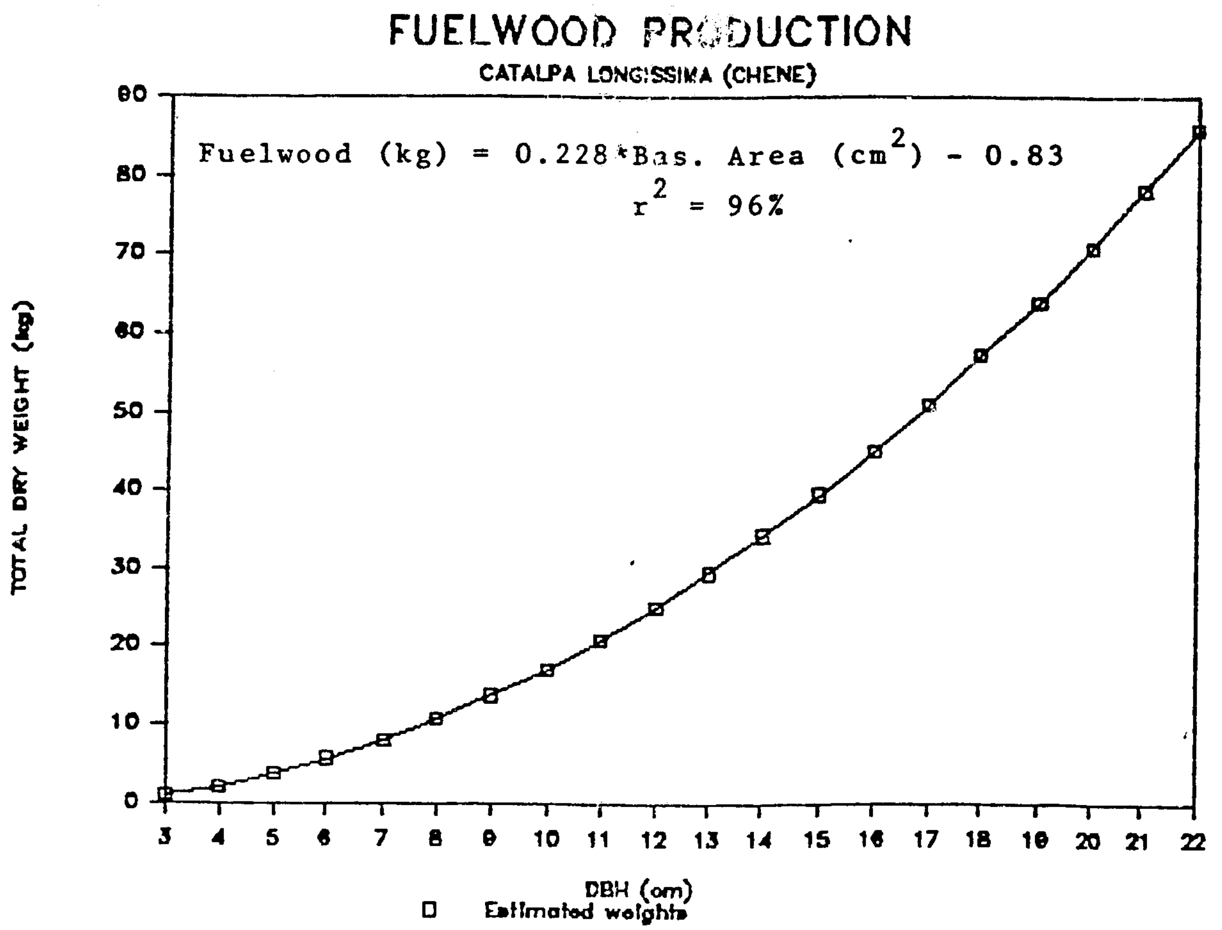

FIGURE 1. Fuelwood production of *Catalpa longissima* in Haiti as a function of dbh.

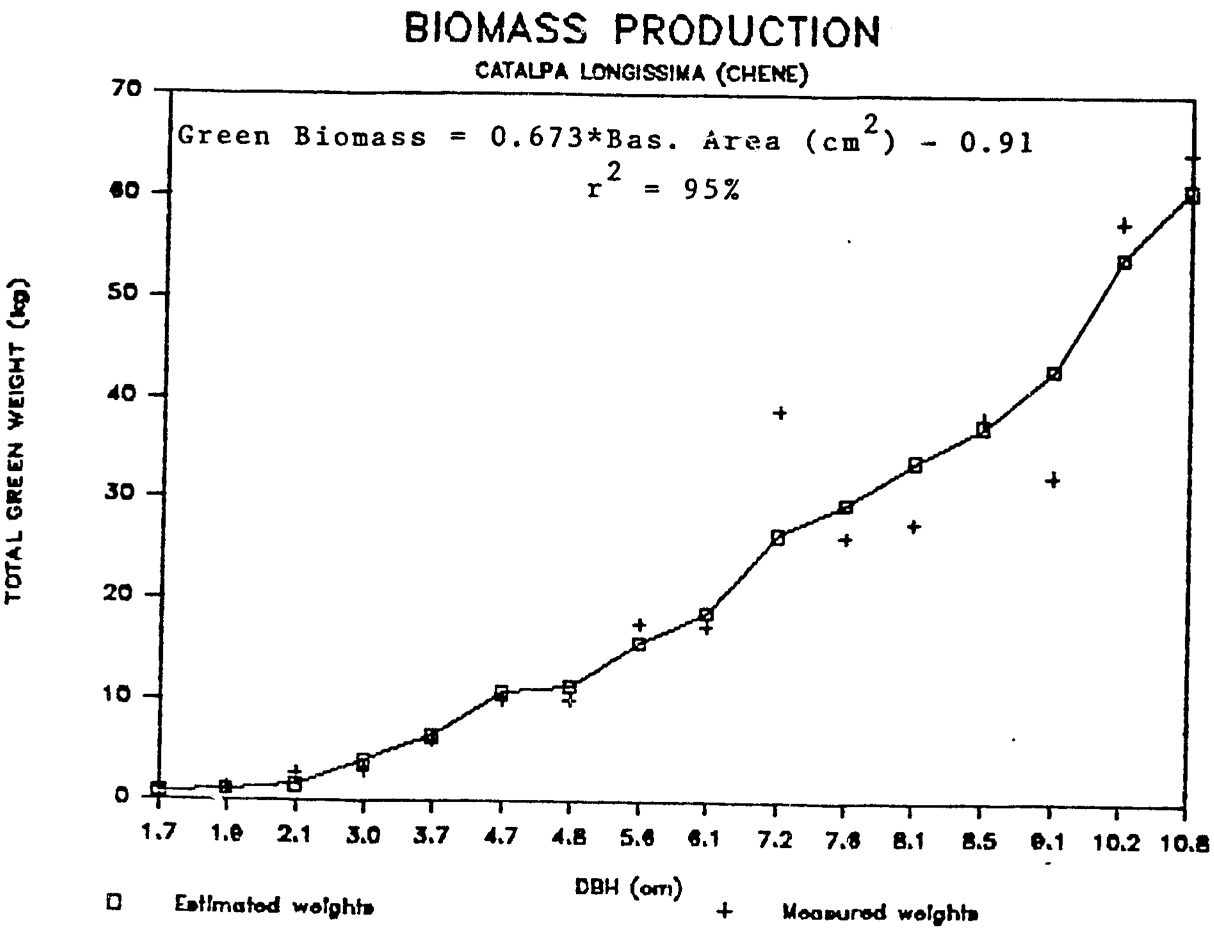

FIGURE 2. A comparison of actual field measurements and values generated using the regression equation for biomass production of *Catalpa longissima* in Haiti as a function of dbh.

Table 1. Production of fuelwood (dry weight in kg.) as a function of dbh (cm) for Catalpa longissima.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Catalpa longissima - Oct. 1986
Dry Fuelwood (kg) = 0.228 * Bas.Area(cm2) - 0.83; r2 = 95.6%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.1	0.79	1.6	2.4	3.1	3.9	4.7	5.5	6.3	7.1	7.9
4	12.6	2.04	4.1	6.1	8.2	10.2	12.2	14.3	16.3	18.4	20.4
5	19.6	3.66	7.3	11.0	14.6	18.3	21.9	25.6	29.2	32.9	36.6
6	28.3	5.63	11.3	16.9	22.5	28.1	33.8	39.4	45.0	50.7	56.3
7	38.5	7.96	15.9	23.9	31.8	39.8	47.8	55.7	63.7	71.7	79.6
8	50.2	10.65	21.3	32.0	42.6	53.3	63.9	74.6	85.2	95.9	106.5
9	63.6	13.70	27.4	41.1	54.8	68.5	82.2	95.9	109.6	123.3	137.0
10	78.5	17.11	34.2	51.3	68.5	85.6	102.7	119.8	136.9	154.0	171.1
11	95.0	20.88	41.8	62.6	83.5	104.4	125.3	146.2	167.0	187.9	208.8
12	113.0	25.01	50.0	75.0	100.0	125.0	150.0	175.1	200.1	225.1	250.1
13	132.7	29.49	59.0	88.5	118.0	147.5	177.0	206.4	235.9	265.4	294.9
14	153.9	34.34	68.7	103.0	137.3	171.7	206.0	240.4	274.7	309.0	343.4
15	176.6	39.54	79.1	118.6	158.2	197.7	237.2	276.8	316.3	355.9	395.4
16	201.0	45.10	90.2	135.3	180.4	225.5	270.6	315.7	360.8	405.9	451.0
17	226.9	51.02	102.0	153.1	204.1	255.1	306.1	357.2	408.2	459.2	510.2
18	254.3	57.30	114.6	171.9	229.2	286.5	343.8	401.1	458.4	515.7	573.0
19	283.4	63.94	127.9	191.8	255.8	319.7	383.7	447.6	511.5	575.5	639.4
20	314.0	70.94	141.9	212.8	283.8	354.7	425.6	496.6	567.5	638.5	709.4

USAID/AFORP/UMO/Ehrlich (1986)

TABLE 2. Production of total biomass (dry weight in kg.) as a function of dbh (cm) for *Catalpa longissima*.

YIELD TABLE
Production of total biomass (dry weight in kg)
as a function of DBH (cm).
Catalpa longissima - Oct. 1986
Dry Biomass (kg) = 0.308 * Bas.Area(cm2) - 0.542; r2 = 95.1%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	0.42	0.8	1.3	1.7	2.1	2.5	3.0	3.4	3.8	4.2
3	7.07	1.63	3.3	4.9	6.5	8.2	9.8	11.4	13.1	14.7	16.3
4	12.57	3.32	6.6	10.0	13.3	16.6	19.9	23.3	26.6	29.9	33.2
5	19.64	5.50	11.0	16.5	22.0	27.5	33.0	38.5	44.0	49.5	55.0
6	28.27	8.16	16.3	24.5	32.6	40.8	48.9	57.1	65.2	73.4	81.6
7	38.48	11.30	22.6	33.9	45.2	56.5	67.8	79.1	90.4	101.7	113.0
8	50.27	14.92	29.8	44.8	59.7	74.6	89.5	104.4	119.4	134.3	149.2
9	63.62	19.03	38.1	57.1	76.1	95.1	114.2	133.2	152.2	171.2	190.3
10	78.54	23.62	47.2	70.8	94.5	118.1	141.7	165.3	188.9	212.5	236.2
11	95.03	28.69	57.4	86.1	114.8	143.4	172.1	200.8	229.5	258.2	286.9
12	113.10	34.25	68.5	102.7	137.0	171.2	205.5	239.7	274.0	308.2	342.5
13	132.73	40.29	80.6	120.9	161.1	201.4	241.7	282.0	322.3	362.6	402.9
14	153.94	46.81	93.6	140.4	187.2	234.0	280.9	327.7	374.5	421.3	468.1
15	176.72	53.81	107.6	161.4	215.3	269.1	322.9	376.7	430.5	484.3	538.1
16	201.06	61.30	122.6	183.9	245.2	306.5	367.8	429.1	490.4	551.7	613.0
17	226.98	69.28	138.6	207.8	277.1	346.4	415.7	484.9	554.2	623.5	692.8
18	254.47	77.73	155.5	233.2	310.9	388.7	466.4	544.1	621.8	699.6	777.3
19	283.53	86.67	173.3	260.0	346.7	433.3	520.0	606.7	693.4	780.0	866.7
20	314.16	96.09	192.2	288.3	384.4	480.5	576.5	672.6	768.7	864.8	960.9

USAID/AFORP/UMO/Ehrlich (1986)

Table 3. Production of fuelwood (dry weight in kg.) as a function of stump diameter (cm) for <u>Catalpa longissima</u>.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of STUMP DIAMETER (cm).
Catalpa longissima - Oct. 1986
Dry Fuelwood (kg) = 0.12 * (Stump Diam.)^2(cm2) - 2.28; r2 = 92.8%

STUMP (cm)	Stump^2 (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
5	25.0	0.73	1.5	2.2	2.9	3.6	4.4	5.1	5.8	6.5	7.3
6	36.0	2.05	4.1	6.2	8.2	10.3	12.3	14.4	16.4	18.5	20.5
7	49.0	3.62	7.2	10.8	14.5	18.1	21.7	25.3	28.9	32.5	36.2
8	64.0	5.42	10.8	16.3	21.7	27.1	32.5	38.0	43.4	48.8	54.2
9	81.0	7.47	14.9	22.4	29.9	37.3	44.8	52.3	59.7	67.2	74.7
10	100.0	9.76	19.5	29.3	39.0	48.8	58.5	68.3	78.1	87.8	97.6
11	121.0	12.29	24.6	36.9	49.1	61.4	73.7	86.0	98.3	110.6	122.9
12	144.0	15.05	30.1	45.2	60.2	75.3	90.3	105.4	120.4	135.5	150.5
13	169.0	18.07	36.1	54.2	72.3	90.3	108.4	126.5	144.5	162.6	180.7
14	196.0	21.32	42.6	63.9	85.3	106.6	127.9	149.2	170.5	191.8	213.2
15	225.0	24.81	49.6	74.4	99.2	124.0	148.8	173.7	198.5	223.3	248.1
16	256.0	28.54	57.1	85.6	114.2	142.7	171.2	199.8	228.3	256.9	285.4
17	289.0	32.51	65.0	97.5	130.1	162.6	195.1	227.6	260.1	292.6	325.1
18	324.0	36.73	73.5	110.2	146.9	183.6	220.4	257.1	293.8	330.6	367.3
19	361.0	41.18	82.4	123.6	164.7	205.9	247.1	288.3	329.5	370.7	411.8
20	400.0	45.88	91.8	137.6	183.5	229.4	275.3	321.2	367.0	412.9	458.8
21	441.0	50.82	101.6	152.5	203.3	254.1	304.9	355.7	406.5	457.4	508.2
22	484.0	56.00	112.0	168.0	224.0	280.0	336.0	392.0	448.0	504.0	560.0

USAID/AFORP/UMO/Ehrlich (1986)

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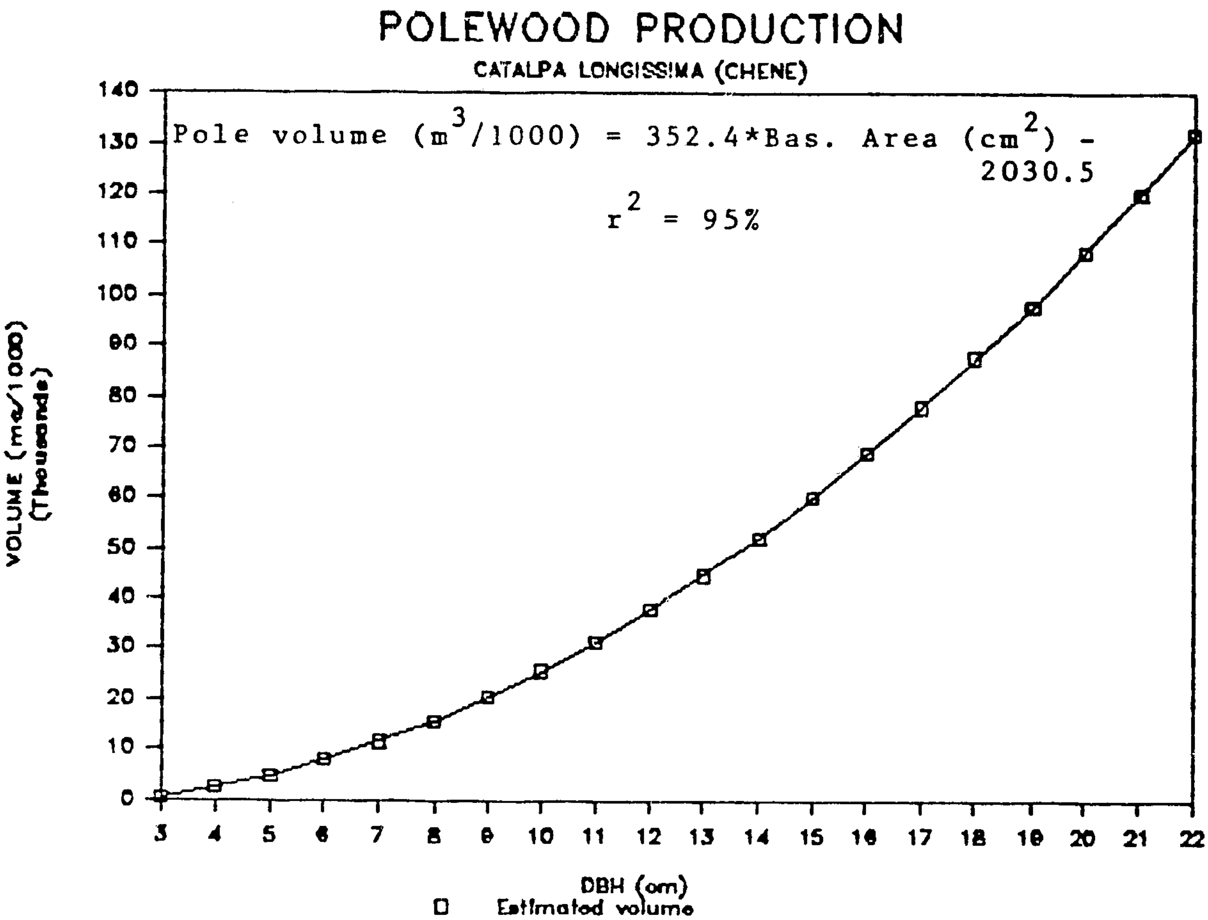

FIGURE 3. Polewood production of <u>Catalpa longissima</u> in Haiti as a function of dbh.

Table 4. Production of polewood (mc/1000) as a function of dbh (cm) for Catalpa longissima.

YIELD TABLE
Production of polewood (mc/1000)
as a function of DBH (cm).
Catalpa longissima - Oct. 1986
Polewood volume (mc/1000) = 352.4 * Bas.Area(cm2) - 2030.5; r2 = 94.9%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	0.46	0.9	1.4	1.8	2.3	2.8	3.2	3.7	4.1	4.6
4	12.57	2.40	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0
5	19.64	4.89	9.8	14.7	19.5	24.4	29.3	34.2	39.1	44.0	48.9
6	28.27	7.93	15.9	23.8	31.7	39.6	47.6	55.5	63.4	71.4	79.3
7	38.48	11.52	23.0	34.6	46.1	57.6	69.1	80.7	92.2	103.7	115.2
8	50.27	15.67	31.3	47.0	62.7	78.4	94.0	109.7	125.4	141.1	156.7
9	63.62	20.38	40.8	61.1	81.5	101.9	122.3	142.6	163.0	183.4	203.8
10	78.54	25.63	51.3	76.9	102.5	128.2	153.8	179.4	205.1	230.7	256.3
11	95.03	31.44	62.9	94.3	125.8	157.2	188.7	220.1	251.5	283.0	314.4
12	113.10	37.81	75.6	113.4	151.2	189.0	226.8	264.6	302.4	340.2	378.1
13	132.73	44.72	89.4	134.2	178.9	223.6	268.3	313.0	357.8	402.5	447.2
14	153.94	52.19	104.4	156.6	208.8	261.0	313.1	365.3	417.5	469.7	521.9
15	176.72	60.21	120.4	180.6	240.9	301.1	361.3	421.5	481.7	541.9	602.1
16	201.06	68.79	137.6	206.4	275.2	343.9	412.7	481.5	550.3	619.1	687.9
17	226.98	77.92	155.8	233.8	311.7	389.6	467.5	545.4	623.3	701.3	779.2
18	254.47	87.60	175.2	262.8	350.4	438.0	525.6	613.2	700.8	788.4	876.0
19	283.53	97.84	195.7	293.5	391.3	489.2	587.0	684.8	782.7	880.5	978.4
20	314.16	108.62	217.2	325.9	434.5	543.1	651.7	760.4	869.0	977.6	1086.2

USAID/AFORP/UMO/Ehrlich (1986)

Casuarina equisetifolia

General Results

Statistical analysis of the data collected in the field revealed that dry fuelwood weight, dry biomass weight and pole volume correlated significantly ($p < .001$) with dbh, stump diameter, and total tree height. The significant correlation of tree height with biomass and polewood productivity is due, as in the case of *Catalpa longissima*, to the form of the tree, especially its straight stem. This same reason explains the fact that 48% of the total biomass (in kilograms dry weight) is accounted for by polewood and only 14% by fuelwood. Still, dbh, and especially its squared function, basal area, have turned out to be the best indicators of the tree's productivity at any given time.

For the sample of trees studied, 38% of total biomass was discarded as foliage. The potential use of the latter as forage has still to be recognized among local peasants. If such potential were to be exploited, practically the entire tree's biomass would be usable and merchantable, especially where extraction and transportation costs could be kept to a minimum.

In the sample of casuarina trees studied, all trees with a dbh of 5cm or higher produced a pole, while trees with a dbh of at least 8.6cm produced two poles. The length of the average pole was 3.9m with a middle diameter averaging almost six centimeters.

The specific gravity of *Casuarina equisetifolia* was calculated at 0.745 g/cm^3 for polewood and at 0.673 gr/cm^3 for fuelwood while the moisture content averaged 35.9% and 41.8% of green weight, respectively. The moisture content of the foliage was found to be 54.3% of green weight, measured after drying the samples for 30 hours at 80°C.

Fuelwood production

The merchantable portion of *Casuarina equisetifolia* trees (poles and fuelwood) can be estimated on the basis of just one simple field measurement, dbh, and by applying the equation:

$$\text{Merchantable wood (kg)} = 0.43 \text{ Bas.Area } (cm^2) - 2.14 :$$

with a determination coefficient of 95 percent. Basal area represents the squared function of dbh: $(dbh)^2 * 3.14/ 4$.

Merchantable wood weight can also be estimated when the tree has been harvested already and only the stump remains. The equation:

$$\text{Merchantable wood (kg)} = (\text{Stump})^2 * 0.2 - 3.7 :$$

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enables the estimation of merchantable wood on the basis of stump diameter (at 10cm) with a determination coefficient of 88 percent.

The total biomass production expressed in kilograms dry weight can be estimated on the basis of dbh by applying the equation:

$$\text{Biomass (kg)} = 0.63 * \text{Bas.Area (cm}^2) \quad 1.44 \;:$$

with a determination coefficient of 98.7%. Dbh clearly proves to be a reliable and practical indicator of the tree's productivity.

Figure 4 displays graphically the production function for merchantable wood on the basis of dbh. Figure 5 shows the relationship between actual merchantable weight measurements in the field and those estimated using the regression equation. Table 5 and 6 present yield tables for *Casuarina eqvisetifolia* as a function of dbh and stump diameter, respectively. Table 7 presents a dry biomass production table as a function of dbh.

<u>Polewood Production</u>

The production of polewood for *Casuarina equisetifolia* is presented in Table 8. This table enables the estimation of pole volume (expressed in $m^3/1000$) as a function of dbh with a determination coefficient of 94 percent. The equation:

$$\text{Pole volume } (m^3/1000) = 482.2 * \text{Bas.Area (cm}^2) - 3078.4 \;;$$

was used in the preparation of the volume table. Figure 6 presents the polewood yield curve as a function of dbh.

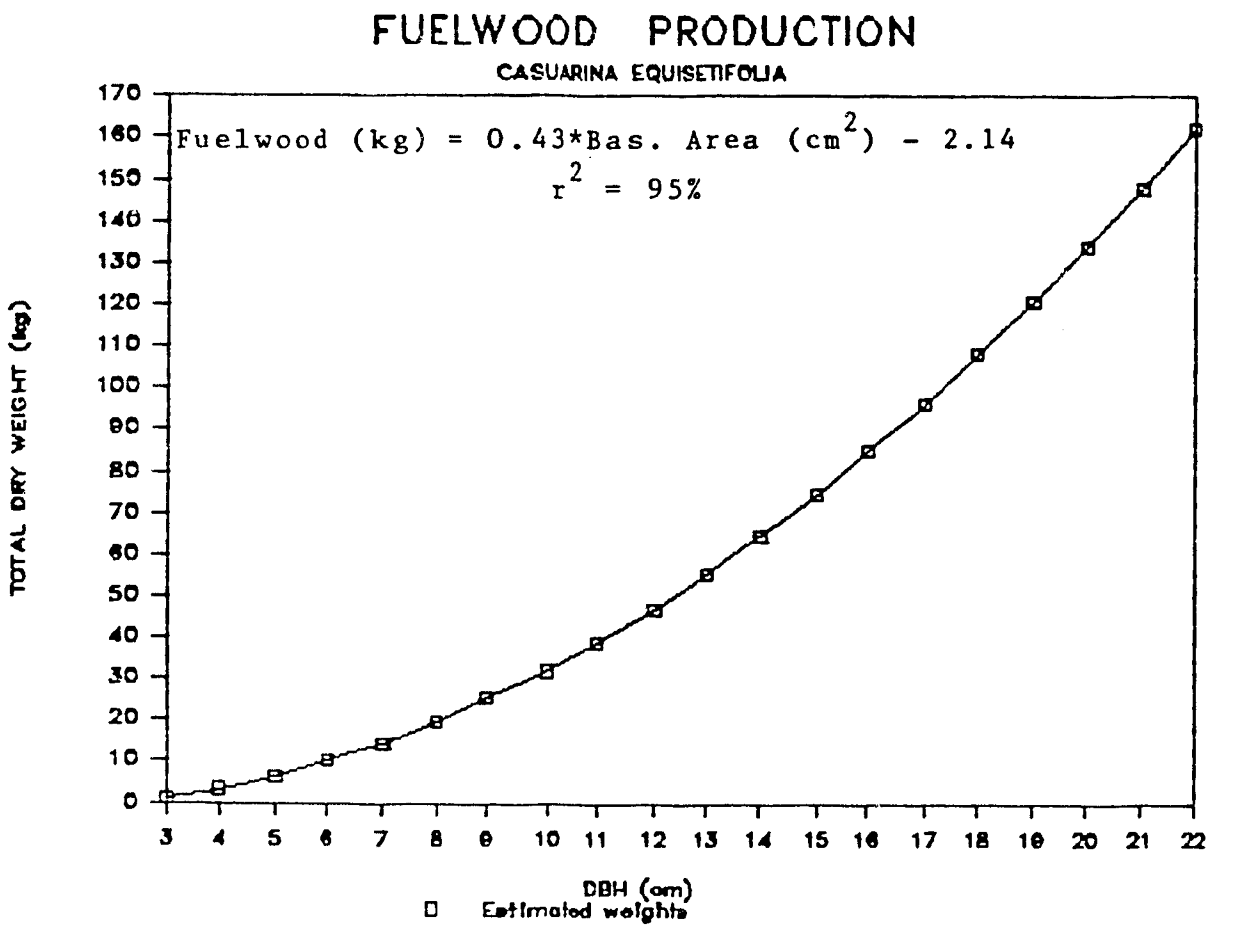

FIGURE 4. Fuelwood production of _Casuarina equisetifolia_ in Haiti as a function of dbh.

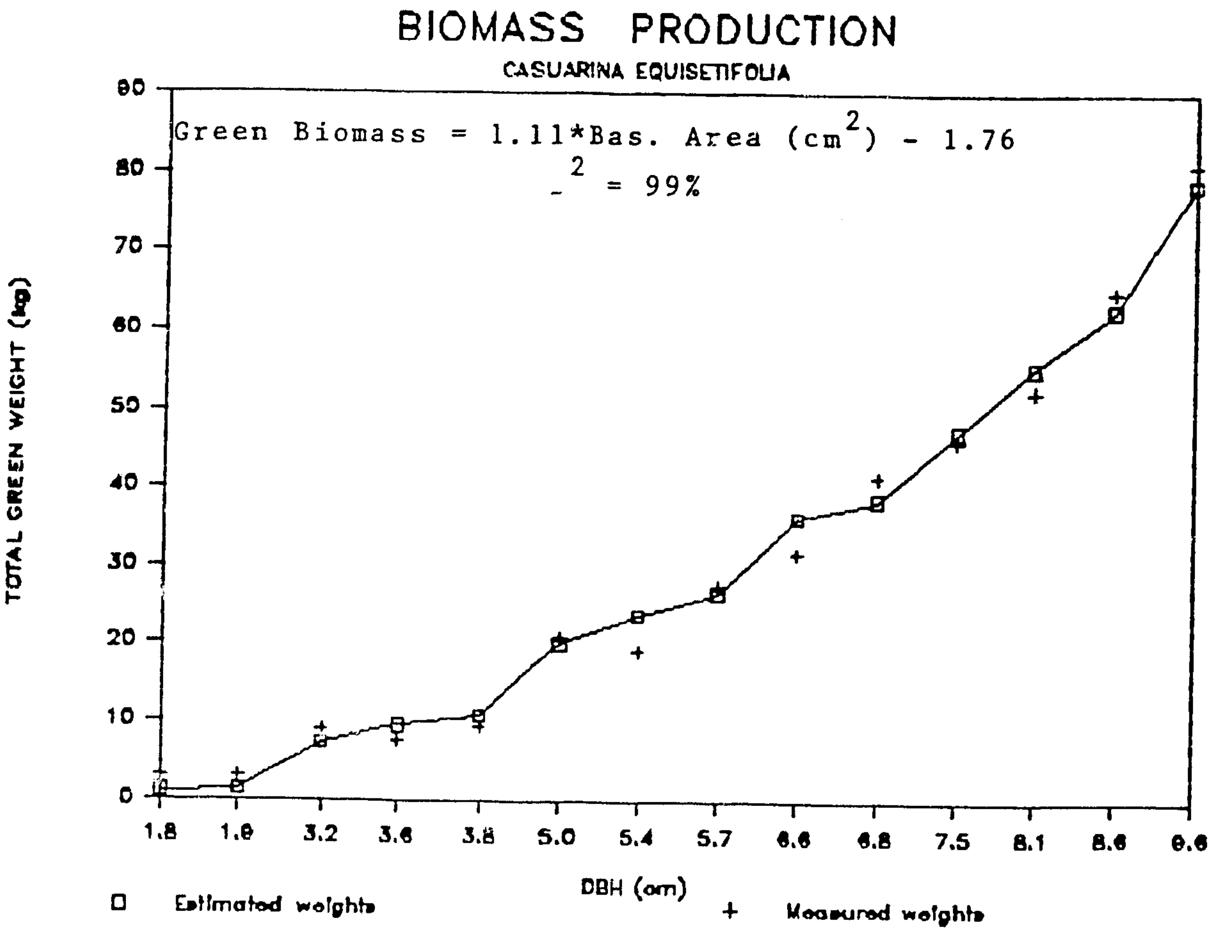

FIGURE 5. A comparison of actual field measurements and values generated using the regression equation for biomass production of <u>Casuarina equisetifolia</u> in Haiti as a function of <u>dbh</u>.

Table 5. Production of fuelwood (dry weight in kg.) as a function of dbh (cm) for Casuarina equisetifolia.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of DBH (cm).
Casuarina equisetifolia - Oct. 1986
Dry Fuelwood (kg) = 0.433 * Bas.Area(cm2) - 2.14; r2 = 95.2%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	0.92	1.8	2.8	3.7	4.6	5.5	6.5	7.4	8.3	9.2
4	12.57	3.30	6.6	9.9	13.2	16.5	19.8	23.1	26.4	29.7	33.0
5	19.64	6.36	12.7	19.1	25.4	31.8	38.2	44.5	50.9	57.3	63.6
6	28.27	10.10	20.2	30.3	40.4	50.5	60.6	70.7	80.8	90.9	101.0
7	38.48	14.52	29.0	43.6	58.1	72.6	87.1	101.7	116.2	130.7	145.2
8	50.27	19.62	39.2	58.9	78.5	98.1	117.7	137.4	157.0	176.6	196.2
9	63.62	25.40	50.8	76.2	101.6	127.0	152.4	177.8	203.2	228.6	254.0
10	78.54	31.86	63.7	95.6	127.4	159.3	191.2	223.0	254.9	286.8	318.6
11	95.03	39.00	78.0	117.0	156.0	195.0	234.0	273.0	312.0	351.0	390.0
12	113.10	46.82	93.6	140.5	187.3	234.1	280.9	327.7	374.6	421.4	468.2
13	132.73	55.32	110.6	166.0	221.3	276.6	331.9	387.2	442.6	497.9	553.2
14	153.94	64.50	129.0	193.5	258.0	322.5	387.0	451.5	516.0	580.5	645.0
15	176.72	74.36	148.7	223.1	297.4	371.8	446.2	520.5	594.9	669.2	743.6
16	201.06	84.90	169.8	254.7	339.6	424.5	509.4	594.3	679.2	764.1	849.0
17	226.98	96.12	192.2	288.4	384.5	480.6	576.7	672.8	769.0	865.1	961.2
18	254.47	108.02	216.0	324.1	432.1	540.1	648.1	756.1	864.1	972.2	1080.2
19	283.53	120.60	241.2	361.8	482.4	603.0	723.6	844.2	964.8	1085.4	1206.0
20	314.16	133.86	267.7	401.6	535.4	669.3	803.1	937.0	1070.9	1204.7	1338.6

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Table 6. Production of fuelwood (dry weight in kg.) as a function of stump diameter (cm) for <u>Casuarina</u> <u>equisetifolia</u>.

YIELD TABLE
Production of fuelwood (dry weight in kg)
as a function of STUMP DIAMETER (cm).
Casuarina equisetifolia - Oct. 1986
Dry Fuelwood (kg) = 0.203 * (Stump Diam.)^2(cm2) - 3.69; r2 = 88.2%

STUMP (cm)	Stump^2 (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	4.0	7.84	15.7	23.5	31.4	39.2	47.0	54.9	62.7	70.6	78.4
3	9.0	22.25	44.5	66.8	89.0	111.3	133.5	155.8	178.0	200.3	222.5
4	16.0	42.43	84.9	127.3	169.7	212.2	254.6	297.0	339.5	381.9	424.3
5	25.0	68.37	136.7	205.1	273.5	341.9	410.2	478.6	547.0	615.4	683.7
6	36.0	100.08	200.2	300.2	400.3	500.4	600.5	700.6	800.7	900.7	1000.8
7	49.0	137.56	275.1	412.7	550.2	687.8	825.3	962.9	1100.5	1238.0	1375.6
8	64.0	180.80	361.6	542.4	723.2	904.0	1084.8	1265.6	1446.4	1627.2	1808.0
9	81.0	229.80	459.6	689.4	919.2	1149.0	1378.8	1608.6	1838.4	2068.2	2298.0
10	100.0	284.57	569.1	853.7	1138.3	1422.8	1707.4	1992.0	2276.5	2561.1	2845.7
11	121.0	345.10	690.2	1035.3	1380.4	1725.5	2070.6	2415.7	2760.8	3105.9	3451.0
12	144.0	411.40	822.8	1234.2	1645.6	2057.0	2468.4	2879.8	3291.2	3702.6	4114.0
13	169.0	483.46	966.9	1450.4	1933.9	2417.3	2900.8	3384.3	3867.7	4351.2	4834.6
14	196.0	561.29	1122.6	1683.9	2245.2	2806.5	3367.8	3929.1	4490.4	5051.6	5612.9
15	225.0	644.89	1289.8	1934.7	2579.6	3224.4	3869.3	4514.2	5159.1	5804.0	6448.9
16	256.0	734.25	1468.5	2202.7	2937.0	3671.2	4405.5	5139.7	5874.0	6608.2	7342.5
17	289.0	829.37	1658.7	2488.1	3317.5	4146.9	4976.2	5805.6	6635.0	7464.4	8293.7
18	324.0	930.26	1860.5	2790.8	3721.1	4651.3	5581.6	6511.8	7442.1	8372.4	9302.6
19	361.0	1036.92	2073.8	3110.8	4147.7	5184.6	6221.5	7258.4	8295.3	9332.3	10369.2
20	400.0	1149.34	2298.7	3448.0	4597.4	5746.7	6896.0	8045.4	9194.7	10344.0	11493.4

USAID/AFORP/UMO/Ehrlich (1986)

TABLE 7. Production of total biomass (dry weight in kg.) as a function of dbh (cm) for <u>Casuarina equisetifolia</u>.

YIELD TABLE

Production of total bioaass (dry weight in kg)
as a function of DBH (cm).
Casuarina equisetifolia - Oct. 1986
Dry Biomass (kg) = 0.63 * Bas.Area(cm2) - 1.44; r2 = 98.7%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
2	3.14	0.52	1.0	1.6	2.1	2.6	3.1	3.7	4.2	4.7	5.2
3	7.07	2.98	6.0	8.9	11.9	14.9	17.9	20.9	23.9	26.8	29.8
4	12.57	6.42	12.8	19.3	25.7	32.1	38.5	45.0	51.4	57.8	64.2
5	19.64	10.85	21.7	32.5	43.4	54.2	65.1	75.9	86.8	97.6	108.5
6	28.27	16.26	32.5	48.8	65.0	81.3	97.5	113.8	130.1	146.3	162.6
7	38.48	22.65	45.3	67.9	90.6	113.2	135.9	158.5	181.2	203.8	226.5
8	50.27	30.02	60.0	90.1	120.1	150.1	180.1	210.2	240.2	270.2	300.2
9	63.62	38.38	76.8	115.1	153.5	191.9	230.3	268.7	307.1	345.4	383.8
10	78.54	47.72	95.4	143.2	190.9	238.6	286.3	334.1	381.8	429.5	477.2
11	95.03	58.05	116.1	174.1	232.2	290.2	348.3	406.3	464.4	522.4	580.5
12	113.10	69.36	138.7	208.1	277.4	346.8	416.1	485.5	554.9	624.2	693.6
13	132.73	81.65	163.3	244.9	326.6	408.2	489.9	571.5	653.2	734.8	816.5
14	153.94	94.92	189.8	284.8	379.7	474.6	569.5	664.5	759.4	854.3	949.2
15	176.72	109.18	218.4	327.5	436.7	545.9	655.1	764.3	873.5	982.6	1091.8
16	201.06	124.42	248.8	373.3	497.7	622.1	746.5	871.0	995.4	1119.8	1244.2
17	226.98	140.65	281.3	421.9	562.6	703.2	843.9	984.5	1125.2	1265.8	1406.5
18	254.47	157.86	315.7	473.6	631.4	789.3	947.1	1105.0	1262.9	1420.7	1578.6
19	283.53	176.05	352.1	528.1	704.2	880.2	1056.3	1232.3	1408.4	1584.4	1760.5
20	314.16	195.22	390.4	585.7	780.9	976.1	1171.3	1366.6	1561.8	1757.0	1952.2

USAID/AFORP/UHO/Ehrlich (1986)

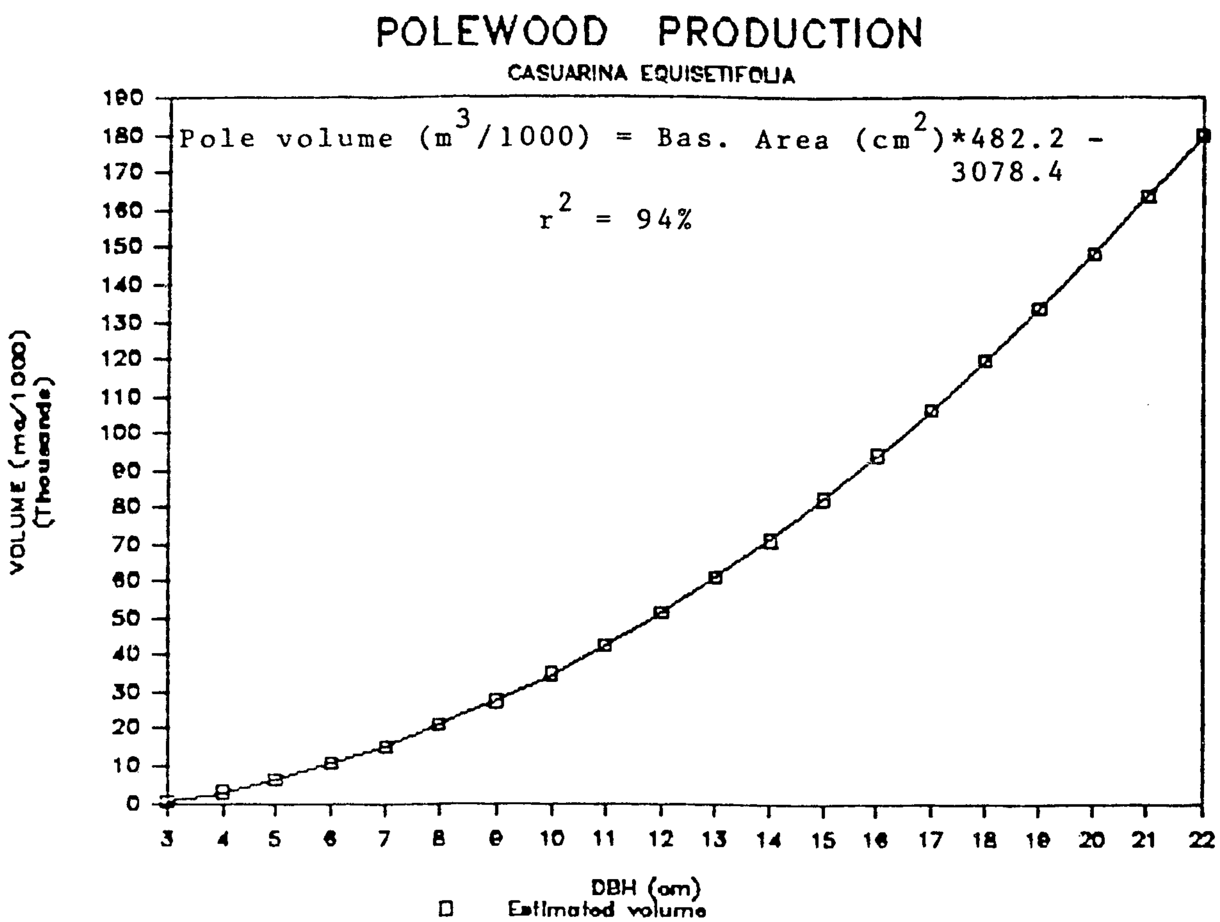

FIGURE 6. Polewood production of _Casuarina equisetifolia_ in Haiti as a function of dbh.

Table 8. Production of polewood (mc/1000) as a function of dbh (cm) for Casuarina equisetifolia.

YIELD TABLE
Production of polewood (mc/1000)
as a function of DBH (cm).
Casuarina equisetifolia - Oct. 1986
Polewood volume (mc/1000) = 482.2 * Bas.Area(cm2) - 3078.3; r2 = 93.5%

DBH (cm)	Bas.Area (cmq)	NUMBER OF TREES 1	2	3	4	5	6	7	8	9	10
3	7.07	0.33	0.7	1.0	1.3	1.6	2.0	2.3	2.6	3.0	3.3
4	12.57	2.98	6.0	8.9	11.9	14.9	17.9	20.8	23.8	26.8	29.8
5	19.64	6.39	12.8	19.2	25.5	31.9	38.3	44.7	51.1	57.5	63.9
6	28.27	10.55	21.1	31.6	42.2	52.7	63.3	73.8	84.4	94.9	105.5
7	38.48	15.47	30.9	46.4	61.9	77.4	92.8	108.3	123.8	139.2	154.7
8	50.27	21.15	42.3	63.4	84.6	105.7	126.9	148.0	169.2	190.3	211.5
9	63.62	27.58	55.2	82.8	110.3	137.9	165.5	193.1	220.7	248.3	275.8
10	78.54	34.78	69.6	104.3	139.1	173.9	208.7	243.4	278.2	313.0	347.8
11	95.03	42.73	85.5	128.2	170.9	213.6	256.4	299.1	341.8	384.5	427.3
12	113.10	51.43	102.9	154.3	205.7	257.2	308.6	360.0	411.5	462.9	514.3
13	132.73	60.89	121.8	182.7	243.6	304.5	365.4	426.3	487.2	548.1	608.9
14	153.94	71.12	142.2	213.3	284.5	355.6	426.7	497.8	568.9	640.0	711.2
15	176.72	82.09	164.2	246.3	328.4	410.5	492.6	574.7	656.7	738.8	820.9
16	201.06	93.83	187.7	281.5	375.3	469.1	563.0	656.8	750.6	844.5	938.3
17	226.98	106.32	212.6	319.0	425.3	531.6	637.9	744.2	850.6	956.9	1063.2
18	254.47	119.57	239.1	358.7	478.3	597.8	717.4	837.0	956.5	1076.1	1195.7
19	283.53	133.57	267.1	400.7	534.3	667.9	801.4	935.0	1068.6	1202.2	1335.7
20	314.16	148.34	296.7	445.0	593.4	741.7	890.0	1038.4	1186.7	1335.0	1483.4

USAID/AFORP/UMO/Ehrlich (1986)

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Catalpa longissima has a great potential for agroforestry applications in Haiti. Although quite demanding in terms of rainfall, it adapts well to poor and alkaline soils, even on steep slopes, and is tolerant of water logging. Its most appreciated features are the quality of the wood and the form of the stem. It is extensively used as construction timber and lumber for furniture. It is well known to the Haitian peasant who shows a definite preference for this species even when it grows slower than exotic trees.

Appreciated for its polewood production and for its adaptability to different edaphic and climatic conditions, *Casuarina equisetifolia* is undoubtedly adaptable to the diverse environments of Haiti. If its growth in less than ideal conditions could be improved through better seed selection and through improved seedling production techniques and outplanting practices, *Casuarina* trees will become strong competitors among tree species used in agroforestry applications in Haiti.

Future research efforts should focus on improving the growth performance of *Casuarina equisetifolia* on sites which are edaphically poor, climatically extreme, or both, by carefully selecting seed sources and improving nursery techniques and outplanting methods. The effect of nitrogen-fixing bacteria on tree survival and growth in the field should be given top research priority.

Research should also assess the potential of *Casuarina equisetifolia* in contour hedgerows for soil conservation and stabilization purposes and as a potential source of forage.

Better performance under difficult environmental conditions such as those that characterize the Haitian hillsides and a wider range of uses, would definitely increase the popularity of *Casuarina equisetifolia* all over the island and beyond.

Comparative analysis of the two tree species

The yield tables for *Casuarina equisetifolia* and *Catalpa longissima* (*chêne*) represent a significant first step in assessing the fuelwood and polewood production potential of these species. Their practical value in terms of predicting specific yields on similar site conditions, could prove extremely useful in the planning and design of agroforestry applications across the Haitian countryside and elsewhere. Site variation, however, can significantly affect the tree's actual production potential, thus application of these tables must be cautious. Figure 7 compares the fuelwood yield curves for the two tree species, while figure 8 compares polewood yields. These figures can only be used as an indication rather than proof of yield differences.

The yield tables for *Casuarina equisetifolia* add scientific insight for a tree species well known abroad, but never studied in Haiti. The production tables for *Catalpa longissima* contribute new knowledge about a tree species native to Haiti, and unknown abroad, yet potentially valuable for agroforestry applications in many semi-humid regions of the tropics.

In this regard it is recommended that similar research be conducted for other tree species with unquestionable agroforestry potential such as: *Simaruba glauca (frêne)*, *Swietenia mahoganii (acajou)*, *Swietenia macrophylla* and *Cedrela odorata (cédre)*.

Finally, the results of this research endeavour contribute significantly to the general body of knowledge about tree species used in agroforestry applications in the Caribbean and Central American regions. The Center for Research in Tropical Agriculture (CATIE) located in Costa Rica has expressed specific interest in both the exchange of scientific data as well as in the publication of research findings from the study reported here.

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PRELIMINARY SHOOT/ROOT RATIOS AND GROWTH CURVES FOR CONTAINERIZED SEEDLINGS OF

CASSIA SIAMEA

AZADIRACHTA INDICA

LEUCAENA LEUCOCEPHALA

By

David P. Fournier

The author is a student intern for the University of Maine Agroforestry Outreach Project. The work reported here was sponsored under USAID Project No. 521-0122.

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ACKNOWLEGEMENTS

This experiment was done with the help and cooperation of many people within AOP. CARE, PADF and ODH administrators were instrumental in setting up the experiment at the three forest nurseries. Special thanks to the nurserymen at the different sites who expedited the data collection process, as well as the setting up and growing of the tree seedlings.

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EXECUTIVE SUMMARY

This paper discusses the derivation of preliminary shoot/root ratios and growth curves for three species of containerized tree seedlings. Shoot/root ratios and growth curves can be used for monitoring the development of containerized seedlings. Height is the most practical measure for the statistical evaluation of seedling crop size. It can be measured easily with simple equipment and without damaging the seedlings.

The ability to predict seedling crop growth is essential for production planning, both in the nursery and in field planting. Standard growth curves can be prepared for different species and conditions. For example, graphs were drawn for height, and dry weight shoot/root ratios of *Cassia siamea*, *Azadirachta indica*, and *Leucaena leucocephala*. The seedlings in this study were still growing at the end of the data collection period with 2 to 8 weeks before the scheduled time for outplanting. Thus, the upper curve values should not be equated with those expected at the time of planting.

Graphical representation of dry weight ratio vs. time and height vs. time each show variation between nurseries even though each nursery has attained good seedling survival. An acceptable range of values rather than a standard value has been established which can be used to monitor seedling crops and is presented in figures 2, 4, 6, and 8 for each species.

Correlation between growth data and survival data is required in future research. This project was done to provide preliminary estimates of the growth and ratios expected from successful nurseries. To validate this, seedlings of known ratios need to be outplanted, their survival followed and subsequently correlated with the known ratios at some point in time, such as at the nursery's scheduled time of outplanting.

CHAPTER 1

INTRODUCTION

This paper sets forth a procedure for developing shoot/root ratios and growth curves. It illustrates introductory ratios and curves for three tree species of containerized seedlings commonly used in the Agroforestry Outreach Project (AOP). AOP is constantly attempting to improve seedling quality at outplanting. One method which may help involves the use of growth standards such as optimum shoot height, which may influence seedling survival after outplanting. Once such standards are determined, a practical guide for nurserymen can be devised.

Historically, failure to meet specifications generally means that the grower is faced with the dilemma of what to do with a substandard seedling crop. An undersized crop may either be held for a second growing season or planted. It has been observed that attempting to grow large seedlings in small containers will result in quality reduction and possibly unfavorable shoot/root ratios at time of planting (Hallett 1982). Hallett recommended that for temperate softwood seedlings in the Maritime Provinces, Canada. However, this observation is also relevant in the tropics (Pellek 1986). It is useful, therefore, to develop standard curves for each nursery, species, and cropping method used. Such curves could then be used by nurserymen to make mid-course adjustments, enabling more precisely scheduled outplanting of optimum sized seedlings. By monitoring seedling growth, the nurserymen can alert the planting supervisor if the crop is not ready for outplanting.

At most nurseries, the suitability of the seedling for outplanting is checked visually, by observing the amount of lignification, and a subjective judgement is made as to its suitability. Nurserymen recognize the deficiencies of this method, but with the aid of an appropriate monitoring system, such as height growth at a specified age, they may be able to overcome these limitations. Nurserymen are striving for improved stock quality, and therefore should have clear standards against which to measure their progress. Closer monitoring of each aspect of the operation (especially growing medium, nutrient regime, and hardening off) is required to capitalize on the technology that has made containerized seedlings a viable undertaking.

CHAPTER 2

METHODS AND MATERIALS

The prime objective of this report is to establish growth curves and ratios which could be used by nursery managers to guide their nursery management (watering and fertilizing). The following methodology sets forth a procedure for establishing an acceptable range of shoot/root ratios. A shoot/root ratio is simply the amount (i.e. length or weight) of the seedling shoot divided by the amount of the seedling root resulting in a ratio. Length ratios can be used to indicate the amount of root development at a certain age without destructive determination. This is accomplished by a simple height measurement at any given age, consulting a graphical representation of the optimum growth curve, and calculating the optimum root development by dividing the shoot length, if it corresponds with the graph, by shoot/root ratio . Differences between the actual and optimal shoot height will require modification in seedling growth before the seedling will be ready for outplanting.

An experiment was devised to obtain average shoot/root ratios at three AOP nurseries which have produced seedlings with high survival rates; a CARE nursery at Jean Rabel in North-western Haiti, the Christian Rural Life Training Center (ICVR) nursery at Vialet in the South-west, and the Operation Double Harvest (ODH) nursery at Caseau in the South-central region of Haiti.

Each nursery grew approximately 2,500 seedlings of each of the three species *Cassia siamea*, *Azadirachta indica*, and *Leucaena leucocephala* with ODH seed. To minimize bias from varying amounts of sunlight, water, and fertilizer, spacial arrangement of the racks were periodically alternated. Due to the geographical arrangement of the nurseries, differences in regional rainfall, temperature, and day length were observed but not recorded. No controls were placed on the growth variables due to the preliminary nature of the experiment.

Sampling began in the third week after the seeds were sown. Each week twenty randomly selected seedlings were measured for shoot length, root length (up to 10 cm), shoot dry weight, and root dry weight.

Procedure

Seedlings were cut at the root collar with sharp pruning shears. The root collar was assumed to be located at soil level. However, the container mix sometimes disintegrated when young seedlings were extracted. In these cases, the root collar was estimated at the distinct color or texture change above the lateral roots which usually marks the soil-air interface.

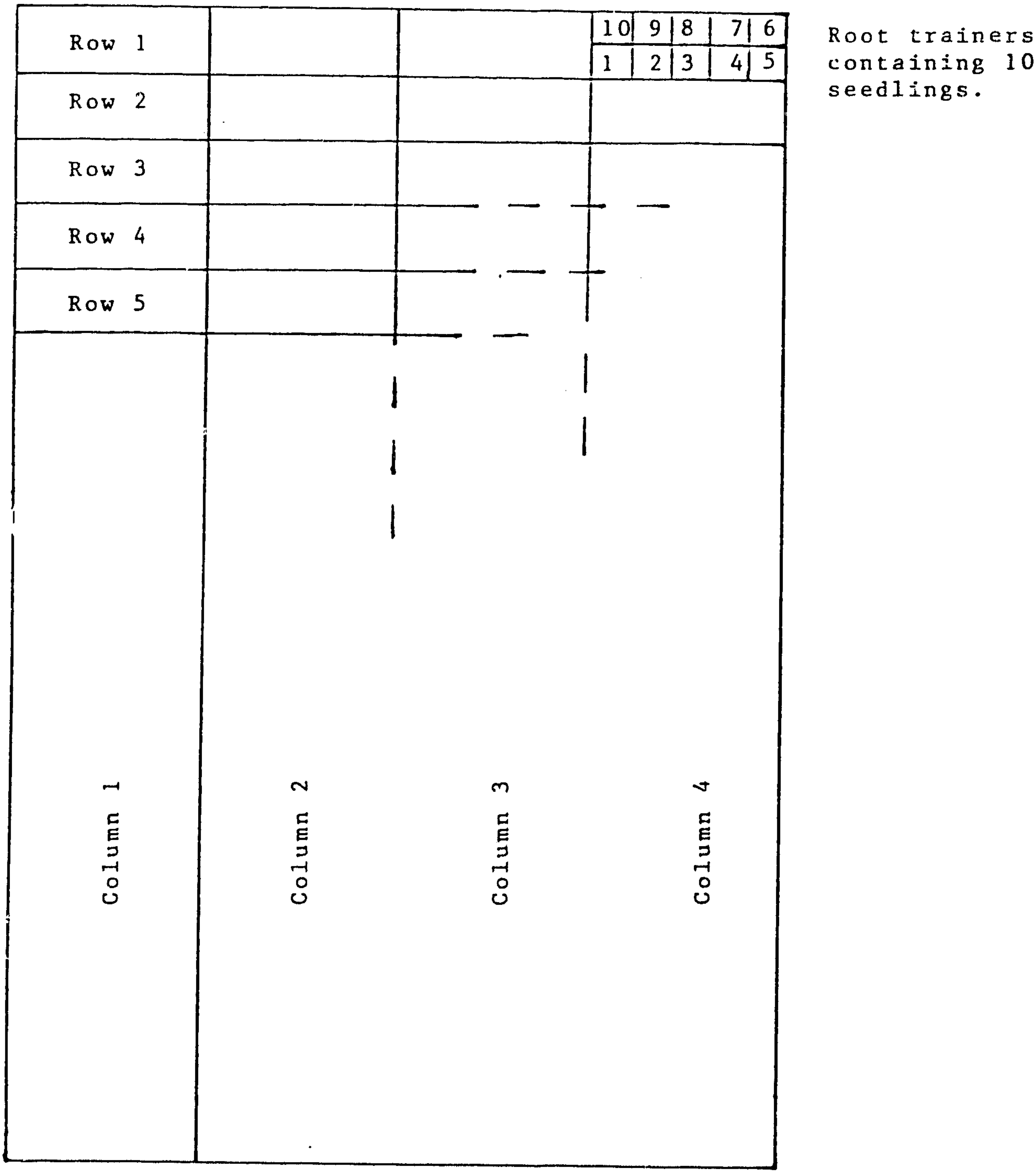
Shoot length was measured to the nearest millimeter from the root collar to the apical meristem. Root length was measured to the nearest millimeter from the root collar to the tip of the longest root. The root length maximum was set at ten centimeters after the root system reached the bottom of the Spencer-Lemaire root-trainer 5, to prevent an error in length into the shoot/root ratios for height. Growth curves were generated instead of height ratios.

The shoot and root of each seedling was bagged separately in plastic bags and then tied together. Each bag was labelled by nursery, species, rack, row, column, seedling and date. Figure 1 illustrates the rack design used in all three nurseries.

When sample collection in the field was completed, the materials were dried and weighed in the lab. Drying of the samples was accomplished in small paper bags at 80°C for a minimum of twelve hours according to the standards set by The Center for Tropical Agriculture for Research and Teaching (CATIE 1984). The samples were then weighed on an open-plate electronic scale to the nearest 1/100 gram. Shoots and roots were dried in groups of five to obtain mean weights. Each group of five corresponded by nursery, species, and age.

Data was averaged and plotted graphically to show trends and ranges of variability in growth over time at various geographical locations in Haiti.

Figure 1. Seedling rack design with reference to random sampling.



Note: numbers for the random selection of seedlings were generated by using the total number of rows, columns, racks, and seedlings.

CHAPTER 3

RESULTS AND DISCUSSION

The data revealed great variation between nurseries in growth and shoot/root ratios for each species. However, the trends in height growth as well as shoot/root ratios are similar. Variation between nurseries suggests that unless controls are placed on the growth variables, a universal curve for each species cannot be derived. Therefore, an acceptable range of values must be determined.

The following figures depict height growth and shoot/root ratios over time in three forest nurseries. Graphs of each species illustrate a range of values attained between the nurseries. The ICVR nursery at Vialet generally shows greater height values and more uniform increases and decreases in shoot/root ratios over time. Its location in south western Haiti typically receives more rainfall and higher temperatures throughout each growing season, accounting for the higher values.

The growth data for each species by nursery is illustrated in Tables 1 to 3, where differences in seedling heights and dry weights are, by the author's observation, related to seasonality and geographical location.

Predicting growth accurately depends on the establishment of a good data base which includes information on seedling development (e.g. height growth data), soil water, fertility, and seedling nutrient content. In using such data, problems can be better assessed with confidence since it is soil water and fertility; combined with climate and weather conditions, that determine the growth of a crop.

The nurseryman's greatest influence on crop development is usually through the use of water and fertilizer, although he may not have adequate knowledge of what is happening biologically (Hallett 1982).

The collection of growth data, including periodic measurements of height and dry weights, is useful for providing the beginnings of a quality control program. Once sufficient growth data is collected and standard growth curves prepared for a particular combination of species, nursery, and cultural regime, nurserymen have the basic ingredients for tracking growth at any point in the seedling crop cycle. In other words, growth records in the form of standard growth curves provide a management tool which can be used to alter growth through cultural manipulation.

Considerations to keep in mind when using shoot/root ratios or growth curves are as follows:

1. Seedling size is correlated with container size. Container volume determines the size of tree seedling that can be grown in the container.

2. Plantable seedlings may be produced in a shorter period of time if they are designated for a good site. Size of container-grown seedlings should be matched to site conditions.

3. Shorter growing days slow down height growth creating different seasonal growth curves since most nurseries produce two seedling crops per year.

Figure 2. Height vs. time growth curves for <u>Cassia siamea</u> at three AOP nurseries.

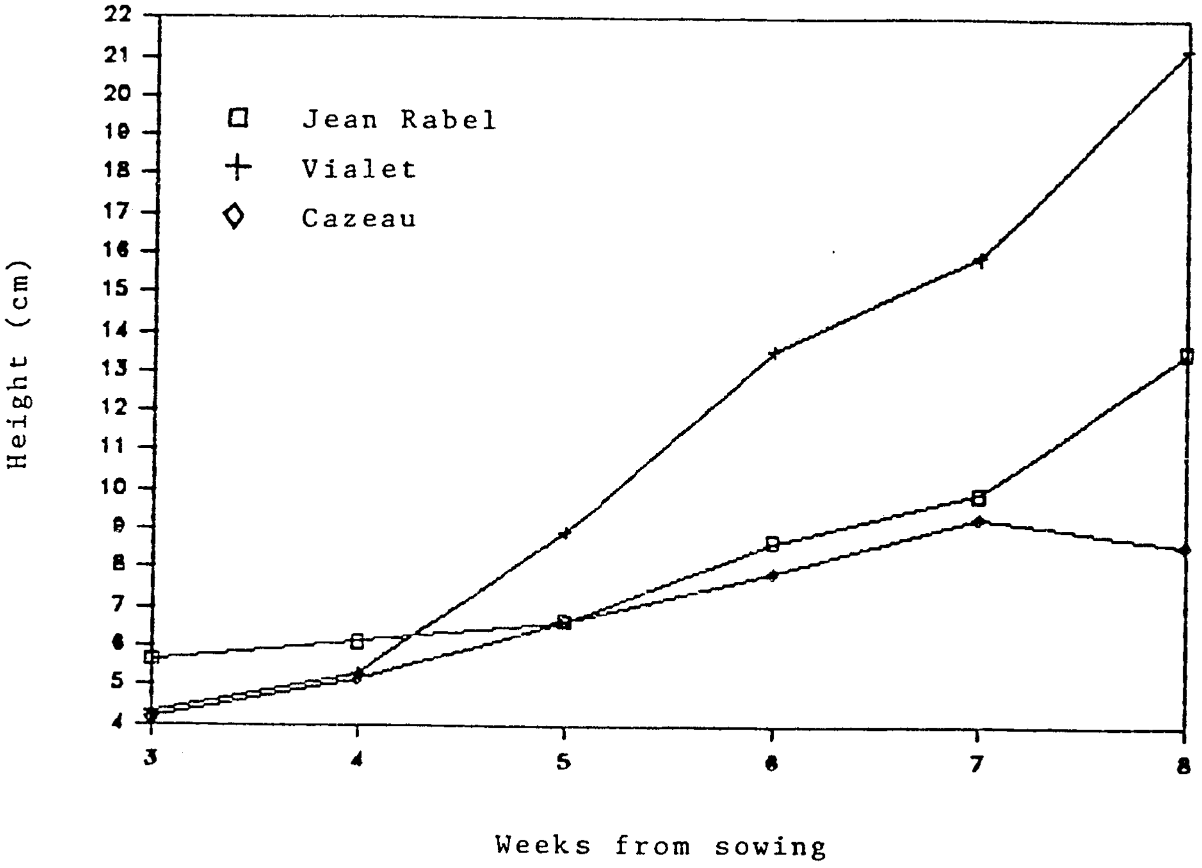


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Figure 3. Dry weight shoot/root ratios vs. time for _Cassia siamea_ at three AOP nurseries.

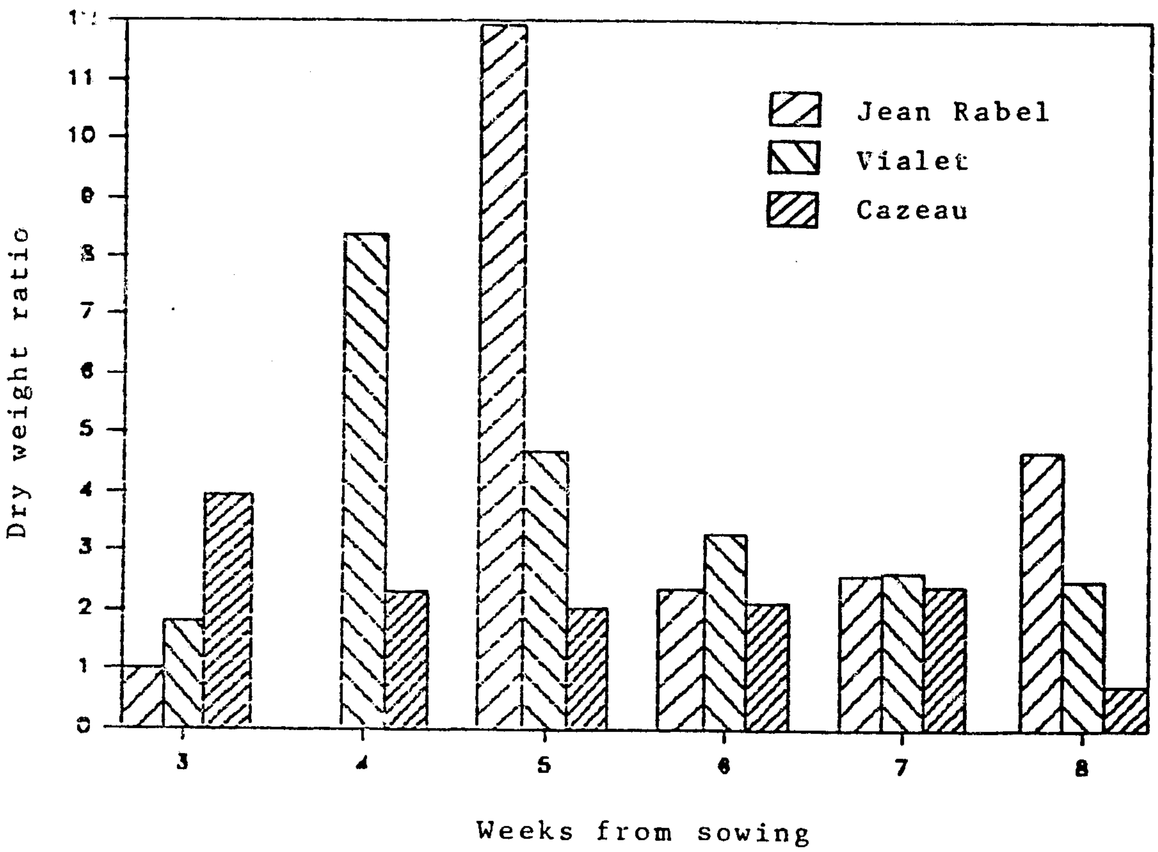

Figure 4. Height vs. time growth curves for *Azadirachta indica* at three AOP nurseries.

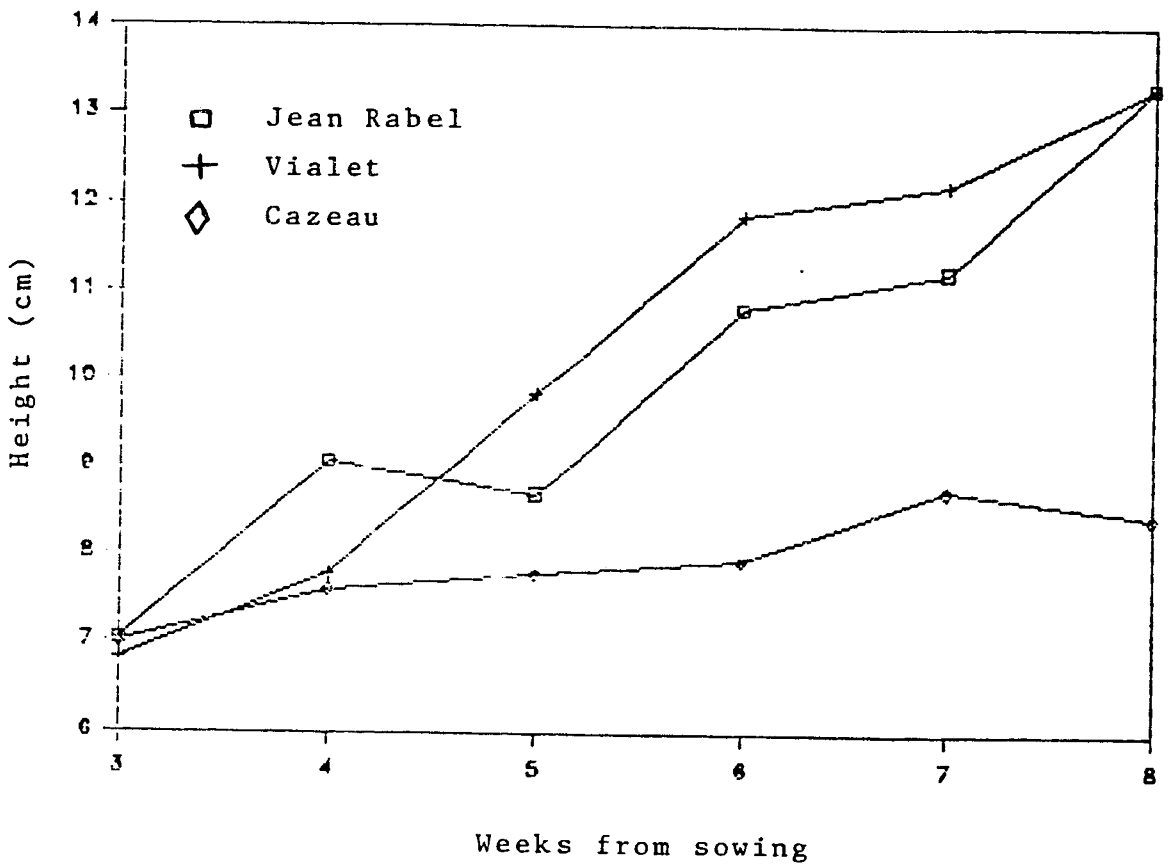

Figure 5. Dry weight shoot/root ratios vs. time for Azadirachta indica at three AOP nurseries.

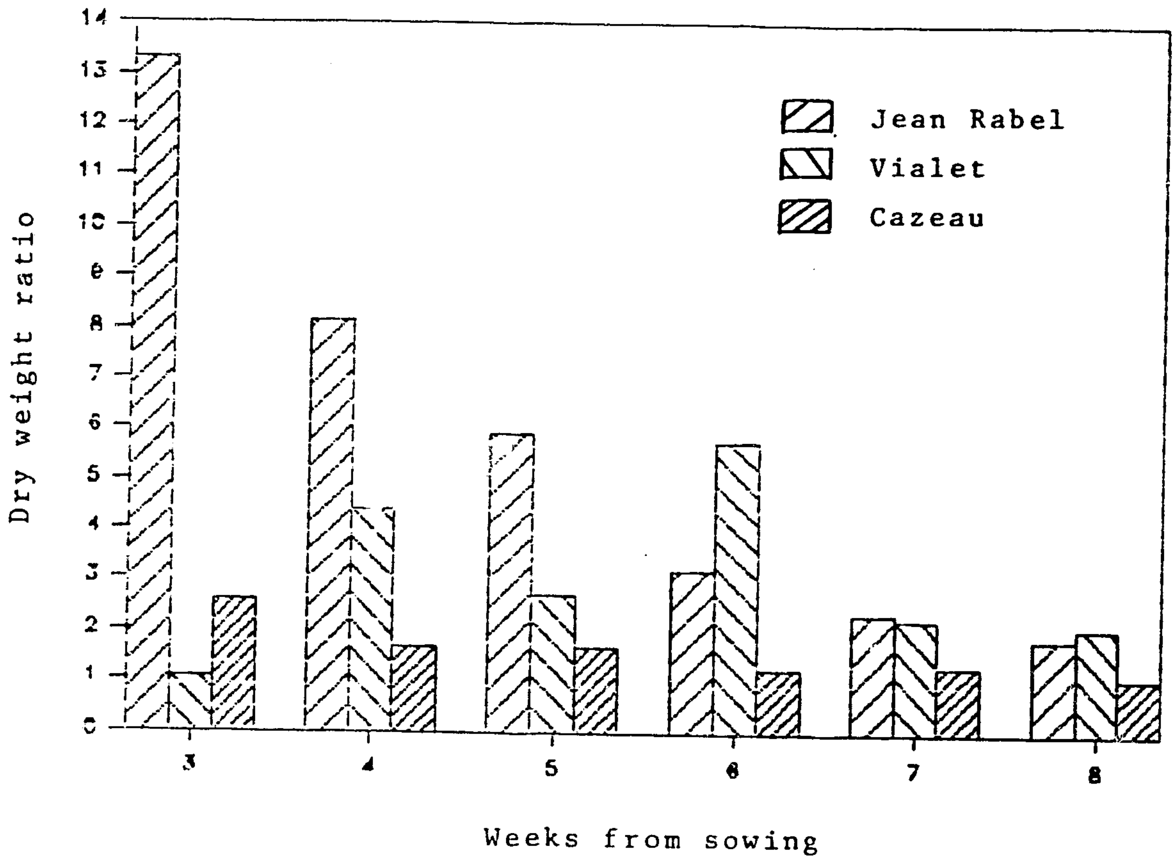

Figure 6. Height vs. time growth curves for <u>Leucaena leucocephala</u> at three AOP nurseries.

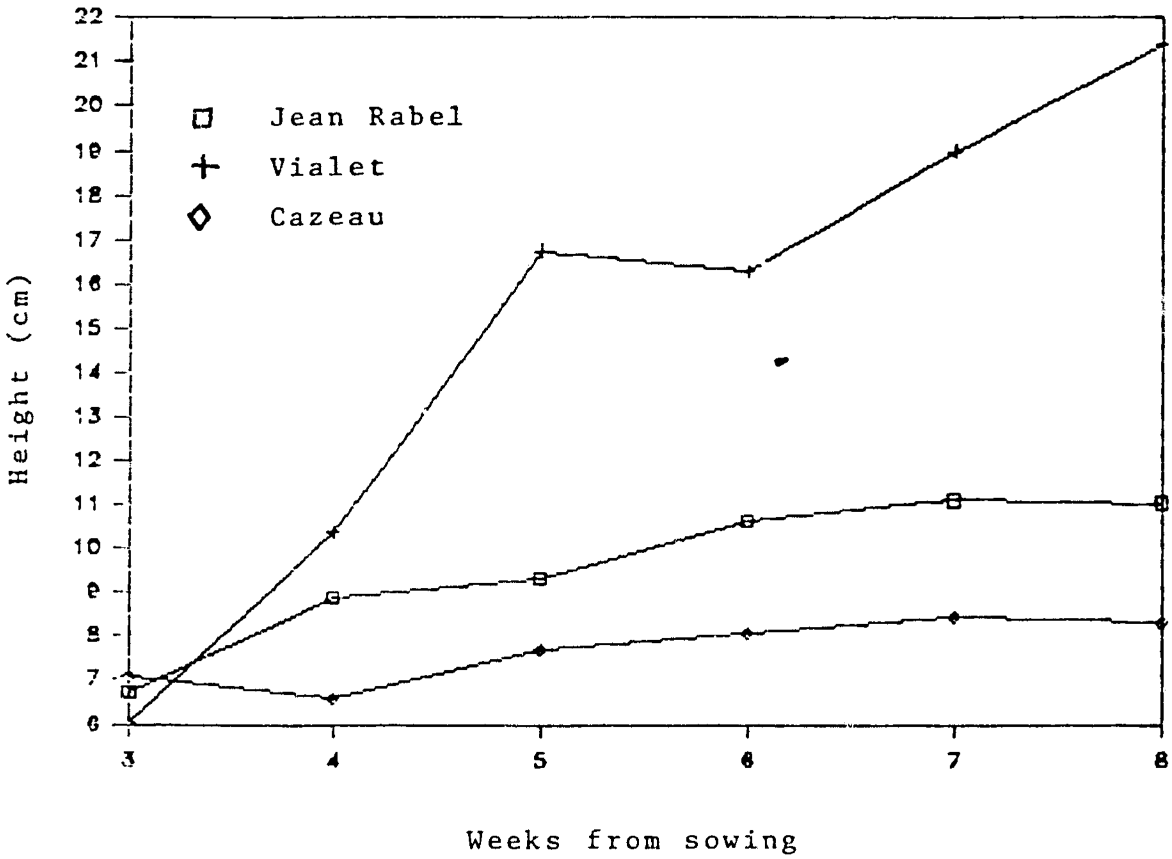

Figure 7. Dry weight shoot/root ratios vs. time for *Leucaena leucocephala* at three AOP nurseries.

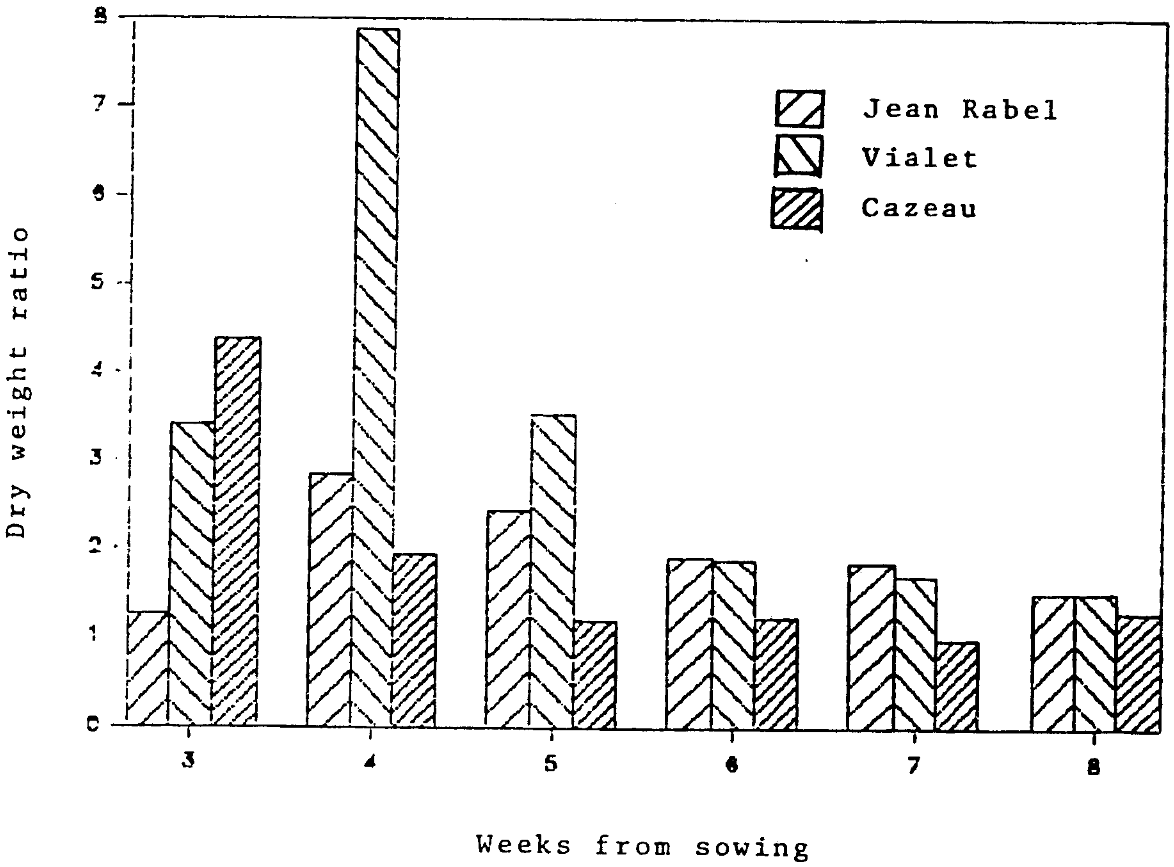

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Table 1. Growth data for containerized tree s..dlings at CARE nursery at Jean Rabel, Sept-Nov 1986.

SPECIES	AGE (weeks)	SHOOT LENGTH (cm)	DRY WEIGHTS SHOOT (g)	DRY WEIGHTS ROOT (g)	RATIO
Cassia	3	5.65	0.14	0.14	1.00
Cassia	4	6.11	0.00	0.00	0.00
Cassia	5	6.66	0.29	0.02	11.94
Cassia	6	8.70	0.72	0.27	2.34
Cassia	7	9.90	0.87	0.36	2.57
Cassia	8	13.52	1.45	0.35	4.68
Azadirachta	3	7.05	0.25	0.03	13.33
Azadirachta	4	9.07	0.55	0.08	8.13
Azadirachta	5	8.71	0.55	0.20	5.90
Azadirachta	6	10.82	0.96	0.35	3.19
Azadirachta	7	11.23	1.31	0.59	2.30
Azadirachta	8	13.33	2.04	1.11	1.85
Leucaena	3	6.73	0.26	0.14	1.25
Leucaena	4	8.90	0.20	0.07	2.86
Leucaena	5	9.33	0.54	0.22	2.43
Leucaena	6	10.66	0.71	0.39	1.90
Leucaena	7	11.12	0.78	0.44	1.87
Leucaena	8	11.04	0.90	0.60	1.50

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Table 2. Growth data for containerized tree seedlings at ICVR nursery at Vialet, Sept-Nov 1986.

SPECIES	AGE (weeks)	SHOOT LENGTH (cm)	DRY WEIGHTS SHOOT (g)	DRY WEIGHTS ROOT (g)	RATIO
Cassia	3	4.33	0.25	0.14	1.79
Cassia	4	5.30	0.42	0.15	8.37
Cassia	5	8.96	0.88	0.22	4.68
Cassia	6	13.56	1.39	0.43	3.31
Cassia	7	15.92	2.33	0.92	2.63
Cassia	8	21.28	2.77	1.10	2.51
Azadirachta	3	6.84	0.16	0.10	1.07
Azadirachta	4	7.80	0.55	0.13	4.38
Azadirachta	5	9.83	0.72	0.23	2.70
Azadirachta	6	11.86	1.13	0.23	5.77
Azadirachta	7	12.20	1.31	0.62	2.19
Azadirachta	8	13.34	1.47	0.72	2.03
Leucaena	3	6.04	0.47	0.17	3.40
Leucaena	4	10.42	0.52	0.11	7.88
Leucaena	5	16.76	1.06	0.32	3.54
Leucaena	6	16.28	1.51	0.81	1.90
Leucaena	7	19.01	1.92	1.15	1.69
Leucaena	8	21.40	1.89	1.31	1.51

Table 3. Growth data for containerized tree seedlings at ODH nursery at Cazeau, Sept-Nov 1986.

SPECIES	AGE (weeks)	SHOOT LENGTH (cm)	DRY WEIGHTS SHOOT (g)	ROOT	RATIO
Cassia	3	4.15	0.55	0.21	3.93
Cassia	4	5.18	0.74	0.35	2.33
Cassia	5	6.66	0.93	0.47	2.03
Cassia	6	7.88	1.56	0.73	2.14
Cassia	7	9.30	1.69	0.72	2.41
Cassia	8	8.62	0.98	1.34	0.73
Azadirachta	3	7.01	0.76	0.31	2.57
Azadirachta	4	7.62	1.06	0.65	1.66
Azadirachta	5	7.79	1.01	0.65	1.66
Azadirachta	6	7.94	1.09	0.90	1.25
Azadirachta	7	8.74	1.63	1.27	1.30
Azadirachta	8	8.43	1.86	1.70	1.09
Leucaena	3	7.09	0.82	0.29	4.37
Leucaena	4	6.58	0.69	0.37	1.95
Leucaena	5	7.71	0.87	0.73	1.20
Leucaena	6	8.10	1.22	1.02	1.22
Leucaena	7	8.48	1.21	1.26	0.97
Leucaena	8	8.32	1.36	1.09	1.29

Figure 8. Height vs. time growth curve averages for three tree seedling species at three AOP nurseries.

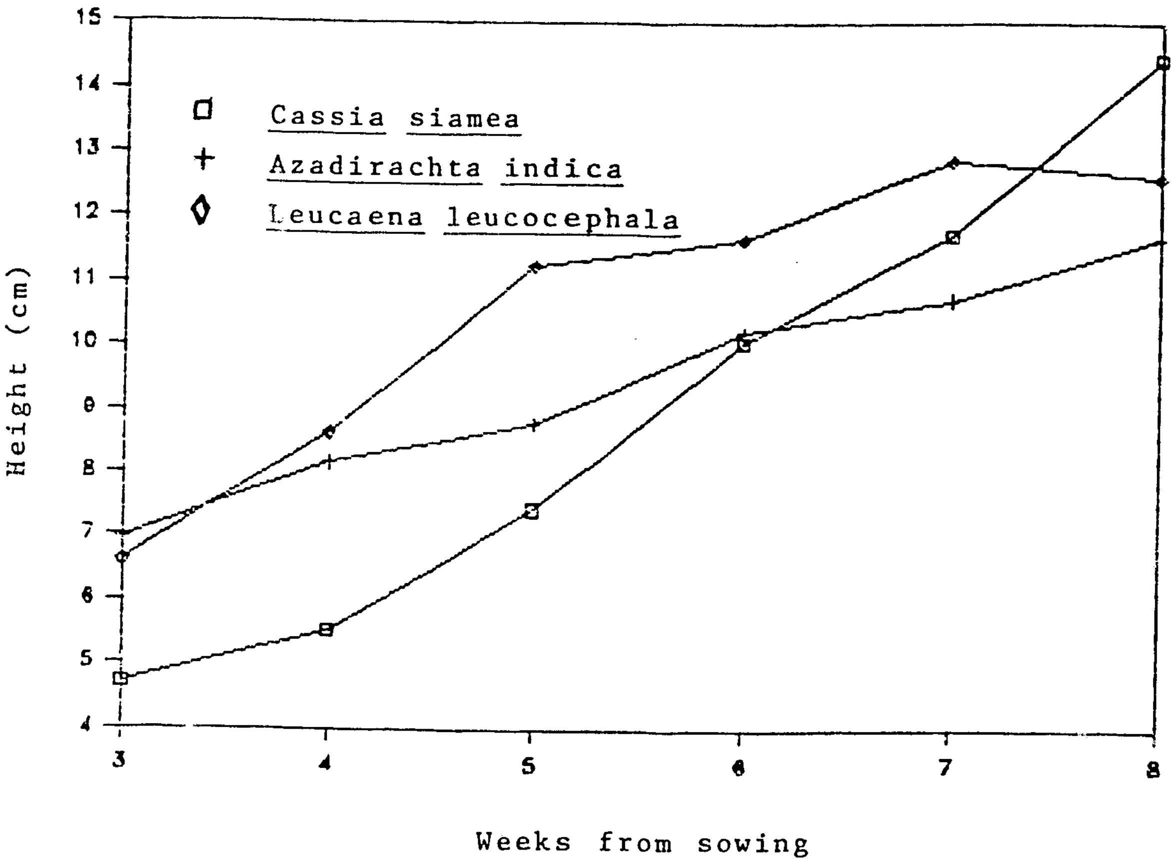
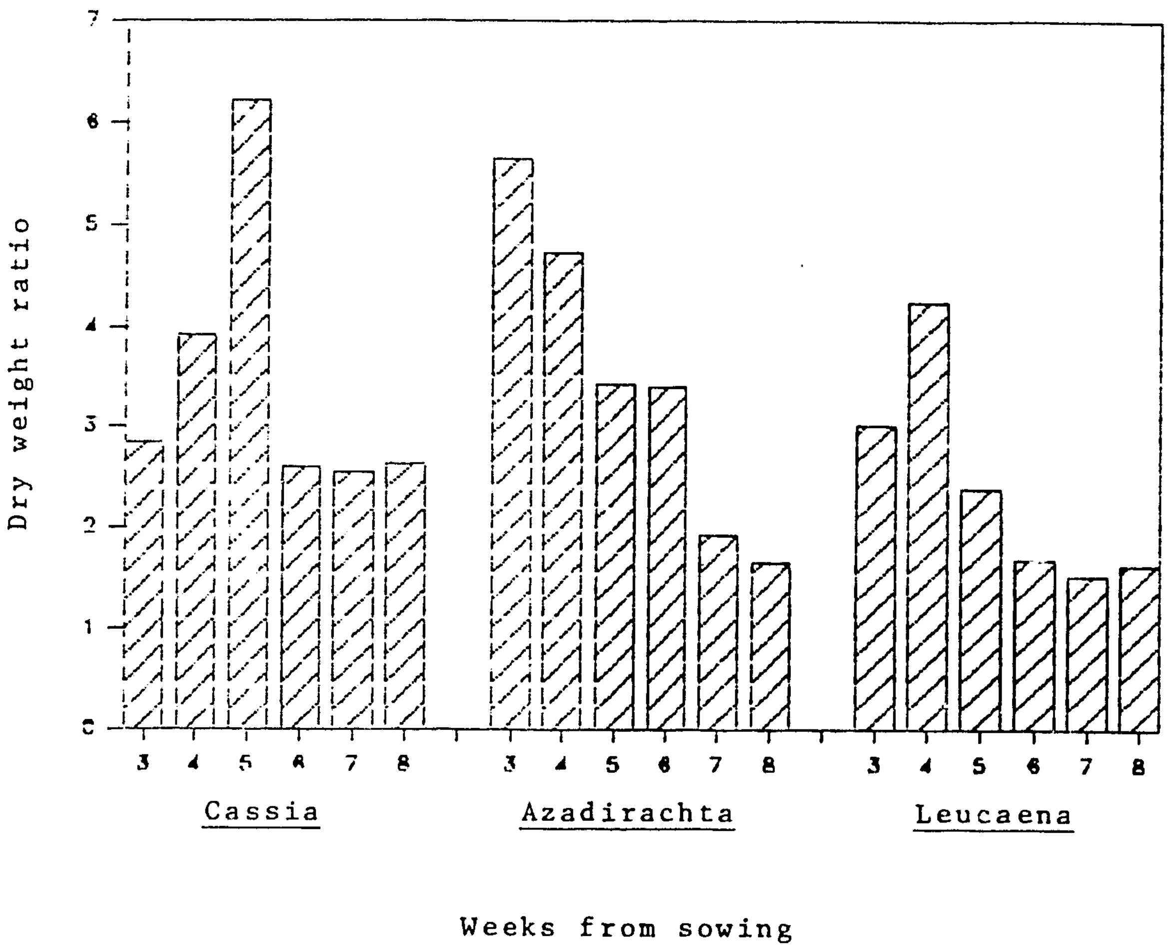


Figure 9. Dry weight shoot/root ratio averages for three tree seedling species at three AOP nurseries.



CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

Further derivation of shoot/root ratios and growth curves is needed for AOP trees to provide a specific monitoring system for the grantee nurseries. Standard heights at each stage of seedling development which would take into consideration day-length, watering and nutrient regimes, and temperatures for inside and outside the shade house need to be developed.

Shoot/root ratios do not monitor the degree of hardening (stage of seedling development which acclimates seedlings to the proposed planting environment). There is temptation to shorten the hardening process, if seeds were sown late, due to a specific outplanting time schedule established in the nursery. Since change in root development is not usually evaluated, an appropriate monitoring system is required which would allow adequate time under proper hardening conditions.

There must be a continuing effort to adhere to known biological principles if high quality seedling stock is to be consistently produced. The challenge in moving from a relatively small production to many millions of seedlings annually is in organizing a smooth expansion of services and facilities, which will not jeopardize cultural principles, and therefore seedling quality. (Mathews 1982)

Monitoring of containerized seedlings on the basis of standard height or shoot/root curves is highly recommended. However, this research was preliminary and of value primarily to demonstrate the methodology to be used in any future studies of shoot/root ratios. Such studies are needed, one series for those to be planted in the spring, and another for those to be planted in the fall. The results of the research should be written for practical use by nurserymen within AOP.

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