AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH

Final Report - ACIAR Project 8613

FUELWOOD AND SANDALWOOD SILVICULTURE IN EASTERN INDONESIA

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT,
WESTERN AUSTRALIA

Contents

Front Cover: *A successful introduction from this project. A. crassicarpa grows well on certain sites in NTT.*

Executive Summary

Project:	Fuelwood and Sandalwood Silviculture in Eastern Indonesia.
Commissioned Organisation:	Department of Conservation and Land Management, Western Australia.
Collaborating Organisation in Australia:	Curtin University of Technology, Perth, Western Australia, involving Dr John Fox of the Mulga Research Centre.
Developing Country Collaborator:	Agency for Forest Research and Development (AFRD), Ministry of Forestry, Jakarta, Indonesia.
Project Leaders:	(i) **Australia:** Dr Frank McKinnell (ii) **Indonesia:** Initially Ir Komar Soemarna, later Dr Ombo Satjapradja, AFRD Bogor, Indonesia
Date of Commencement:	1 September 1987
Date of Completion:	30 June 1991

DESCRIPTION OF WORK

The objectives of the Project were:

1. To assemble germplasm of a range of Indonesian and exotic tree species which can satisfy NTT requirements for fuelwood and/or forage.

2. To test the adaptability and growth of these species on a range of soil types in NTT in the seasonally dry regions.

3. To improve the research capabilities of Indonesian researchers in NTT.

4. To assist Indonesia in obtaining basic silvicultural information needed to underpin a program for regeneration of the sandalwood industry in NTT.

There were thus two distinct components of the project. The first part, although intended to be concerned mainly with selection of species for fuelwood, quickly expanded its scope to encompass multipurpose tree species, for reasons explained in the text. This component was carried out by CALM staff. The second component was concerned with the sandalwood problem in NTT, and was mainly carried out by Dr Fox at Curtin University, but partly by CALM, as it has a direct interest in the development of a reliable and effective sandalwood plantation system for use in the Ord River Irrigation Area in the north of Western Australia.

Each component developed its direct contacts and on-ground collaborators in Kupang. In NTT the project was strongly supported by the staff of the Balai Penelitian Kehutanan, or BPK (Forestry Research Station), and especially by its officer in charge, Ir Sutarjo Suriamihardja.

The achievement of the project objectives involved several activities:

- improvement of nursery facilities in NTT;
- nursery experiments at Curtin University;
- the establishment of a series of field trials at several sites sampling the main soil types and highland and lowland climatic zones in NTT;
- provision of research equipment; and
- training of Indonesian research staff both on the job and at special short courses in Australia.

CALM and Curtin University became involved largely due to their long-standing interest in sandalwood research in WA, and especially as the sandalwood research program was becoming more focused on *S. album*, so that research on this species could provide benefits to both countries, an essential feature of ACIAR projects. CALM was appointed as commissioned organisation for the project with Curtin as a contractor for most of the sandalwood research, through Dr John Fox.

RESULTS

Multipurpose Tree Component

This component achieved all three of its objectives, although testing of germplasm is an open-ended matter that could go on for many years. The approach taken was to test what appeared to be the most promising species and then ensure that the capability to continue this type of research was left behind in the BPK so that it could be continued if desired.

The field trials moved systematically from species screening trials covering about 65 species and provenances, to provenance trials of a small number of species which showed initial promise for use in NTT, to the establishment of larger areas of a few species for later use for further research on spacing and other cultural treatments.

The most promising exotic species emerging from the field trials in West Timor were *Acacia crassicarpa*, *A. holosericea*, *A. auriculiformis*, *A. ampliceps*, *Eucalyptus camaldulensis*, *E. tereticornis* and *Sesbania formosa*.

A. crassicarpa, *E. camaldulensis* and *E. tereticornis* have potential for the production of high quality timber on rhodustalf soils. *S. formosa* and *A. ampliceps* are good fodder plants that could be used by small farmers in NTT. *A. holosericea* in not palatable to stock but produces useful fuelwood and could be used for the rehabilitation of degraded soils. *A. auriculiformis*, a species already used in NTT, could be more widely used for timber or fuelwood production if better tree form could be assured.

Two staff members of the BPK were brought to Perth for a special four week training session arranged with CALM staff and with the Government Chemical Laboratories. One officer specialised in chemical analysis methods for sandalwood quality assessment and in the use of the statistical analysis package Minitab, while the other spent most time on field trial establishment and management, and some time on the Minitab training.

Funds were obtained from the Crawford Fund to sponsor the OIC of the BPK and another MOF officer from Bogor to attend a special forestry research managers course arranged with Dr Mike Slee at the ANU Department of Forestry.

As a result of the special training courses, the provision of equipment and on the job training, a considerable improvement in the research capacity of the BPK was achieved over the period of this Project.

Sandalwood Component

The sandalwood part of the Project has been written up separately by Dr Fox, and is attached as Appendix 1. A summary is given below. The other sandalwood research and development undertaken by CALM is described here. This included work at Kununurra on sandalwood plantation establishment and activities funded by an extra grant from ACIAR, in which an attempt was made to establish contact with other groups in South Pacific countries who were interested in sandalwood research, and to establish a sandalwood species/provenance trial in several countries.

The research carried out by Dr Fox included several aspects, perhaps the most important of which was the screening of potential host plants. The most conclusive study to date was the selection of the best soil mixture for use at Kupang.

Before commencing research in NTT, Curtin University staff carried out an extensive literature survey on *Santalum album* (Barrett, 1988). The work in Timor can conveniently be divided into eight sub-projects as follows:

- selection of trees for seed collection;
- seed production from selected trees;
- nursery techniques-seed handling and pot hosts;
- nursery techniques-potting mixes and fertilisers;
- planting techniques;
- tending requirements;
- growth and yield plots.

The main thrust of the first sub-project was the demonstration of selection criteria for trees to be reserved as 'plus trees' for seed collection. About 80 sandalwood trees felled for the commercial harvest near Kefamenanu were examined for heartwood content in relation to diameter. Based on cross-sectional area, heartwood percentage varied from 20 to 70 per cent. An arbitrary figure of 60 per cent heartwood content at breast height was set as the threshold for candidate plus trees, which implies that any tree of 12-14 cm diameter and <2.5 cm sapwood radius or a tree of 14-20 cm diameter with <3.0 cm sapwood radius, could be taken as a candidate.

The phenology of seed production was studied in selected plus trees in Timor to gain an appreciation of the variability in seed production in this species. A number of experiments were undertaken in cooperation with BPK staff to refine nursery procedures, including soil amelioration, degree of shading and nutrient trials. It was shown that a moderately light nursery soil mix gave better sandalwood seedling growth than heavy mixtures.

The pot host usually used in NTT before this Project was *Capsicum*, but work by Dr Fox demonstrated that other species such as *Breynia*, *Calitropis gigantea*, *Desmanthus virgata* and *Crotalaria juncea* were also good pot hosts. A range of *Acacia* species was also tested, with *A. ampliceps* seeming to be the best.

Field trials at Oilsonbai, near Kupang, showed that control of competing grasses was essential to achieve good sandalwood plant survival. The necessity for adequate measures to be taken to prevent fire and cattle entering new sandalwood plantations was also noted. Sandalwood is very vulnerable to fire and is highly palatable to cattle.

Some preliminary estimates of sandalwood growth and yield in NTT were made from limited evidence in some older plantations at various sites in West Timor.

PUBLICATIONS

Barrett, D.R. (1988). *Santalum album* (Indian sandalwood) literature review. Mulga Research Centre, Curtin University, WA.

Haines, M.W., McKinnell, F.H., Marcar, N.E., and J.W. Turnbull. (1991). Recommendations for Research into Tropical Acacias. ACIAR Proceedings No. 35, Advances in Tropical Acacia Research, J.W. Turnbull (ed). (Based partly on the results from this Project).

McKinnell, F.H. and Harisetijono. (1991). Testing Acacia species on Alkaline Soils in West Timor. Advances in Tropical Acacia Research, ACIAR Proceedings No 35:183-188, J.W. Turnbull (Ed).

McKinnell, F.H. and Harisetijono. (1991). Pengujian Jenis Akasia Pada Tanah Alkali di Timor. Savanna 6:7-15. (Translation of the above article into Bahasa Indonesia).

McKinnell, F.H. (1990). Status of Management and Silviculture Research on Sandalwood in Western Australia and Indonesia. Proc Symposium on Sandalwood in the Pacific, April 9-11, Honolulu, Hawaii, General Technical Report PSW-122, US Department of Agriculture, Forest Service, 19-25.

McKinnell, F.H. (1990). Species Trials on Alkaline Soils in Indonesia. ACIAR Forestry Newsletter 10:1, 3.

Surata, I.K., J.E.D. Fox and S. Suriamihardja. (1989). Soil texture for early seedling growth in *Santalum album*. Santalum 4:1-13.

FOLLOW-UP

As this Project was designed to run for three years, it was clear that more time was required to thoroughly evaluate the potential of some of the more promising species. It was also desired to extend the species screening work to eastern Sumba Island, where there is a particularly severe fuelwood and fodder shortage.

For these reasons, and also because the sandalwood research needed more time to show definitive results, a new ACIAR Project, 9043, was approved to follow up Project 8613.

During the course of project 8613, the use of the information gained was considered at several levels. Contacts were established at an early stage with the AusAid-funded NTT Integrated Area Development project (NTTIADP) as well as the NTT Agricultural Support Project. Through NTTIADP we established close ties with the agricultural section of Nusa Cendana University, hoping that the involvement of agricultural students would improve their knowledge of and appreciation for the role of trees in NTT land management systems. The cessation of NTTIADP in 1991 meant that this objective was only partly fulfilled. We also provided a collection of seed of*Gliricidia sepium* to Mr Bruce Short, an agronomist with NTTIADP, for field trials at Soe. He did establish a very good demonstration of the various *Gliricidia* provenances at a site near Soe used for training farmers by the extension section of the Sub-Balai Reboisasi Lahan dan Konservasi Tanah (soil conservation service). However, all records relating to the trial were lost when NTTIADP terminated.

SANDALWOOD RESEARCH COMPONENT UNDERTAKEN BY CALM

PACIFIC ISLAND COOPERATION

The Department of Conservation and Land Management was able to undertake additional activities related to the sandalwood part of Project 8613 due to a further grant of $30 000 through ACIAR, from AIDAB. The intent of this grant was to promote cooperation in research on sandalwood among several Pacific Ocean countries that had native sandalwood species.

Countries thought to be of particular interest in this respect were Vanuatu and Fiji. It was also known that the French forest research organisation Centre Technique Forestier Tropicale (CTFT, now known as CIRAD-FORÊT) had carried out some research on sandalwood in New Caledonia and there was a possibility of useful cooperation in sandalwood research.

The focus of this cooperation was intended to be the establishment of a replicated sandalwood species trial in several countries as well as in Australia. To this end, the Project Leader made a visit to New Caledonia, Vanuatu and Fiji late in 1988, to hold discussions with local forestry staff and research officers.

In New Caledonia contact was made with staff of the then CTFT research station. The acting OIC, M. Loic Cremiere, was most outgoing and cooperative, and very supportive of the idea of a sandalwood species trial, promising involvement by his group. He was also most cooperative in showing the results of several years of research on the New Caledonian species of sandalwood, *S. austro-caledonicum.*

New Caledonia sandalwood nursery system showing Alternanthera sp pot host

It was clear that the nursery technique used in New Caledonia was very successful and reliable, as evidenced by excellent stock in the research nursery. The system used a pot host of a species of *Alternanthera*, a low growing shrubby plant, easily and cheaply propagated by cuttings, together with a secondary field host, usually *Paraserianthes falacataria.* The basic ideas of the technique were written up and passed on to Dr Fox and our colleagues in Kupang, with an immediate benefit to the nursery research program there.

The existence of successful seven year old, almost fully stocked, sandalwood plantations was a valuable confirmation that the objectives of the sandalwood part of the ACIAR project were achievable, given development of a reliable nursery procedure and sufficient attention to field establishment techniques.

Seven year old Santalum austro-caledonicum plantation in New Caledonia

Arrangements were made to exchange seed of *S. austro-caledonicum* and *S. spicatum* and to transfer some funds from ACIAR to enable the preparation of a field trial site at Pindai, NC. The exchanges of seed subsequently took place and the *S. austro-caledonicum* is now established at the Kununurra field trial site and the *S. spicatum* trial at Pindai has also been established, although subsequent comments by CTFT staff indicate that this species does not thrive in the tropical environment.

The seed provided by CTFT was collected from 10 widely separated parent trees, and has been planted out at Kununurra as a progeny trial, so it has the potential to yield much useful information about the variation in growth and wood properties within that species. It will be especially valuable if the replicate of this field trial at Pindai is also successful and the data at age 10 or more can be compared.

We are very grateful to M. Loic Cremiere, and Christophe Chemin at the forest research station in Noumea and to Jean-Paul Chauvin at the research nursery, for sharing the results of their research.

Visits to Vanuatu and Fiji were much less productive. In Port Vila, discussions were held with Mr Adrian Barrance, an ODA forester working with the Department of Agriculture and Forestry, who had carried out some preliminary nursery trials with the local sandalwood species, which is also *S. austro-caledonicum*. He was also keen to take part in the proposed trial and a potential field trial site was inspected.

However, there was concern at the possible introduction of spike disease if*S. album* were introduced. There was also concern at the difficulty of collecting sandalwood seed, partly due to the cost and difficulty of getting the seed from the other islands and partly due to loss of whole seed crops in recent cyclones. These same difficulties also arose later in Fiji. Although it was agreed to go ahead and collect seed from Vanuatu and establish the trial, Barrance left Vanuatu at a critical time for seed collection and as he was not immediately replaced, and local staff were unable to take on the project. As a result, the cooperation with Vanuatu lapsed.

In Fiji, discussions were held with Mr Alec Chang, acting Conservator of Forests, on the potential for cooperation with his Department. He was most concerned at the possibility for bringing in spike disease with the seed of other species of sandalwood. It was also difficult to get seed of the local species, *S. yasi*, as it mostly occurred on the outer islands, thus cost was a major factor in obtaining seed. In the end, he decided that Fiji would not participate but was quite ready to supply seed of *S. yasi* when it was available. I was able to take home a small parcel of seed, but when sown at Broome nursery, it proved to be non-viable.

An inspection was made of a small amount of work being carried on at the forestry nursery at Colo-i-Suva, and it was evident that little progress had been made on developing an effective nursery technique. This is especially of concern as *S. yasi* is a species with very good wood quality, perhaps as good as *S. album*, and there are concerns expressed by Departmental staff in Fiji about its long term survival in the face of recent harvesting. The isolation of Fiji from what is happening in sandalwood research elsewhere is striking, and indicated a need for some form of networking to help inform foresters in isolated places about what is happening in sandalwood research. The same situation is no doubt applicable to several other Pacific region countries that have very small forestry agencies.

SYMPOSIUM ON SANDALWOOD IN THE PACIFIC

Following the above activities in relation to sandalwood in the Pacific region, contact was made with Dr Larry Hamilton at the East-West Center in Hawaii, who was arranging an international symposium on sandalwood in the Pacific region in Honolulu in April 1990.

The Project Leader was able to participate in this symposium, together with Dr Graeme Applegate of the Queensland Forest Service research station at Atherton. A paper on the current research on sandalwood in Western Australia and in West Timor was presented, and the Project Leader also assisted in the drafting of the final summary of the state of knowledge about sandalwood, later published by the USFS Pacific Northwest Research Station as General Technical Report PSW-122.

This symposium was most valuable in establishing contact with a number of people in Pacific island countries, and in India and Hawaii, who have an interest in sandalwood conservation or cultivation. To keep up the impetus created by the 1990 symposium, the Project Leader was able to arrange, through contacts in Hawaii, for another symposium on sandalwood to be held as part of the 1991 Pacific Science Congress, held in Honolulu. This is reported on more fully in the final report for Project 9043. Additional funding to assist attandants from Fiji and Vanuatu was obtained through AIDAB ISSS sources.

These two visits to Hawaii enabled the inspection of the conditions under which the native species of sandalwood in Hawaii still survive. Attempts were made to arrange for the supply of seed of at least two species that appeared to have some potential for trial in Australia. Despite a number of subsequent reminder letters, there has been no success in obtaining Hawaiian seed up to early 1996.

FIELD TRIALS AT KUNUNURRA

Between 1987 and 1990 CALM continued with its own program of research on the establishment of *S. album* plantations in the Ord River Irrigation Area. These activities were handicapped by poor results in the Department's Broome nursery. Although the techniques being tested in NTT were used, there was a persistent disease problem that resulted in a high percentage of seedling losses. The seed used for this work was obtained from commercial seed merchants in India, and in some instances this seed was also of poor viability.

It had been intended to use sandalwood seed from Timor for this work, as the Project Agreement provided for Indonesia to make available experimental quantities of *S. album* from Timor, but this did not take place as Indonesian authorities did not give approval for release of the seed. The Project Leader made several approaches to his counterpart in Bogor to obtain this seed, and also spoke directly to two successive Directors-General of AFRD, Dr Setyono and Mr Wartono Kadri, but without success.

CALM was therefore obliged to continue its work at Kununurra using seed from commercial suppliers in India. By trying three or four different suppliers, in different parts of India, it was hoped that the risk of a narrow genetic base for the sandalwood would be avoided. However, it was not possible to gain any control over the genetic quality of this seed.

Eventually, CALM decided to transfer the nursery phase to a commercial nursery at Kununurra. This avoided the disease problem at Broome and resulted in an immediate improvement in the success rate of the field trials there. This nursery was able to capitalise on the nursery research undertaken in New Caledonia, at Kupang and at Curtin University. It adopted the *Alternanthera sp* pot host system used in NC with immediate success and was able to consistently produce healthy and vigorous seedlings for outplanting.

Even so, progress was slow because it was possible to make only part time input to the field trials from the Project Leader and by one of the CALM administrative staff in Perth. It was found that the modus operandi of leaving the supervision of fieldwork to CALM operational staff based at Kununurra was not workable, as they already had an overfull work program, and the timing of sandalwood planting and cultural operations clashed with other field activities. As a consequence, the field trials were not as successful as hoped, except for the 1990 plantings, when everything came together as it should have.

The success of the 1990 planting, when a first year survival of over 50 per cent was obtained, was a vindication that the potential for commercial sandalwood plantations on the Ord was realisable, if we had better control over the quality and timing of nursery and field operations. It was also a convincing demonstration of the success of the combination of *Alternanthera* as a pot host and *Sesbania formosa* as the second stage field host plant. The sandalwood in this plot are very vigorous and healthy and are an obvious success. We can now look forward to further refinement of research trials with some confidence that we are on the right track.

MULTIPURPOSE TREE COMPONENT

INTRODUCTION

Background

The initial impetus for this project came from two requirements which are widely acknowledged in the province of Nusa Tenggara Timur (NTT) as being important for the people and the economy of the region;

(i) improved fuelwood supplies; and
(ii) a reliable technique for the regeneration of the indigenous sandalwood (*S. album*).

It was on these premises that the original Project Arrangement was drawn up under the aegis of the existing ACIAR/AARD Memorandum of Understanding.

The fuelwood part of the project was intended to concentrate largely on the testing and selection of exotic tree species for use in NTT climatic and soil conditions. Although fuelwood was to be the principal value sought, the potential for possible use for forage, for small farmer timber requirements, or even commercial timber production, was to be kept in mind. This part of the Project was therefore concerned with multipurpose trees.

At the time the Project commenced, there was a new forestry research station being established in Kupang, NTT. Its staff were mostly new and inexperienced and the station, the Balai Penelitian Kehutanan, had very little equipment.

Project Design

The objectives of the Project were as follows:

1. To assemble germplasm of a range of Indonesian and exotic tree species which can satisfy NTT requirements for fuelwood and/or forage.

2. To test the adaptability and growth of these species on a range of soil types in NTT in the seasonally dry regions.

3. To improve the research capabilities of Indonesian researchers in NTT.

4. To assist Indonesia in obtaining basic silvicultural information needed to underpin a program for regeneration of the sandalwood industry in NTT.

By the time the Project had commenced, the decimation of the widely used fodder and fuelwood tree *Leucaena leucocephala* by the 1987 psyllid attack was in full swing. It soon became clear that an additional important parameter for multipurpose tree selection for NTT should be fodder value.

It was also intended at the time of signing the Project Arrangement, that the multipurpose tree side of the project would take place on Sumba and Flores, in addition to West Timor. In the first few months of the Project, it became obvious that the lack of facilities for research on the other islands, and the poor facilities in Timor at that time, would make it impossible to extend useful work beyond West Timor. For that reason, the Project was confined to several locations within reasonable proximity of Kupang, West Timor. A brief visit was made to east Sumba (Waingapu) to assess the local support for work there. It was clear that, although local forestry staff were keen to see research initiated in Sumba, there was no suitable nursery facility and no staff who could be dedicated to looking after field trials. There was also a severe shortage of vehicles in the Dinas office.

ENVIRONMENTAL DESCRIPTION

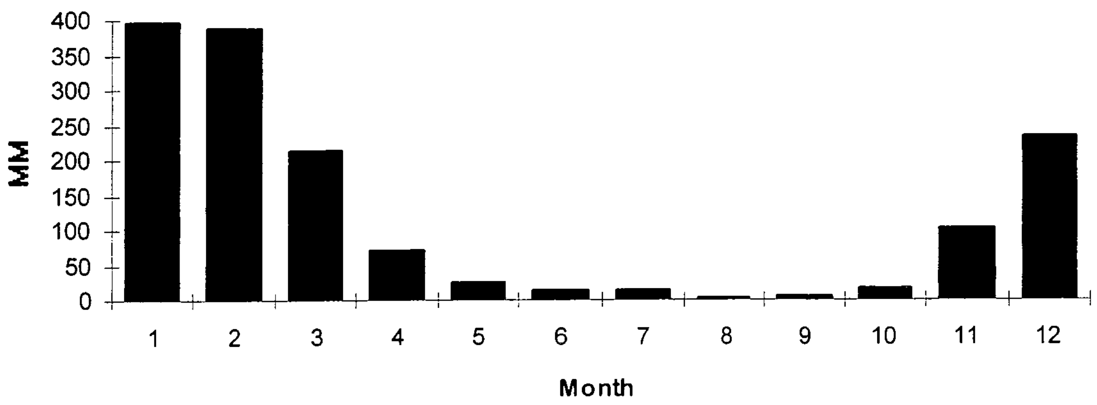
It is necessary to give a brief description of the climate and soil conditions found in West Timor in order to appreciate the difficulties encountered in this Project.

Climate of West Timor

The climate of Timor is characterised by a short rainy season and uniformly high temperatures. However, there are marked spatial as well as season to season differences in rainfall distribution and timing. Rainfall is often of high intensity, making for a high erosivity potential (Duggan 1989).

The average annual rainfall at Penfui, near Kupang airport, is 1489 mm, but this is extremely variable, being as low as 163 mm and as high as 2379 mm during the period 1966-92 (data from Crippen Consultants, Kupang). The average distribution of the rainfall during the year is shown in Figure 1. However, the variation in the distribution during the wet season is as important as the total rainfall in a year.

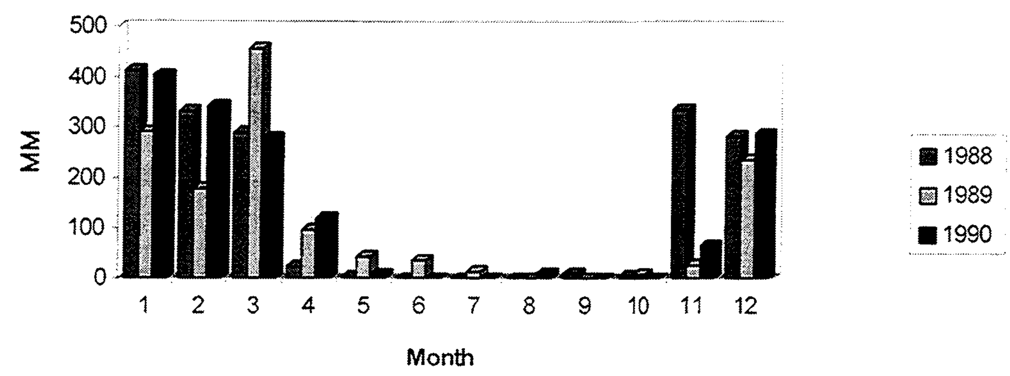
Figure 1. Average Monthly Rainfall Penfui 1966-92



To give an indication of how the rainfall factor varies during the course of the project, the seasonal rainfall for 1988-1990 is shown in Figure 2.

The mountainous topography is responsible for a high degree of spatial variation, and the relatively dry monsoonal climate is highly variable in the time it begins and in total rainfall received in different parts of the island. The latter characteristic made it difficult to get consistent results from field trials and presented difficulties in judging the optimum time to go to Timor for the planting season. We sometimes planted in December and sometimes in January. The convention used in this report is to date the trials by the January of the wet season (December-March) in which they were planted. Thus a plot actually planted in December 1988 would be called a 1989 plot. This is done to avoid confusion if two series of plots were planted in the one calendar year, but two different planting seasons.

Figure 2. Rainfall During Project



Geomorphology and Soils

Timor is one of the Outer Banda arc of islands, which also includes Roti, Sawu and Sumba. All are fundamentally different from the remaining Indonesian archipelago in that they are formed on the edge of the Banda tectonic plate, a small plate which is being uplifted by the northward movement of the large Australian plate.

The basic building block of these islands is a stony clay known as Bobonaro clay (after the type site in East Timor) which was laid down in a submarine environment. In places, depending on subsequent geomorphological history, the Bobonaro clay is overlain by coral or marl deposits. All of these three basic soil parent materials have given rise to a group of soils with fairly consistent characteristics. Subsequent erosion and natural processes have served to complicate this situation.

The three basic parent materials and the soils which have developed on them are as follows:

- Bobonaro clay, on which are found soils classified generally as vertisols, or pellusturt in the new soil classification system.
- Viqueque marls, on which the main soil type is an entisol. We could not easily classify these soils in the new system.
- Raised coral terraces which produce ultisol soil types, or rhodustalfs.

This is, of course, an oversimplification of the situation in West Timor, but it provides sufficient background to understand the reasons for the design of the field trials.

The red loams developed on the raised coral terrace, classified usually as rhodustalfs, are the most fertile soils found on Timor and are consequently keenly sought after for agriculture. They are moderately alkaline, with a pH of 7-7.5. The soils developed on the other two parent materials are considerably less fertile and are highly alkaline, commonly having a pH of 8 and greater. Soils developed on Bobonaro clay tend to be sodic, with exchangeable sodium percentages often exceeding 15 per cent (Aldrick, 1985).

In the field, the soils are extremely variable, and even within the vertisols found on the Bobonaro parent material, there is considerable variation to be found. We wanted to encompass the most harsh sites found on Bobonaro clay, since this is the most refractory site found in Timor, and the one where most land degradation is taking place. However, this was not always possible. We did use one such site at Besi Pae, but this became virtually unusable after the departure of ACIL staff from the area. Consequently, we used a different phase of the same basic soil type, on level ground rather than on a slope, but the description of the soil more accurately matched that of a pellustert. This is the case at the Siso site and part of the Oetium site.

The entisols were not sampled adequately in Timor, as such sites were simply not readily available. However, the second ACIAR Project in NTT will use this type predominantly in Sumba.

We did not carry out any soil analysis of the field trial sites. The research station had neither the skills nor equipment to do the required analysis, and our contacts with other agencies gave us no confidence that any analysis performed in NTT would be properly carried out. The normal practice is to send soil and plant samples to Bogor, in Java, for analysis, and this process is notorious for delay. We did not attempt to bring any samples back to Australia for testing as it was not considered worth the very considerable effort that would have been involved.

Since a great deal of soils research had been carried out by the Canadian water resources project, we used their data as reference points. Typical soil analysis data at 0-12 cm depth given by CIDA are as follows:

	Olsen P_2O_5 ppm	*Organic C*	*Organic N*	*% Sand*	*% Silt*	*% Clay*	*CEC me/100 g*
Rhodustalf	132	2.65	0.24	22	42	36	32.4
Pullusturt	4	1.06	0.13	2	51	47	52.9

Data quoted here are for a pellusturt soil sample site not far from Oetium, and typical of the plot sites at Oetium and Siso. These data indicate an extreme phosphate deficiency on the pellusturt soils, and a relatively high phosphate status for rhodustalfs. We might therefore expect a growth response to phosphate application on the former but not the latter.

Combined with its rugged topography, the soils of Timor are highly variable spatially, usually stony, normally alkaline, usually sodic, and sometimes saline. All these factors combine to make it a difficult environment in which to grow trees and carry out field trials. The occurrence of stone, in particular on the rhodustalfs, is a major constraint to the layout of large field trials. There is also a marked altitudinal change in average temperature across the island, often accompanied by increased rainfall, and this has to be considered in choice of field trial sites.

Socio-economic Factors

Two major additional factors that complicate field research in Timor are the land tenure and land management. Most land is held under a customary form of tenure, but the Government had overlain forest reserves and national parks over this, resulting in considerable conflict between local people and the Ministry of Forestry. This conflict means that local people are often unsympathetic to research field trials established in their region. Free range cattle grazing is rife in the island, especially since the psyllid epidemic devastated *Leucaena* populations which were the mainstay of the economically important beef industry. Grazing resources are in short supply and farmers try to use anything available, even if it is behind a barb wire fence.

There is also very strong demand for land in the province. Unless land is being consciously spelled, as part of a shifting cultivation cycle, it is in constant use. Cultivation cycles vary according to soil type, but on the upland topographic situations, which are dominated by soils derived from Bobonaro clay and Viqueque marls, the return cycle is of the order of seven years, far too short for adequate recovery of the land. Consequently, most observers believe the province is in a steady downward spiral of productivity. The widespread occurrence of obvious land degradation through soil erosion supports this view.

Fire is extensively used to improve grazing potential during the long dry season, and much of the burning is uncontrolled. These two factors mean that field trials are under threat of damage or loss every dry season. Consideration of these factors sometimes constrained selection of trial sites. The project also lost some plots to fire and grazing during the three years and thus lost useful information.

INSTITUTIONAL ASPECTS

Indonesia

The nominated counterpart for the Project was initially Ir Komar Soemarna, Director of the Forest Research and Development Centre at Bogor, later succeeded by Dr Ombo Satjapradja. This arrangement was, in practice, a burden to the project, since liaison with the counterpart officer required a special trip to Jakarta by the Project Leader. The normal difficulties with communication on occasion meant that a trip would be made to Bogor in vain, even though care had been taken to set up a meeting through the ACIAR country manager in Jakarta. It is evident, from the experience of this project, that the Agency for Forest Research and Development is not adequately resourced to provide the necessary liaison for projects of this nature in eastern Indonesia.

It also proved difficult to ensure that the Bogor-based counterpart was able to take part in annual Project reviews. Only one review during this project was able to include the counterpart, despite considerable efforts being made to facilitate his attendance.

On the local level, the first point of contact was with Ir Sutarjo Suriamihardja, officer in charge of the Kupang forest research station (BPK). His role in the Project was one of support (which was readily forthcoming and most cooperative) rather than direct involvement in the research. That was delegated to Harisetijono (Hari), a fairly new graduate with some previous experience in dipterocarp regeneration surveys in Kalimantan. This proved to be a happy choice, as Hari was very capable, enthusiastic and diligent. Without his hard work, the Project would have achieved little.

Department of Conservation and Land Management

Several CALM staff took part in this Project. In addition to the Project Leader, Roger Edmiston took part in the early nursery development and the first year of field trial establishment. After his retirement, Peter White from CALM's Broome nursery took his place for the next two years while specialist nursery expertise was still required. Mr Joe Havel, a retired CALM officer with extensive research experience in WA and in tropical forestry in PNG gave invaluable input for the duration of the Project. As the nature of the work changed it was necessary to bring in agroforestry expertise from Mr Richard Moore.

Our normal modus operandi was to undertake a trip to Kupang in August each year to plan and organise the research program for the coming wet season. After discussions with Mr Sutarjo and with Harisetijono we drew up a research plan for the season. We then discussed areas available for field trials with Dinas staff. We inspected the site and worked out what activities were required to achieve the objectives set to in the research plan. This was done in writing, with Bahasa Indonesia translation if required. In all our activities we were conscious that we were in a partnership with our Indonesian colleagues.

Seed was ordered from the Tree Seed Centre in Canberra and taken up to Kupang, usually by Roger Edmiston or Peter White in early October. On this trip the nursery details were worked out and all the seed sown, with instructions and training given for any unusual procedures.

In most years the whole team came to Kupang in early January for the planting season to assist the BPK to carry out herbicide application and lay out the trials. In most years various nursery problems meant that the research program had to by modified on the fly in order to gain most benefit from what seedlings were available. This phase was always a risk as travel arrangements had to be made several weeks ahead, and there was always a possibility that our visit would coincide with a dry spell. This did happen more than once but we usually found that it was possible to reschedule activities to use the time usefully.

Our approach to fieldwork was very much hands on. While we employed local farmers to carry out planting operations, we always took part in training them to ensure proper procedures were followed, and if resources were limiting we often took part in weed control or planting operations.

Curtin University

Most of the work undertaken by Curtin University was carried out by Dr John Fox, but he was assisted in nursery work at Curtin by Dr Diana Barrett. Dr Fox had a similar modus operandi to CALM personnel.

Communication

A major problem throughout the Project was communication with Kupang. After 1989 the BPK had its own telephone, but achieving a connection during working hours from Australia was almost impossible. Telex to the central telecommunication office was more reliable, in that at least the message reached Kupang, but unfortunately it often went no further than the central telex office. This problem was often a complication in trying to warn the research station about our visits. Mail was even more uncertain. After one consignment of seed sent in the mail was lost, we made a practice of arranging trips to Timor so that we could take up the seed ourselves.

At the commencement of this Project the BPK had almost no research equipment and its capacity for field research was extremely limited. Lack of operating funds and limited staff resources in Kupang continued to be a difficulty throughout the Project. As conditions at the BPK improved over the three years, it became under heavy pressure from the Dinas to undertake research to assist their management, making it difficult at times to devote adequate attention to longer term research.

Provision of Equipment

One of the objectives of the Project was to upgrade the research capacity of the Kupang station by providing some equipment. During the three years of the Project the following materials were provided:

One vehicle (Kijang station wagon)
Laboratory oven for dry weight determination
Lab balance
Stihl motorised sprayer

Relaskop
Motorcycle
Statistical analysis software
Compass and measuring tapes
Sundry picks and mattocks
Refrigerator for seed storage
Miscellaneous lab glassware
Plastic tape, labels and other field markers
Safety equipment
Projector
Overhead projector
One copy of Minitab statistical analysis software

In addition we frequently bought polybags, fertiliser and soil for the nursery, and paid for hire of trucks to take seedlings out to the field and for labour to prepare sites and plant seedlings.

Training

During 1989 two of the research station staff, Harisetijono and Udi Tiyastoto, were brought to Perth for five weeks for intensive training on several aspects of forestry research. They also travelled to Kalgoorlie to inspect the operation of the sandalwood industry in Western Australia. Udi spent part of his time at the WA Government Chemical Labs, learning how to sample and measure sandalwood oil content, and to use the Minitab statistical analysis software package. Hari was more concerned with research field trial establishment and management, although he also spent some time on Minitab. Unfortunately, much of the benefit of this training was lost when Udi later transferred to Java.

In addition, to this formal training, we went to considerable trouble to use our visits to Timor to maximise the in-service training aspect. We always included Hari on discussions about research planning and jointly worked out work schedules with him, usually translating them into Bahasa Indonesia (the CALM team devoted considerable effort to learning Bahasa Indonesia in order to improve communication with colleagues from Timor). We also made it a practice to take up copies of relevant scientific journal articles for the station library, including some spare copies of journals bought by CALM.

From early 1991, Hari was absent for extended periods undertaking English language training in order to apply for an ACIAR Fellowship. This adversely affected plot maintenance and meant reduced capacity to carry out plot measurements.

During 1990, funding was obtained from the Crawford Fund for Agricultural Research to bring Ir Sutarjo Suriamihardja and another colleague from the Bogor research centre to Canberra for a special short course in research administration operated by ANUTECH. A report on the content of this course is attached at Appendix 2.

Poor nursery practices were early seen as a problem in Timor and much effort was devoted to rectifying this situation. An Australian-style shade house was constructed and a lot of time was spent with the research nursery staff explaining procedures and monitoring performance. This was reflected in greatly improved nursery stock in the second and third years of the Project. The proof of successful technology transfer in this instance was the subsequent construction of a similar shade house by the research station, for their own work.

Harisetijono and Udi Tiyastoto training on Minitab system with Dave Ward

Taken as a whole, it is considered that the Project has adequately met the objective of improving the research capacity of the Balai Penelitian Kehutanan. There has been a high level of skills transfer to Harisetijono and his principal technician Dedi Setiadi. Hari demonstrated his improvement by establishing a very well designed and executed agroforestry trial at Buat in 1990. The equipment provided by the Project, especially the vehicle, have greatly aided its capacity to support field research. The main area where the improvement was not sustained was in the field of computing, where the departure of Udi and Hari's other work left the BPK without adequate skills in that area.

Sikumana shadehouse. Sarlon cloth sidewalls removed to harden off seedlings

Second shadehouse built by BPK for sandalwood seedling production

EXPERIMENTAL APPROACH

Sampling soil types

In order to provide useful information for the regional forest service as to what species of tree would do well under Timor conditions, it was considered necessary to test the three main soil types on the island, and also to test the variation between the hotter lowlands and the cooler highlands. Ideally, a single experimental site would have been selected for the duration of the Project. This would have enabled more efficient protection of the plots and more economical field operations. However, it was not possible to do this, and we were obliged to use a new set of plots almost every year, after extensive discussion between the station and the Dinas (regional forestry service) staff.

The first step on arrival in Timor in September 1987 was to gather any information available on the climate, soils, and forestry activities. In this we were aided by the excellent survey work and environmental information complied by the Canadian Crippen Consultants, for the Timor Water Resources Study. Canadian staff with Crippen were most helpful with the provision of information.

Additional information on geomorphology and soil formation was provided by the Australian company ACIL, who were engaged in the AIDAB-funded NTT Integrated Area Development Project. Some ACIL staff members actively supported the ACIAR Project, especially Mr John Janes, an agronomist lecturing at the University of Nusa Cendana (Undana), who made available trial sites at Besi Pae, and arranged for two series of plots to be established there. The intention was to use the plots as a student exercise, both in plot establishment, and later for measurement. ACIL also kindly provided more practical assistance with the loan of a vehicle when no other was available during the second planting season in 1988/89. We are most grateful to ACIL staff, especially Alan Smith, then ACIL project leader, for their kind assistance.

Until the ACIAR Kijang arrived in Kupang, access to vehicles was a problem as the BPK had only one (very unsuitable) Mitsibishi van. We did attempt to use an AIDAB-owned Land-Rover stationed in Kupang but as this was a vehicle of legendary unreliability it was more trouble than it was worth.

There are no detailed soil maps for NTT, apart from some produced for specific, limited agricultural projects, but on the basis of the information available, it was decided to establish field trials on soils developed on the three main parent materials: Bobonaro clay, Viqueque marl and raised coral terrace, and on highland sites near Soe, 120 km from Kupang, and on lowland sites nearer Kupang. The inevitable consequence of this was the creation of a number of scattered field plots, with the attached difficulties with maintenance and protection. However, we believed it was necessary to do this if the results were to be helpful to local foresters in a practical way.

In retrospect, it would have been most advantageous if the Kupang research station had been able to have a series of large (say, 50 ha) research sites on the main soil types set aside and secured, with staff living on site, as they have at Sikumana. This would have greatly improved efficiency in plot establishment and maintenance, and the level of protection afforded the plots.

The field trials established during the Project were as follows:

Year	*Bobonaro*	*Viqueque*	*Raised Coral Terrace*
1988	-	Besi Pae	Sikumana
1989	Besi Pae Buat (Soe)	Besi Pae -	Sikumana Buat (Soe)
1990	Siso, Oetium -	- -	Sikumana Binaus

Species selection

In selecting species for trial in Timor, we concentrated on species from the northern part of Australia, for two reasons:

1. seed from that region was easily available from the CSIRO Tree Seed Centre;
2. species from this area were adapted to similar climate and soil conditions.

A further consideration was that we could obtain some information on the weediness potential of Australian species but could not count on similar information for potential species from other parts of the world. Some species, such as *Prosopis julifera*, which is likely to be well adapted to Timor, were deliberately not tested in this project due their known weed potential.

The Project was not intended to test all possible species in any case. If the necessary research skills were successfully transferred, the research station could continue this line of research if it were accorded a continuing priority by the Ministry of Forestry.

A complete list of the species tested in each year of the Project is given in the Results section of this report. In each year's planting we adopted the practice of always using several local species as markers, in addition to eucalypts, Acacias, Sesbanias and other species from Australia. There were two reasons for this:

1. if the introduced species could not do better than the local marker species it would be unlikely to be of value in Timor;
2. some local species were not widely used for reforestation and their inclusion in the Project was a good way of gaining familiarity with their performance on a range of sites.

Nursery procedures

All seedlings for the project were raised at the Sikumana nursery, about 6 km from Kupang. As noted above, considerable effort was required to ensure that suitable seedlings were produced in time for planting out in December or January. We normally sowed seed in September, aiming to raise seedlings which were 30-45 cm in height by the following January. We were concerned about the provision of *Rhizobium* for the *Acacia* species we used and, lacking any information at all on *Rhizobia* in NTT, brought inoculum from Perth for the first two years. This was a cocktail of various strains of *Rhizobium* used for agricultural purposes. We had no way of knowing at that time whether this inoculum was well suited to *Acacia*, but there seemed no difficulty in raising good quality seedlings when it was used.

We also provided Sikumana nursery with fungicides for control of damping off, and trained nursery staff in their use. Diseases were not a major problem in the nursery, but there were occasional instances of severe insect attack, mainly by beetles.

We normally sowed, in the case of large seeded species like*Acacia*, two seeds per polybag, and then thinned as necessary to one healthy seedling per bag. For the eucalypts, seed was broadcast in a tray and later pricked out into polybags.

Experimental design

The standard plot design used in the Project was a 25-tree plot, planted at 1 m x 1 m spacing. As the intent of the Project was to screen species for suitability and utility for the Timor environment, this was sufficient to give an indication of survival and early growth up to about three years. It also minimised plot establishment, maintenance and protection costs and workload. For a research station with limited resources, this was a very real consideration.

Normally, we aimed to get four replicates of each species at each site, in a randomised block arrangement. The idea was to simplify data analysis, however, it was found that this simple approach was inadequate, due to missing plots and variation in species planted at different sites, and more sophisticated analytical techniques had to be used (see Results section below).

We based our assessments of growth on survival and height growth measurements. It was realised that height data are not an entirely satisfactory way of evaluating performance of some species, especially those which tend to have a flat-topped growth habit. We would like to have used more complex measurement techniques, but were limited by staff availability at the station.

The research program was planned to move in a systematic way from identification of a group of more successful species for each major soil type (if significant differences existed between them), to provenance testing to establish the best source of seed for NTT, to silvicultural trials to point the way to how candidate species might be managed in a small farmer situation. The first two years of trials were occupied completely by species screening trials, but the third year contained a smaller series of species trials and concentrated on provenance trials of a few target species and the establishment of 'production trials' aimed at the provision of sufficient material for silvicultural research.

In 1990 we established two such 'production trials' at the Oetium field trial site.*S. grandiflora* and *A. colei* were planted at row spacings of 2 m, 3 m, and 5 m, with the intention of using them for alley cropping with local farmers. Unfortunately this did not happen, partly due to the hiatus during the development of the second ACIAR project to follow this one, partly because Hari left for English language training in Bali, and partly because the demands on the resources of the BPK escalated at that time and it was not possible to divert other staff onto this work. Because it would have involved much careful negotiation and extension work with local farmers, it would have been a very resource-intensive exercise. However, both these areas did later serve as useful sources of seed of those two species.

Establishment Procedures

While most plots were laid out in areas already cleared, it was sometimes necessary to clear some natural vegetation off the trial area. In the latter case, care was taken to move all debris off the trial areas before burning in order to avoid localised ash bed effects.

As all plots carried a heavy sward of grass and other herbaceous material, we always carried out a complete pre-planting spray with Roundup. For this purpose, we purchased a Stihl backpack motorised sprayer, which was a very effective way of covering a large area quickly and efficiently. Research station staff readily adapted to its use. Care was taken to ensure that appropriate safety precautions were followed.

'Production trial' established at Oetium for alley cropping experiments

Applying Roundup from knapsack sprayer. Note protective clothing.

Although the Roundup gave good initial grass control, it was normally necessary for station staff to arrange for one or two subsequent hand cuttings of regrowth grass around each seedling in the first year. In addition, we went to considerable lengths to ensure that there was a good firebreak around each field trial area before the onset of each burning season. This proved its value several times when wildfires burnt up to the boundary of the plots. As there is no effective bush fire fighting system in NTT, the plots had to be rendered more or less non-flammable by June each year. However, we did lose one series of plots at Sikumana in the first dry season after planting. This was a series of plots scattered among rock outcrops which research station staff could not adequately protect by firebreaks.

We ensured all plots were properly fenced with barbed wire to exclude cattle and pigs. This did not prevent the native deer (*Rusa timorensis*) jumping over the fences and attacking seedlings, especially at Besi Pae. It also did not prevent antagonistic farmers breaking down gates and deliberately bringing their stock into the plots. This happened at Buat RCT and at Siso. It also happened at Sikumana, although Hari's action in shooting a cow belonging to an offending farmer put a stop to the problem at that site.

It was not possible to have field trials ploughed, as would have been desirable, as few tractors exist in NTT. The soils normally set quite hard during the dry season and require breaking up with a short crowbar before planting is possible. For planting we hired local people on a daily basis to dig the planting holes and plant the seedlings. The ACIAR Project normally covered the cost of hired labour, their drinking water and midday meal.

Buat Raised Coral Terrace plot 1989 showing grass control from Roundup spray

For the species screening trials we had no information on the possible need for the use of fertiliser in NTT. We did know that apart from the rhodustalfs, the soils are considered to be deficient in P, N and perhaps K, but the requirements of the species being tested were unknown. We attempted to gain some information on this aspect by applying fertiliser to half the four replicates of each species at each site. The fertiliser used was triple superphosphate applied at 50 g per tree in a circle about 20 cm from the seedling in the month after planting. In practice, this did not provide any useful information at all, as we nowhere observed anything better than a transient growth response. We presume the level of applied fertiliser was insufficient to overcome the soils' capacity to fix phosphate, or that the deficiencies in the other nutrients was so acute that the plants could not respond to the phosphate.

RESULTS

The original intent of the experimental design was to use a relatively simple design, randomised complete blocks, established on different soil types and climatic conditions, so that the whole dataset could be combined to make statements about the suitability of various tree species for the range of soils and climate found in NTT.

In practice, it was not possible to obtain a 'clean' field trial situation due to lack of sufficient seedlings in some species, variable representation of species at all field sites and highly variable survival. We took the view that it was better to provide some information about a species' performance, by including fewer seedlings than desired, or seedlings of marginal quality, than to reduce the field program severely in order obtain ideal field trials. The inevitable consequence of this was data which required much more complex statistical analysis.

In this report we have used both raw plot data to illustrate trends, and more sophisticated analysis to make general conclusions.

Advice was sought from CALM biometrician Matt Williams, who advised the use of modified joint regression analysis (Digby, 1979), as being suitable for incomplete data of this nature. This approach was not without its problems, as noted further on, but appeared to be the best one could use under the circumstances. As a result, the data quoted here for the analyses of tree growth in the various trials are not the actual treatment or species means, but the Best Linear Unbiased Predictors (BLUPs).

The field data collected by the BPK in most cases constituted tree heights. Late in the Project it was possible to obtain some diameter data, but they are relatively limited. It is fully realised that height measurements have their limitations, especially if one is comparing species with very different growth habits, but it was felt that it was the only practically feasible approach to take, given the resources available to the BPK.

We would like to have undertaken much more intensive field measurements along the lines described by Briscoe (1989), but the resources available at the BPK, and the time available to CALM staff did not permit this on all field trials. We did, however, do detailed measurements for trees thinned for fuelwood from the first field trial at Sikumana, when they were thinned in 1992. Only a summary of the data gathered is presented here as it still remains to be analysed.

The results are presented in five sections,as follows:

- Section one covers the first year's (1988) species screening field trial on the Raised Coral Terrace (RCT) site at Sikumana, in the lowlands near Kupang and on a Viqueque site at Besi Pae, about 70 km from Kupang.
- Section two includes further species screening trials on RCT and Bobonaro soil types in the highlands near Soe, and in the lowlands at Sikumana (RCT) and at Besi Pae (Bobonaro and Viqueque) in 1989.

- Section three covers Acacia provenance trials (of the most promising species from 1 and 2 above) established in 1990 at Oetium in the lowlands and Siso in the highlands, both being pellusturt soils types.

- Section four presents the results of species trials with Sesbania in 1990 at the same sites as for Section three and also at Binaus, on a rhodustalf (Raised Coral Terrace).

- Section five includes further species trials established in 1990 at Siso and Binaus in the highlands.

Plot site descriptions

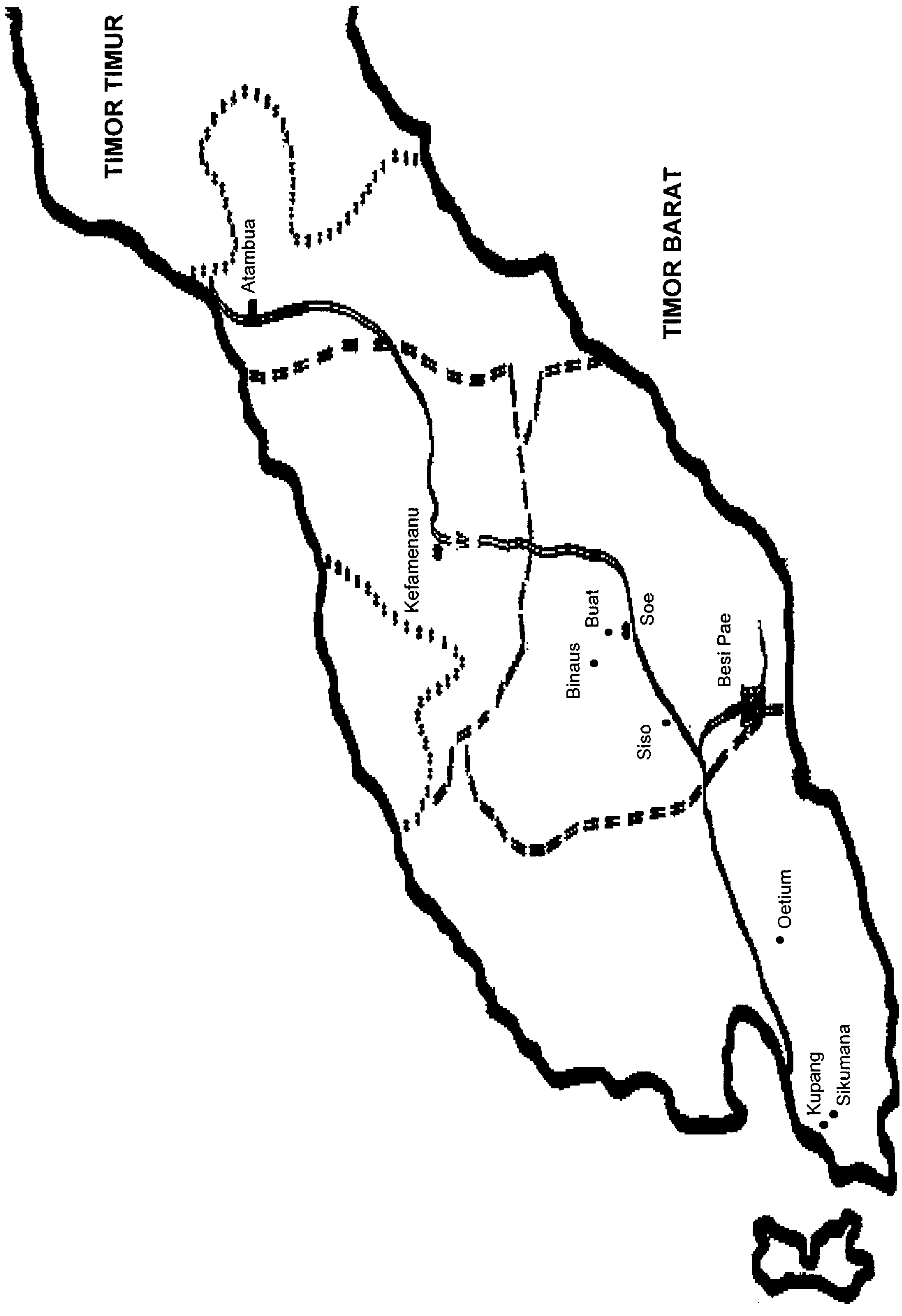
Sikumana is located about 7 km south from Kupang (see Figure 3). It is an area of about 20 hectares in total. mostly a very stony Raised Coral Terrace site, which is owned by the Dinas Kehutanan. It has carried high forest in the distant past but has been heavily modified by human occupation over centuries. Occasional remnant trees of *Alstonia* sp and other dry monsoon forest species may be seen but the dominant present vegetation is a woodland of *Tecoma* sp. Despite its tenure, local people still cut fuelwood and fodder off the area, and this was somewhat of a problem during the Project as we lost some trees of the best species taken for fuelwood and for fodder (mainly *Sesbania grandiflora*). The BPK maintains a pondok (a small residential outstation) there with staff living on site and operating the research nursery. rainfall is about 1000 mm. Where there is soil on this site, it is the most fertile of those used in this Project. Soil pH is in the range 7-7.5.

Besi Pae is about 70 km east of Kupang, close to sea level, and was the site of intensive integrated area development activities by the ACIL staff in cooperation with Undana (Nusa Cendana University). Soil types are quite variable, as everywhere, but part of the area had been intensively mapped by ACIL so that we had access to area of known Viqueque and Bobonaro types. While ACIL staff were still there we also had assistance with fencing and firebreak maintenance. Rainfall is about 800 mm. In terms of general fertility, the Viqueque site at Besi Pae would be rated as moderate by Timor standards, although it is very alkaline (pH 8-8.5), while the Bobonaro site was extremely harsh, being shallow, stony highly alkaline (pH 8-9) and obviously of poor fertility. The natural vegetation of the Viqueque site is savannah with patches of kabesak (*A. leucophloia*) and gewang palm (*Corypha gebanga*), while the Bobonaro site is a more open grassland, presumably maintained that way by fire, with scattered gewang and *C. junghuhniana*.

Siso is a small area cleared in the past for ladang within a relictual area of dry monsoon forest about 100 km east of Kupang, at about 700 m altitude. Even though it is reserved forest land, there is continual grazing by horses and cattle. The soil type is a pellusturt, having a heavy texture, severe cracking on drying, highly alkaline and probably sodic as well. pH was not measured directly but would have been 8-8.5. Rainfall is similar to Besi Pae at about 800 mm, judging by the natural vegetation. Even though its parent material is Bobonaro clay it is in a depositional position, and is therefore deeper than extreme sites like Besi Pae Bobonaro and has a higher organic matter content. The plot area is savannah with an overstorey of kabesak.

Oetium is a Bobonaro clay site about 30 km to the east of Kupang, just south of the village of Oesau. It is located on undulating topography in an area which has been used for ladang for many years, but has been 'reclaimed' by the Dinas. Perhaps due to this action, there is considerable friction with local people and arson is a major problem in the research area. Rainfall is lower than at Kupang, and is estimated to be about 700 mm. The 1990 plot site is very similar to Besi Pae Bobonaro, but not so stony. Natural vegetation is savannah with gewang and *E. alba*, definitely maintained this way by frequent fire. Dinas attempts to establish a plantation of mahogany around our experimental area were twice destroyed by fire.

Figure 3. MAP SHOWING LOCATION OF FIELD TRIAL SITES IN WEST TIMOR



Buat is located just to the north of the town of Soe, 120 km from Kupang. It has two soil types, a rhodustalf on raised coral terrace and a pellusturt on Bobonaro parent material. The altitude is 900 m above sea level, the topography is undulating foothills and the climate is noticeably cooler than Kupang. Annual rainfall is 1200 mm. The rhodustalf site is identical to the Sikumana doline and the Bobonaro site is similar to Oetium and Besi Pae, but with a higher rainfall. Both sites at Buat have an open woodland of *E. alba* with scattered *C. junghuhniana*.

Binaus is a stony rhodustalf site about 10 km to the north of Soe, along the road to Kapan. Rainfall is probably similar to Soe, but it can be adversely affected by localised falls. The soils is thinner and more stony and it was chosen to evaluate this type of site, which is quite common in the area. The vegetation was the same as at Buat.

Section One - The 1988 species screening trials

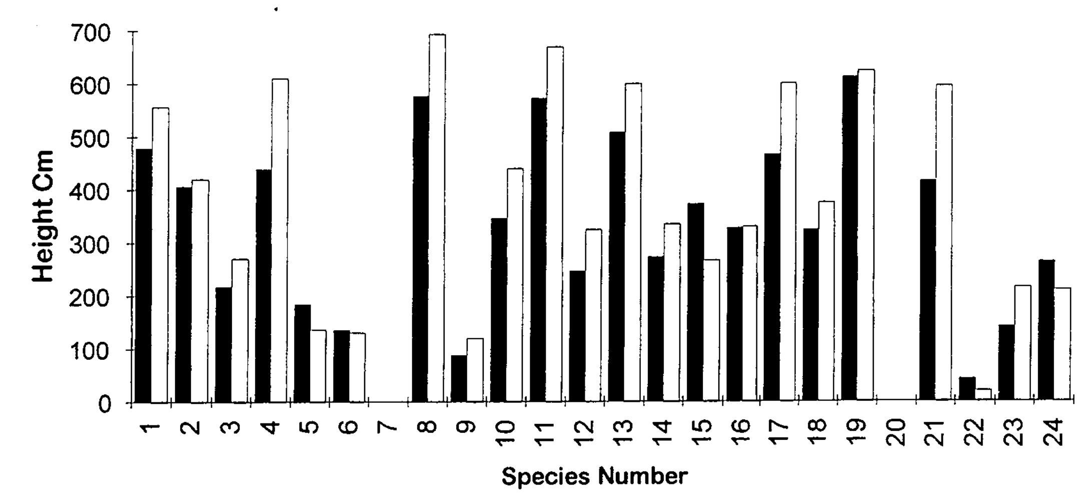
The 1988 field trials at Sikumana were established on two areas; a stony upland site where plots had perforce to be scattered among rock outcrops, and a much better lower site, called here Sikumana doline, as it was a relatively large area of good soil located in a doline, or sink hole, in this karst landscape. We also wanted to sample the Viqueque soils and located one block of the Sikumana trial on an area near Besi Pae which had ben mapped as this type by soil surveyors working for ACIL. The latter was established by John Janes of ACIL.

Data are available for annual height measurements for Sikumana (doline only) and for ages 1 and 2.6 (1990) at Besi Pae. The full scale analysis of the data using the joint regression analysis approach was carried out using the final measurement data in 1991. Therefore, no analyses are available for the 1988 Besi Pae (Viqueque) plots and the upland part of the Sikumana plots was burnt out in the first dry season after planting. The collection of data for the Besi Pae plots was intended to be done by Nusa Cendana University students, but after the departure of ACIL staff it was difficult to establish contact with any responsible person who would fulfil the original intention. The isolation of Besi Pae, the absence of Hari on English language training in Java, and their heavy work program meant that it was extremely difficult for staff of the BPK to carry out the measurements there in 1991.

Due to missing values, only 83 out of 100 plots could be used in the analysis of Sikumana doline.

Although we do not have final measurement data for Besi Pae, we can infer the results fairly well from a comparison of the height data for Sikumana for 1990 and 1991, where the trends are very similar (see Figure 4).

Figure 4. Sikumana Species Trial - Comparison of 1990 Mean Plot Data with 1991 BLUPs



Species Key

1	*A. crassicarpa*	15479	9	*C. cristata*	15216	17	*E. camaldulensis*	15050
2	*A. leptocarpa*	15478	10	*E. alba*	12993	18	*A. holosericea*	14660
3	*A. shirleyi*	14622	11	*E. tereticornis*	14212	19	*A. crassicarpa*	13681
4	*E. tereticornis*	13661	12	*E. microtheca*	13360	20	*Sesbania formosa*	15439
5	*C. equisitifolia*	14196	13	*E. camaldulensis*	13662	21	*S. grandiflora*	local
6	*C. equisitifolia*	14196	14	*E. microtheca*	15322	22	*A. leucophloia*	local
7	*A. ampliceps*	17052	15	*Cassia siamea*	local	23	*A. stenophylla*	14670
8	*A. auriculiformis*	15477	16	*E. citriodora*	14850	24	*C. junghuhniana*	local

It can be seen that there are no gross differences in the mean height data for Sikumana in 1990 and the BLUP estimates for 1991. Therefore, we can reasonably compare 1990 height data from the two sites and be assured that any significant differences will be real. Nevertheless, some caution is necessary in interpreting the results as the data at Sikumana are based on the means of four field plots while data from Besi Pae are based on the mean of only two plots.

Plant Survival at Sikumana

In terms of survival, three of the exotic species were failures at Sikumana, namely:

Acacia ampliceps	17052	Roebuck Plain WA
Sesbania formosa	15439	Maitland R Hwy WA
Acacia stenophylla	14670	Cow Creek WA

These were excluded from the analysis because of low number of survivors, only the occasional plant remaining in 1991.

The highest number of survivals, usually greater than 80 percent, was found in following species:

Acacia auriculiformis	15477	Mt Molloy QLD
Acacia crassicarpa	15479	Coen Qld
Acacia crassicarpa	13681	Mata Prov PNG
Acacia leucophloia		local
Eucalyptus citriodora	14850	Irvine QLD

Apart from the three species above rated as failures, the species with poor survivals in 1991, i.e. less than 30 per cent, were:

Sesbania grandiflora		local
Casaurina cristata	15216	Monto QLD
Acacia shirleyi	14622	Daly Waters NT

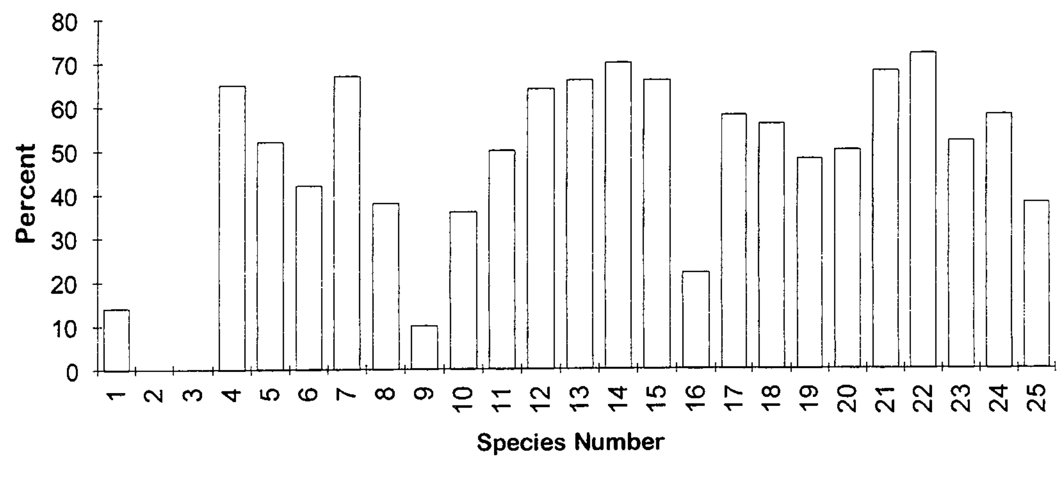
The remaining species had very variable intermediate survival.

These data do not, however, give the whole picture. The initial plant survival at Sikumana after the first dry season was acceptable for all species except those noted above as failures. Some species, such as both *Sesbania* species, suffered severely from termite attack, which is especially prominent on this site.

Survival at Besi Pae

Survival at Besi Pae is well illustrated by data from the 1990 assessment at age 2.6 years. There were some distinct differences from the results at Sikumana, reflecting the lack of tolerance of some species to the highly alkaline soil at Besi Pae (Figure 5).

Figure 5. Survival at age 2.6, Besi Pae P88



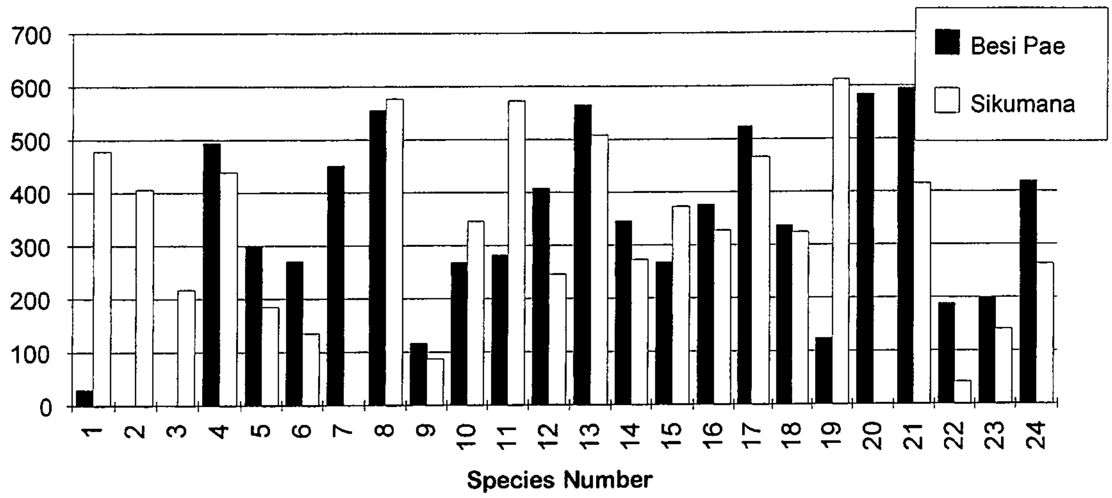
All the three species which were failures at Sikumana had good survival (greater than 50 per cent) at Besi Pae, while *A. leptocarpa* which was average at Sikumana and *A. shirleyi* which had a poor survival there, failed at Besi Pae.

Height Growth

(a) Comparison of Sikumana and Besi Pae Sites

Bearing in mind that one of the objectives of the trial was to evaluate tree performance on the two sites, it is useful to compare height data for the last year in which comparable data are available (1990). These data are presented in Figure 6, with the species numbers being the same as in Figure 4.

Figure 6. Comparison of height growth (age 2.6) for Sikumana and Besi Pae



There are some very significant differences in performance between the two sites for several species. Species 1 (*A. crassicarpa* 15479) was a good performer at Sikumana, but was a virtual failure at Besi Pae, indicating a dislike for alkaline soils. This was confirmed by observations at Besi Pae that this species was always chlorotic. The other provenance of this species, no 19, was not so severely affected, but still performed much better at Sikumana.

Species 2 (*A. leptocarpa*) was a failure at Besi Pae, while it had average performance at the other site. Species 3 (*A. shirleyi*) was also a failure at Besi Pae, however species 4 (*E. tereticornis* 13661 Mt Molloy QLD) performed slightly better at Besi Pae. This is in marked contrast to the other provenance of this species (number 11, S/N 14212 Helenvale QLD) where the height growth at Sikumana was double that at Besi Pae. Other species marginally better at Sikumana were *E. alba* (12993 Mt Molloy QLD).

Several species grew better at Besi Pae, indicating a preference for alkaline soils: 5 and 6 (*C. equisitifolia*), 12 and 14 (*E. microtheca* Richmond QLD), 21 (*S. grandiflora*) and 24 (*C. junghuhniana*), and *A. leucophloia* (22). The most outstanding examples of this characteristic were *A. ampliceps* and *S. formosa*, which were failures at Sikumana but among the most successful at Besi Pae.

Other species which seemed little affected by the site variation were *E. camaldulensis* (13, 17) *A. stenophylla* (23), *A. auriculiformis* (8), *C.cristata* (9), *Cassia siamea* (15), *E. citriodora* (16), and *A. holosericea* (18).

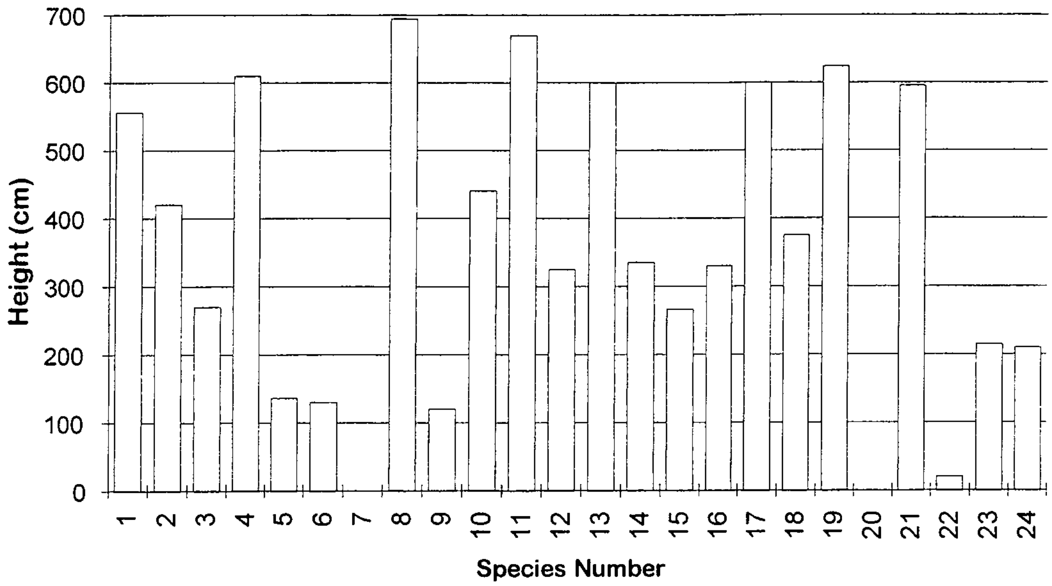
This trial has shown that the provenances of *Sesbania formosa* and *A. ampliceps* tested here and *S. grandiflora* displayed good growth and were highly tolerant of an alkaline site and three other species, namely *E. camaldulensis*, *A. auriculiformis* and one provenance of *E. tereticornis* grew as well and seemed insensitive to alkaline soils. Species with poorer growth performance but demonstrated adaptability to the alkaline site were *C. junghuhniana* (which grows here naturally), *E. microtheca*, and *C. equisitifolia*.

S. grandiflora (left) and *S. formosa* (right) at Besi Pae 8 months old.
The chlorotic plants in front are *A. crassicarpa* 15479

(b) Analysis of Final (1991) Measurement Data

The analysis of variance did not detect any significant effect of the fertiliser treatment, blocks nor any interaction between fertiliser/block or species/fertiliser. The only significant factors, at P=<0.0001, were the species. The data in Figure 7 below are estimates of height (BLUPs) for Sikumana only, derived from the joint regression analysis process.

Figure 7. 1988 Trial Sikumana Mean Height Estimates, Age 3.6 years



Species Key

1	*A. crassicarpa*	15479	9	*C. cristata*	15216	17	*E. camaldulensis*	15050
2	*A. leptocarpa*	15478	10	*E. alba*	12993	18	*A. holosericea*	14660
3	*A. shirleyi*	14622	11	*E. tereticornis*	14212	19	*A. crassicarpa*	13681
4	*E. tereticornis*	13661	12	*E. microtheca*	13360	20	*Sesbania formosa*	15439
5	*C. equisitifolia*	14196	13	*E. camaldulensis*	13662	21	*S. grandiflora*	local
6	*C. equisitifolia*	14196	14	*E. microtheca*	15322	22	*A. leucophloia*	local
7	*A. ampliceps*	17052	15	*Cassia siamea*	local	23	*A. stenophylla*	14670
8	*A. auriculiformis*	15477	16	*E. citriodora*	14850	24	*C. junghuhniana*	local

On basis of the analysis of height growth it is possible to define the following groups for Sikumana at age 3.6:

Total or near total failure:

Acacia ampliceps	17052	Roebuck Plain WA
Sesbania formosa	15439	Maitland R Hwy WA
Acacia stenophylla	14670	Cow Creek WA

Poor growth, mean <240 cm, upper range of confidence limit <390cm:

Casuarina equisetifolia	14196	Wangetti Beach QLD
Casuarina cristata	15216	Moonto QLD
Acacia leucophloia		local
Casuarina junghuhniana		local

The poor growth shown by the native species requires some comment. The *A. leucophloia* has an unusual growth habit, in that it behaves in a manner reminiscent of eucalypt seedling. It grows horizontally for several years, then sends up a dynamic shoot and makes quite rapid height growth before it tends to grow horizontally again in later life, giving the tree its characterstic flat-topped 'Out of Africa' appearance. At Sikumana and Besi Pae, it appeared that this initial horizontal growth period is four years, so it tends to show up badly in these trials.

C. junghuhniana appears to be less suited to the rhodustalf soil type, as indicated for the comparison of performance between Sikumana and Besi Pae above, possibly because it prefers an alkaline soil.

At the other end of the range, it is possible to identify a set of *superior species, mean height > 550 cm, lower range > 390 cm*

Acacia crassicarpa	15479	Coen QLD
Acacia crassicarpa	13681	Mata prov PNG
Eucalyptus tereticornis	13661	Mt Molloy QLD
Acacia auriculiformis	15477	Morehead r QLD
Eucalyptus tereticornis	14212	Helenvale QLD
Eucalyptus camaldulensis	13662	Petford QLD
Eucalyptus camaldulensis	15050	Gibb R WA
Sesbania grandiflora		local

The remainder of the species are *intermediate, with mean >240<550 cm,* lower range over lapping that of some of the inferior species, upper range overlapping that of some of the superior species.

Acacia leptocarpa	15478	Musgrave QLD
Acacia shirleyi	14622	Daly Waters NT
Eucalyptus alba	12993	Mt Molloy QLD
Eucalyptus microtheca	13360	Meda WA
Eucalyptus microtheca	15322	Richmond QLD
Cassia siamea		local
Eucalyptus citriodora	14850	Irvine QLD
Acacia holosericea	14660	Turkey Creek WA

Diameter Growth

On the basis of the analysis of the 1991 diameter measurement at Sikumana only, for unfertilised plots, the following groupings can be made:

Poor growth - mean diameter <2 cm, upper confidence limit at P = 0.05 <3.5 cm:

A. shirleyi	*C. equisitifolia*	*C. cristata*
A. leucophloia	*C. junghuhniana*	

Superior growth - mean diameter 5.5 cm, lower confidence limit at P = 0.05 >3.0 cm:

E. tereticornis	13661	*A. auriculiformis*	15477	*E. tereticornis*	14212
E. camaldulensis	13662	*E. camaldulensis*	15050	*A. crassicarpa*	13681
S. grandiflora	local				

Intermediate growth - mean diameter >2<5.5 cm, lower confidence limit overlapping that of some of the inferior species, upper confidence limit overlapping that of the superior species:

A. crassicarpa	15479	*A. leptocarpa*	15478	*E. alba*	12993
E. microtheca	13360	*E. microtheca*	15322	*Cassia siamea*	local
E. citriodora	14850	*A. holosericea*	14660		

This pattern largely holds for the fertilised plots, though there is a slight shift for many species either upwards or downwards compared with the unfertilised plots.

The only major shifts are *Sesbania grandiflora* which is markedly smaller than the unfertilised plots, however this is probably an artifact caused by partial collapse of the species after age three, due to termite attack. Prior to that, it has been the largest and fastest growing species. There is also a shift in *Casuarina equisitifolia* 14196, which moves it from poor to intermediate performer. However, as this is associated with broadened limits of confidence, due to over all low survivals and complete failure of one replicate, it needs to be taken with great deal of caution. It is therefore best to retain the broad classification of species based on the unfertilised treatment means.

Discussion

The replication of the 1988 trial at the two sites revealed some useful differences in the apparent tolerance of some species to alkaline soils. Some species were adversely affected by the more alkaline soil and others appeared to prefer it. Other species seemed to have wide tolerance of the level of soil alkalinity. The trials also were able to give good estimates of early growth performance on the two soil types. However, additional field trials which use a different design would be required to give definitive estimates of medium term yield.

It may be appropriate at this stage to look at the best performing species in terms of their origin, that is, whether they are local indigenous or naturalised species, or whether they have been introduced through the ACIAR project. The failed species 7 (*Acacia ampliceps* SN 17052), 20 (*Sesbania formosa* SN 15439), and 23 (*Acacia stenophylla* SN 14670) are all introduced species.

The species with superior performance, namely -

Acacia crassicarpa	15479	*Eucalyptus tereticornis*	14661
Acacia auriculiformis	15477	*Eucalyptus tereticornis*	14212
Eucalyptus camaldulensis	13662	*Acacia crassicarpa*	13681

are virtually all introductions through the ACIAR program. Only *A. auriculiformis* had previously been introduced to NTT.

The only exception is *Sesbania grandiflora*, which is an indigenous species already used extensively as part of shifting cultivation. Being a legume, it is a soil improver, as are the introduced Acacias, to which it is superior in terms of fodder value of its foliage. In addition, it has edible flowers, which are used as vegetable for human consumption. On the negative side, its wood is considered an inferior source of firewood and is virtually useless as construction material, being highly susceptible to termites. On susceptible sites, such as in the Sikumana doline, it is already in severe decline by age four.

The two Acacias that are superior in terms of their growth performance possess soil improving qualities and are also excellent sources of fuelwood and pulpwood, and in long term, of outstanding furniture wood. They are only suitable as emergency fodder for the drought season, having low palatability for cattle. They may also be useful as sources of pollen for brood build up of bees. The two Eucalypt species are outstanding sources of firewood, sound building timber and ultimately of sawn construction timber. In addition, they are potential sources of nectar for honey production, capable of supplementing the indigenous *Eucalyptus alba* and *E. urophylla*.

Thinning the Sikumana Trials

These field trials were intended only as species screening trials. Their usefulness for growth data really was confined to about three or four years, depending on the vigour of a particular species. Our intention was to thin the trials at Sikumana to demonstrate how such experiments could be used to gain much more information and to ensure that a few good stems were left for demonstration purposes.

Thinning took place over an extended period of time in 1991 and 1992, with most taking place in 1992, when the CALM team spent two days assisting Balai staff. Each plot, originally of 25 trees, if all had survived, was thinned to 4/5 good stems, as widely spaced as possible. Each tree felled was felled with a bowsaw or chainsaw, then diameter overbark was measured at 0.5 m from the butt, 1.5 m and thence every 1.0 metre to the top. It was then cut into fuelwood lengths of about 50 cm and made up into commercial sized bundles of fuelwood as customarily used in Kupang. Each bundle was weighed with a field balance and its price estimated by local people familiar with fuelwood prices. In this way we were able to estimate the level of production of fuelwood for each species, and also estimate the financial return from its use for fuel. For each tree we also recorded total height, dominance class,

We also weighed the green crown weight and collected foliage samples for dry weight determination, so that crown biomass production could be calculated. This was mainly a training exercise for BPK staff. In the event, the dry weights were not determined for all samples due to a need to move the oven to a different part of the research office, where it temporarily had no power point. This particular activity was therefore unproductive. However, the fuelwood yield data were of considerable value, and certainly of considerable interest to the labourers who carried out the thinning. They commented favourably on the weight and fuel quality of the material from the eucalypts and acacias in particular.

Fuelwood Yields, First Thinning, 1988 Sikumana Plots, Age Four Years

	Serial No.	*Treat-ment*	*Block 1 Total Wt kg*	*Block 1 Total Val. Rp*	*Block 2 Total Wt Kg*	*Block 2 Total Val. Rp*	*Est. Weight Prod t/ha*	*Est. Return Rp/ha*
E. camaldulensis	15050	UF	-	-	75.5	1125	20.97	251 600
E. camaldulensis	15050	F	73.5	475	105.0	1450	24.80	297 600
E. camaldulensis	13662	UF	146.1	1750	43.0	650	26.25	315 000
E. camaldulensis	13662	F	138.5	2525	105.0	1475	33.80	405 600
E. tereticornis	14212	UF	109.5	1525	214.75	3375	45.00	540 000
E. tereticornis	14212	F	240.75	2950	157.6	2450	55.30	664 000
E. tereticornis	14661	UF	109.2	1625	46.0	625	21.55	258 700
E. tereticornis	14661	F	26.5	425	187.0	2250	29.60	355 600
E. alba	local	UF	21.1	550	25.0	375	6.38	76 600
E. alba	local	F	-	-	35.0	550	9.72	116 600
Cassia siamea	local	UF	-	-	19.6	400	5.45	65 000
Cassia siamea	local	F	-	-	40.5	600	11.25	135000

NOTE: The yields are estimated by averaging the weight harvested off each plot, which still leaves two or three trees per plot remaining for other uses. The value returns are estimated by applying an average price of Rp12 per kg. While these are indeed rough estimates, they do indicate the possibilities for profitable land use in the vicinity of main markets like Kupang. The productivity advantages of the exotic species over the native *E. alba* and *Cassia siamea* are clear.

Section Two - The 1989 Species Screening Trials

For the 1989 field trials, a wider range of species was selected, with greater representation of species which are known to have fodder value in northern Australia. This criterion resulted in the testing of such little known species as *Ventilago viminalis* and *Atalaya hemiglauca*. A northern Australian species, *Terminalia ferdinandiana,* was also tested as its fruit is used for human consumption and contains very high levels of Vitamin C.

We were also interested in species which might have value for village level production of "minor forest products". For this reason we tested *Melaleuca acacioides,* as it has potential for use for essential oil production. We also included additional provenances of some species, in the light of the results gained in the previous year. As before, local species were included as markers, but the range of local species was widened to include:

Sesbania grandiflora	*Calliandra calothyrsus*	*Pterocarpus indicus*
Pericopsis mooniana	*Cassia siamea*	*Acacia leucophloia*
Casuarina junghuhniana		

The *Pterocarpus* was included as it is very valuable timber tree still harvested in parts of Timor, but for which there was a local opinion that it was difficult to raise in the nursery. As Joe Havel had dealt with *Pterocarpus* in PNG and had been able to raise it successfully, it was included to demonstrate that it could be grown easily in the nursery. *Pericopsis* is another valuable timber tree from the region, included really to encourage interest by the BPK in its cultivation.

The field trial program in 1989 was very ambitious, as we saw it at the time as being the major species screening part of the project, which would provide information to permit the final year to concentrate on a set of provenance trials of the most promising species. We aimed to encompass the three main soil types in both highland and lowland situations. In the event, we were able to locate field trial sites on Raised Coral Terrace types at Sikumana and Buat, near Soe, Bobonaro types at Buat and Besi Pae, but only one Viqueque site at Besi Pae.

On arrival in Kupang for the planting season we were faced with uneven numbers of seedlings in many species and a marked shortfall in some key species. Taking into account that this was the second year of a planned three year research project, and wishing to obtain the maximum possible amount of information from the trials, we developed the following approach:

- where we had some information on the performance of a species from the previous year's trials, we would concentrate our efforts on as yet untried soil types or locations;
- for species which were in short supply, we would reduce plot size from 25 to 20 or less in order to cover as many soil types and locations for new species.

The outcome of this approach was very uneven representation of some species over the range of field trial sites. In retrospect, better results, for fewer species would have been obtained by reducing the program for that year. It would also have greatly simplified analysis of the data.

For comparison of performance, the 1990 measurement of height, that is, 1.6 years after planting, was chosen as the primary criterion as that was the first and last one for which valid measurements for the Raised Coral Terrace plots at Soe were available. After that measurement, the fence was breached by the villagers and the grazing eliminated all susceptible species and damaged or set back others.

The full list of species, the species number allocated, and the location of planting is given below:

SPECIES USED IN ANALYSIS			*Sik RCT*		*Soe, Bobo*		*Soe RCT*	
Species No.	*Name*	*S/N*	*UF*	*F*	*UF*	*F*	*UF*	*F*
1.	*Terminalia fernandiana*	17442	+	+	+	+	+	+
2.	*Casuarina cristata*	15216	+	+	+	+	+	+
3.	*Casuarina junghuniana*	local	+	+	+	+	+	+
4.	*Acacia holosericea*	14660	+	+	+	+	+	+
5.	*Acacia auriculiformis*	15477	+	+	+	+	+	+
6.	*Acacia torulosa*	14888	+	+	-	-	+	+
7.	*Acacia leptocarpa*	15478	+	+	+	+	+	+
8.	*Acacia polystachya*	13871	+	+	+	+	+	+
9.	*Acacia trachycarpa*	15767	+	-	+	+	+	+
10.	*Acacia polystachya*	15860	+	+	+	+	+	+
11.	*Acacia leucophloia*	local	+	+	+	+	+	+
12.	*Acacia crassicarpa*	15479	+	+	+	+	+	+
13.	*Parinari nonda*	15661	+	+	+	+	+	+
14.	*Ventilago viminalis*	15468	+	+	+	+	+	+
15.	*Ventilago viminalis*	17719	+	+	+	+	+	+
16.	*Atalaya hemiglauca*	17291	+	+	+	+	+	+
17.	*Atalaya hemiglauca*	17107	+	+	+	+	+	+
18.	*Melaleuca acacioides*	17038	+	+	+	+	-	+
19.	*Sesbania formosa*	15439	+	-	+	+	-	+
20.	*Sesbania grandiflora*	local	+	+	+	+	+	+
21.	*Cassia siamea*	local	+	+	+	+	+	+
22.	*Eucalyptus brassiana*	13997	+	+	+	+	+	+
23.	*Eucalyptus brassiana*	13408	+	+	+	+	+	+
24.	*Eucalyptus staigerana*	13631	+	+	+	+	+	+
25.	*Eucalyptus camaldulensis*	13622	+	+	+	+	+	+
26.	*Eucalyptus alba*	12993	+	+	+	+	+	+
27.	*Eucalyptus citriodora*	14850	+	-	+	+	+	+
28.	*Eucalyptus tereticornis*	14212	+	+	+	+	+	+
29.	*Pericopsis mooniana*	local	+	+	+	+	+	+
30.	*Calliandra calothyrsus*	local	+	+	+	+	+	-

Incomplete Planting - Soe Bobonaro and Soe RCT only						
			Soe, Bobo		*Soe, RCT*	
Species No.	*Name*	*S/N*	*UF*	*F*	*UF*	*F*
37	*Acacia crassicarpa*	13681	+	+	+	+
43	*Eucalyptus microtheca*	15321	+	+	+	+
44	*Eucalyptus microtheca*	15322	+	+	+	+
45	*Eucalyptus tereticornis*	13661	+	+	+	+
46	*Acacia ampliceps*	17052	+	+	+	+
47	*Acacia trachycarpa*	15767	+	+	+	+

Species discarded from analysis because of limited planting and/or poor establishment rate								
Species No.	*Name*	*S/N*	*Sik RCT*	*Sik RCT*	*Soe Bobo*	*Soe Bobo*	*Soe RCT*	*Soe RCT*
31.	*Terminalia arostrata*	14630	-	-	+	+	-	+
32.	*Terminalia volucris*	17444	-	-	+	+	-	-
33.	*Terminalia fernandiana*	14506	-	-	+	+	-	-
34.	*Acacia shirleyi*	14662	-	-	+	-	-	+
35.	*Acacia plectocarpa*	16182	-	-	-	-	+	+
36.	*Acacia plectocarpa*	17499	-	-	-	+	+	+
38.	*Acacia stenophylla*	14670	-	-	+	+	-	-
39.	*Pterocarpus indicus*	local	-	-	+	+	-	-
40.	*Eucalyptus pellita*	13999	-	-	+	+	-	-
41.	*Eucalyptus pellita*	16120	-	-	-	+	-	-
42.	*Eucalyptus pellita*	11947	-	-	+	+	-	-
48.			-	-	-	-	-	+
49.			+	+	-	-	-	-

The results will be presented in two ways. Firstly, the actual species means for the fertilised and unfertilised treatments will be shown graphically. This gives a visual impression of how the species performed in relation to one another and across the different field sites. That is, we can readily see how a species performed in the lowland Sikumana RCT site compared with the highland Soe RCT site, and the difference on the poor Bobonaro site at Soe can be appreciated. While the graphical representation has its advantages, it does not give any information where there are missing plots at some sites.

Secondly, the joint regression analysis procedure is used to predict performance for each species on all sites, taking account of missing plots. This gives a much more realistic estimate of the capabilities of each species under various conditions in NTT.

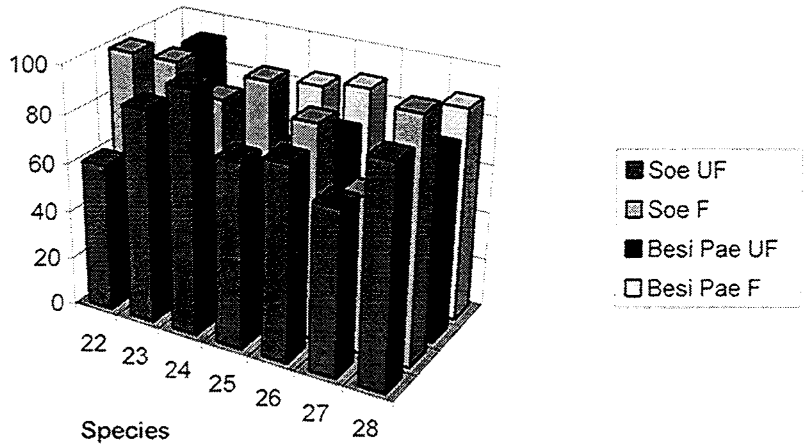
From the large amount of data collected, and with so many species tested, it is difficult to portray the results easily, so they have been broken up into groups. For convenience all the *Acacia* species, all the eucalypts, the Sesbanias and the miscellaneous species have been presented in those groups.

Height data at age 1.6 were analysed using the joint regression analysis procedure, so that the comments below refer to the resulting BLUPs.

Survival

The eucalypts included in the field trials seemed to tolerate the Bobonaro sites fairly well (see Figure 8). Although growth was not vigorous, survival was acceptable on all sites for all species. No consistent trend for an improvement in survival with fertiliser application could be seen.

Figure 8. Survival of eucalypts on Bobonaro Sites (per cent survival)

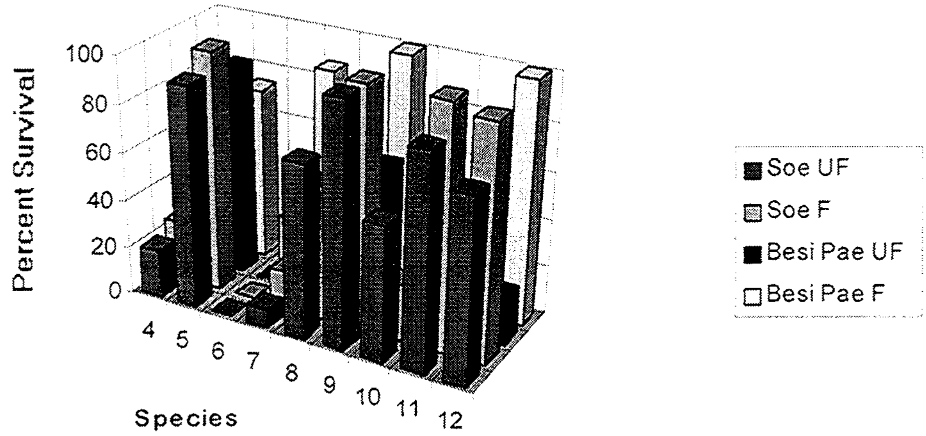


Species Key

22.	*E. brassiana*	13997	26.	*E. alba*	12993
23.	*E. brassiana*	13408	27.	*E. citriodora*	14850
24.	*E. staigeriana*	13631	28.	*E. tereticornis*	14212
25.	*E. camaldulensis*	13622			

In contrast to the eucalypts, one Acacia species showed very poor survival on the Bobonaro sites, namely *A. torulosa* (Figure 9), and others were inconsistent, such as *A. holosericea, A. leptocarpa* and *A. crassicarpa*. The almost complete failure of *A. torulosa* on these soils suggests it will not tolerate alkaline soils. The remaining species showed moderate or good survival.

Figure 9. Survival of Acacia Species on Bobonaro Sites



Species Key

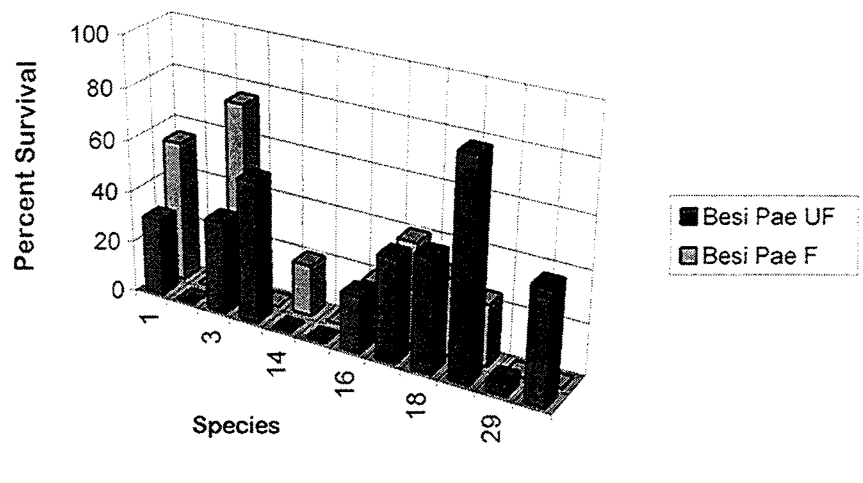
4.	*A. holosericea*	14660	7.	*A. leptocarpa*	15478	10.	*A. polystachya*	15860
5.	*A. auriculiformis*	15477	8.	*A. polystachya*	1387	11.	*A. leucophloia*	local
6.	*A. torulosa*	14888	9.	*A. trachycarpa*	1576	12.	*A. crassicarpa*	15479

The miscellaneous species exhibited erratic behaviour on the Bobonaro sites, some failing altogether at Besi Pae, while on they performed much better at the Soe site. At first sight this is not logical, as both sites had been mapped as 'classic' Bobonaro clay soils by soil surveyors working for AIDAB projects in the region. However, on closer examination it was evident that there was a marked difference in the soil moisture regime at the two sites. At Besi Pae it is a very dry site, whereas at Soe the field trial is on a water gaining site. It is also possible that rainfall patters were different at Besi Pae and at Soe in this season, although we have no data on this.

Acacia holosericea at Besi Pae Bobonaro site, 6 months after planting

Again, no consistent influence of fertilisation could be detected, as shown in Figure 10.

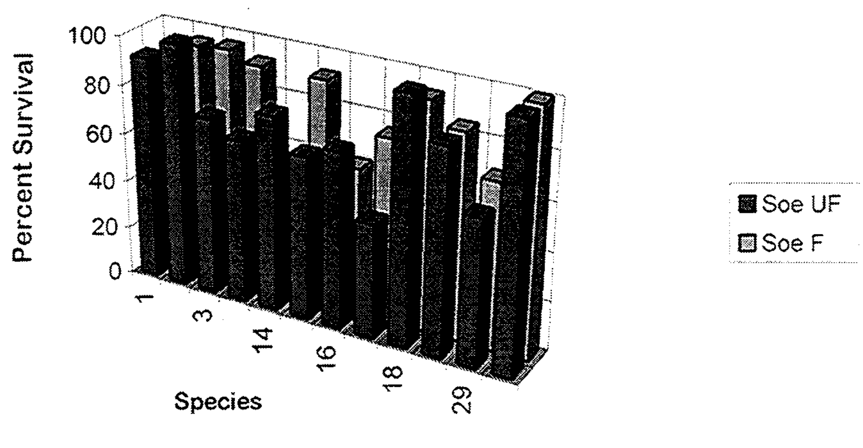
Figure 10. Survival Misc Species Besi Pae Bobonaro



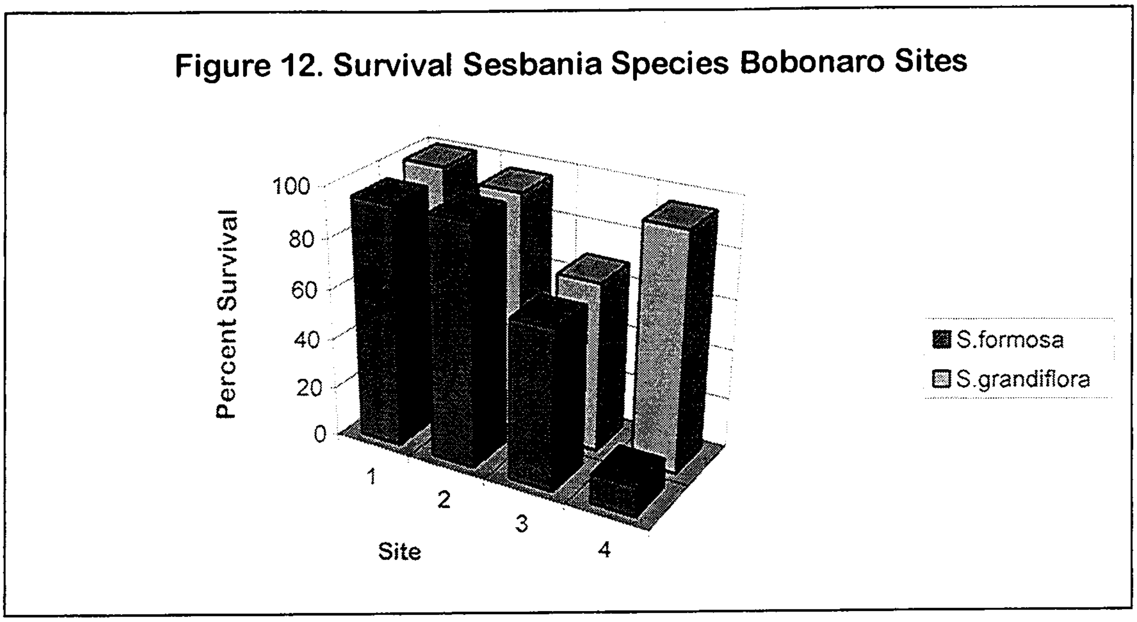
Species Key

1.	*Terminalia ferdinandiana*	17442	16.	*Atalaya hemiglauca*	17291
2.	*Casuarina cristata*	15216	17.	*A.hemiglauca*	1710
3.	*C. junghuhniana*	local	18.	*Melaleuca acacioides*	1703
13.	*Parinari nonda*	15661	21.	*Cassia siamea*	local
14.	*Ventilago viminalis*	15468	29.	*Pericopsis mooniana*	local
15.	*V. viminalis*	17719	30.	*Calliandra calothyrsus*	local

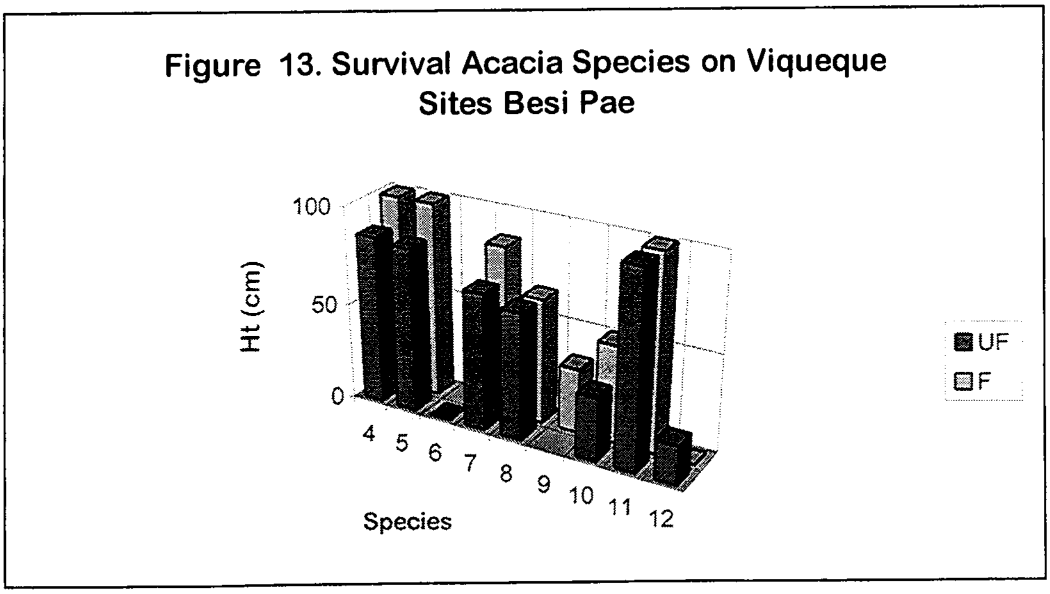
Figure 11. Survival Misc Species Soe Bobonaro



The initial survival of the two *Sesbania* species was simlar at all sites except the Besi Pae fertilised plot.It is unlikely that there was a real difference and the poor figure sfor that plot are due to chance browsing by native deer, which are common in this area.



Site 1 is Soe unfertilised, while site 2 is Soe fertilised. Site 3 is Besi Pae unfertilised and site 4 is Besi Pae fertilised. A marked difference in the performance of *S. formosa* can be seen at the two sites. Its survival was much better on the water-gaining Soe Bobonaro site compared with the dry Besi Pae site. *S. grandiflora* was less affected by the site change. This difference is a reflection of the natural occurrence on the two species. *S. formosa* occurs in northern Australia on moister sites along watercourses and would prefer such areas.

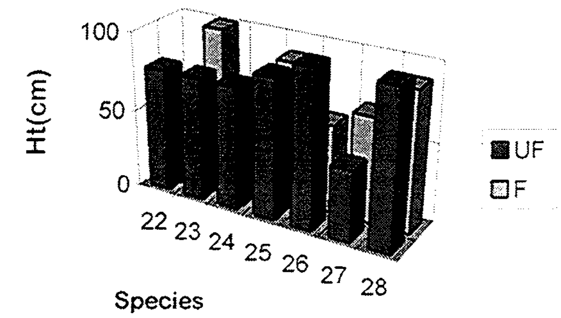


Species Key

4.	*A. holosericea*	14660	7.	*A. leptocarpa*	15478	10.	*A. polystachya*	15860
5.	*A. auriculiformis*	15477	8.	*A. polystachya*	1387	11.	*A. leucophloia*	local
6.	*A. torulosa*	14888	9.	*A. trachycarpa*	1576	12.	*A. crassicarpa*	15479

On the Viqueque soils *A. torulosa* was a complete failure and poor survival was shown by *A. trachycarpa* and *A. crassicarpa* 15479. While the latter was expected on the basis of the previous year's trial results, it was surprising to see *A. trachycarpa* performing so badly, as it appears well adapted to alkaline soils in Australia. The eucalypts generally survived better than the Acacias at Besi Pae Viqueque (Figure 14).

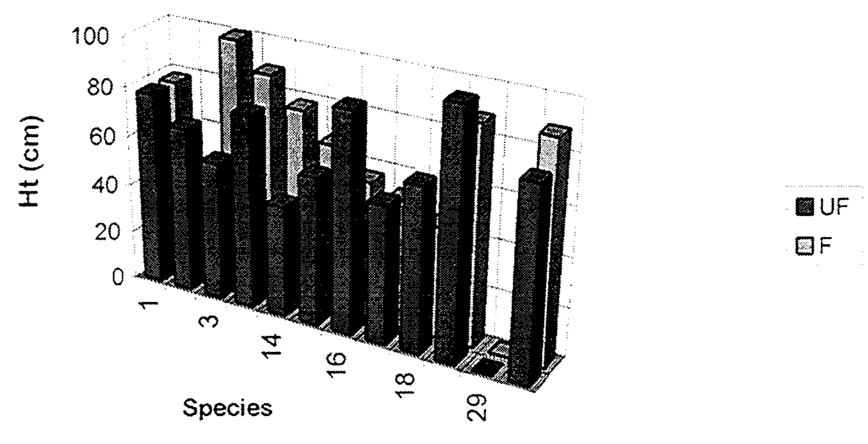
Figure 14. Survival of Eucalypts on Viqueque Sites Besi Pae



Species Key

22. *E. brassiana*	13997		26. *E. alba*	12993
23. *E. brassiana*	13408		27. *E. citriodora*	14850
24. *E. staigeriana*	13631		28. *E. tereticornis*	14212
25. *E. camaldulensis*	13622			

Figure 15. Survival of Minor Species Viqueque Site



Species Key

1. *Terminalia ferdinandiana*	17442	16. *Atalaya hemiglauca*	17291
2. *Casuarina cristata*	15216	17. *A. hemiglauca*	1710
3. *C. junghuhniana*	local	18. *Melaleuca acacioides*	1703
13. *Parinari nonda*	15661	21. *Cassia siamea*	local

14. *Ventilago viminalis*	15468	29.	*Pericopsis mooniana*	local
15. *V. viminalis*	17719	30.	*Calliandra calothyrsus*	local

The only species in the miscellaneous group that failed on this site was *Pericopsis mooniana*. All the others had acceptable levels of survival.

Height Growth

The height growth data for eucalypts at Soe (RCT and Bobonaro), Sikumana (RCT) and Besi Pae (Viqueque and Bobonaro) are presented in Figures 16 and 17.

Figure 16. Comparison of First Year Growth of Eucalypts at Soe and Sikumana

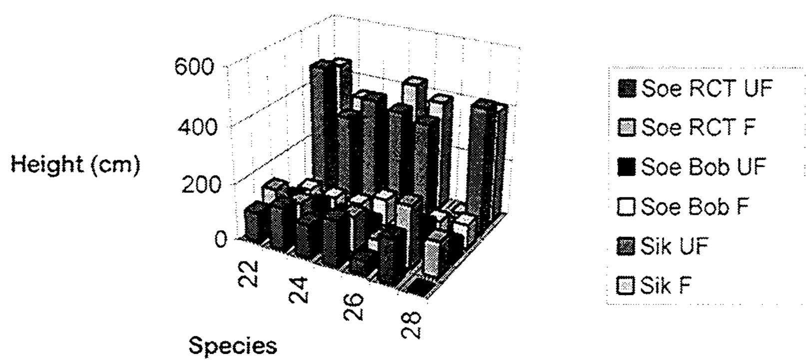
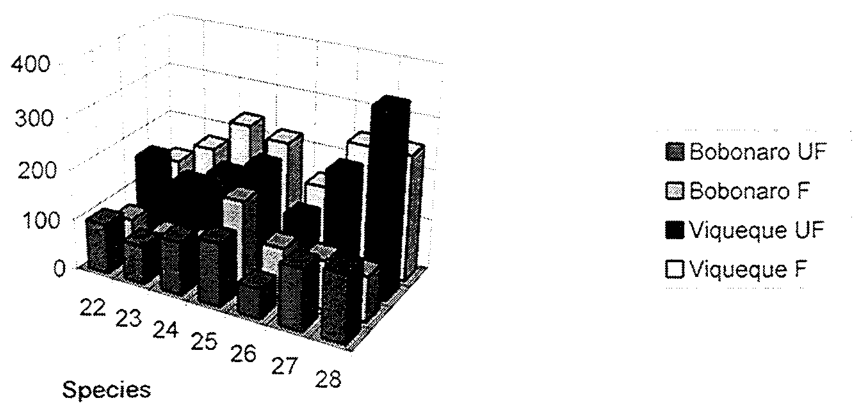


Figure 17. Eucalypt Species Height Growth Age 1.6 Years Besi Pae



Species List

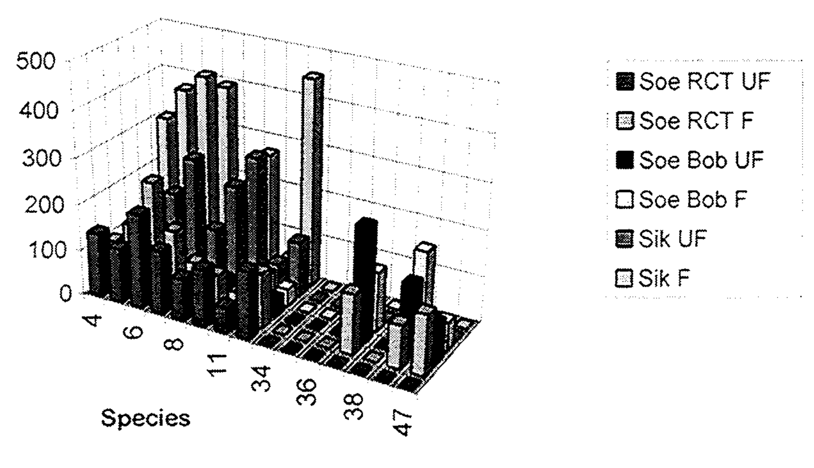
22. *E. brassiana*	13997	25.	*E. camaldulensis*	13622
23. *E. brassiana*	13408	26.	*E. alba*	12993
24. *E. staigerana*	13631	27.	*E. citriodora*	14850
28. *E. tereticornis*	14212			

There is quite a clear difference in performance for all eucalypt species between the sites. All species performed badly on both Soe sites, but only *E. citriodora* performed badly at Sikumana. The poor height growth for all species at the Soe Bobonaro site was expected, but it seems illogical that all eucalypts should have grown so badly on the Soe RCT site, which has a soil very similar to that at Sikumana, but cooler growing conditions, a longer growing season and somewhat higher rainfall. The only explanation which readily comes to mind is the influence of immediate past land use. At the Sikumana site, the field trial area had been under regrowth natural vegetation for some years, and was in the process of rebuilding fertility. However, at Soe RCT, the area was being actively used for grazing and may have carried a crop of some sort in recent years, so had not commenced the fertility rebuilding cycle.

The data for the fertilised and the unfertilised plots are displayed together for each species. Inspection of the graph indicates that for the eucalypts there was no consistent difference in growth between the two treatments, and this was confirmed by subsequent analysis.

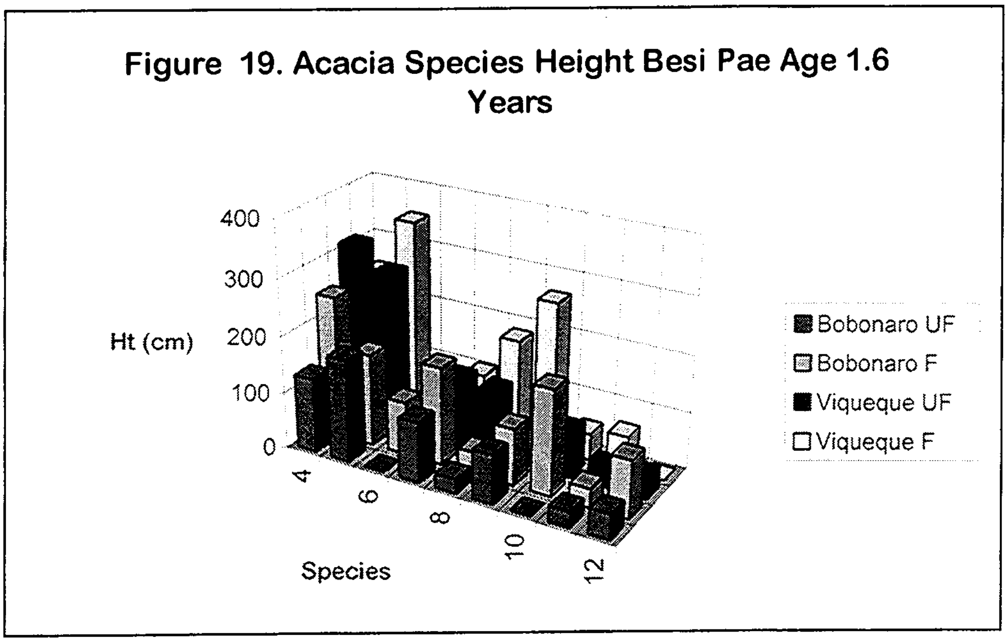
In the Acacias, some species were complete failures, notably *A. shirleyi*, *A. plectocarpa* (two provenances) and *A. stenophylla* (see Figures 18, 19). Some species appear to have performed poorly but the graph is misleading as all the above species, *A. crassicarpa* 13681 and *A. ampliceps* 17052 were not planted at Sikumana in this year.

Figure 18. Comparison of Acacia Species at Soe and Sikumana Mean Height Age 1



Species List

4.	*A. holosericea*	14660	10.	*A. polystachya*	15860	37.	*A. crassicarpa*	13681
5.	*A. auriculiformis*	15477	11.	*A. leucophloia*	local	38.	*A. stenophylla*	14670
6.	*A. torulosa*	14888	12.	*A. crassicarpa*	15479	46.	*A. ampliceps*	17052
7.	*A. leptocarpa*	15478	34.	*A. shirleyi*	14662 3	47.	*A. trachycarpa*	15767
8.	*A. polystachya*	13871	35.	*A. plectocarpa*	16182			
9.	*A. trachycarpa*	15767	36.	*A. plectocarpa*	17499			

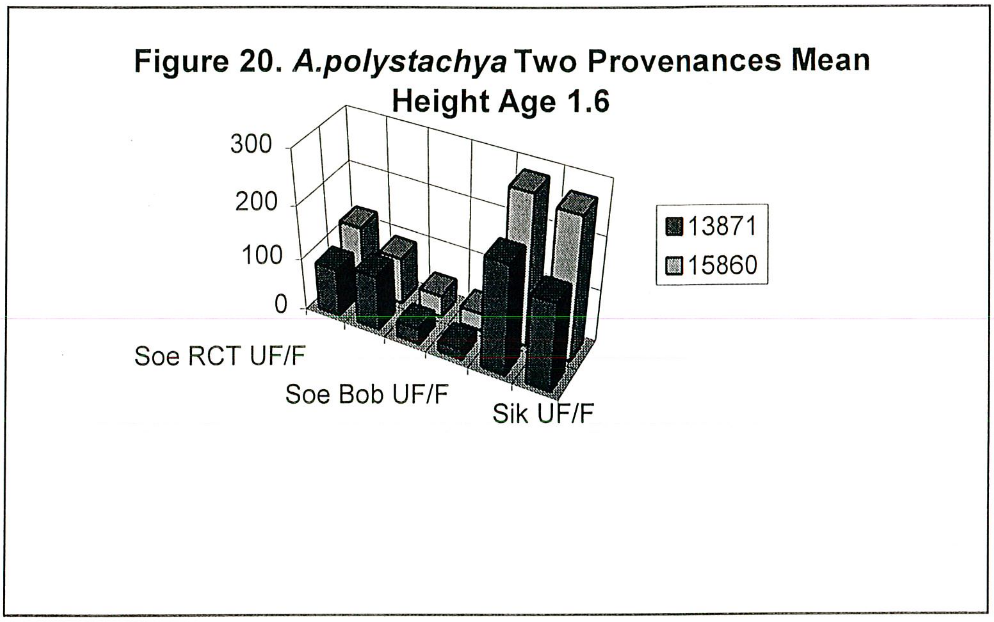


Species Key

4.	*A. holosericea*	14660	7.	*A. leptocarpa*	15478	10.	*A. polystachya*	15860
5.	*A. auriculiformis*	15477	8.	*A. polystachya*	1387	11.	*A. leucophloia*	local
6.	*A. torulosa*	14888	9.	*A. trachycarpa*	1576	12.	*A. crassicarpa*	15479

If we look at species 4-12, which were all planted at all sites, some very clear trends emerge. Most performed poorly on the Bobonaro site, and growth was generally much better at Sikumana than on the same soil type at Soe. Within the Sikumana site, there is also a general trend for height growth to be better with fertiliser application, in contrast to the situation observed in the eucalypts. No special importance is attached to this result, although it indicates that further work to explore fertiliser response might be justified.

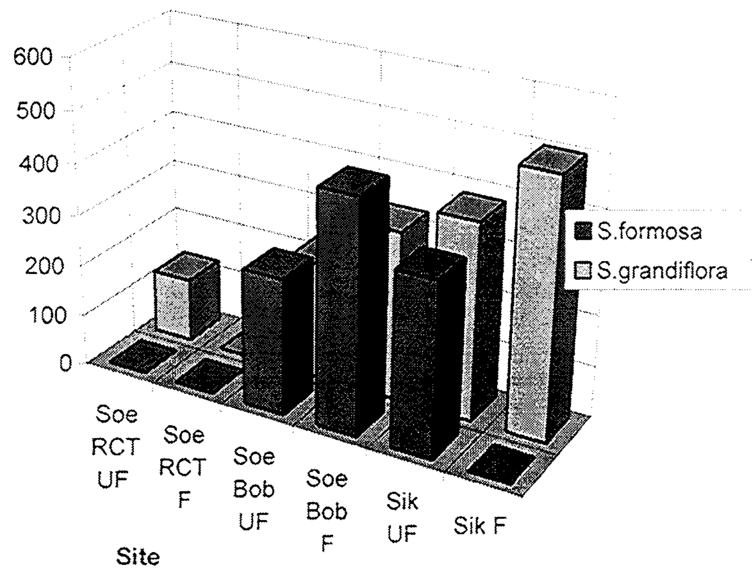
While some species were quite variable in their evident performance at the different sites, but others were relatively consistent. A good example is the two provenances of *A. polystachya*, which performed in much the same way on each site where they were planted. Like the eucalypts, this species grew much better on the lowland Sikumana RCT site than at the Soe RCT site. It is also, like most species, evidently not well adapted to the Soe Bobonaro site.



The two *Sesbania* species also behaved in a relatively consistent manner over the three sites, except at Sikumana, where *S. formosa* (as in the previous year's planting) virtually failed due to heavy termite attack. Termite attack was observed to be much less severe on the vertisol soil at the Soe Bobonaro site and *S. formosa* performed extremely well there. It is of interest that this species also grows well in the Kimberley region only on cracking clays where termite attack is similarly reduced compared with other soil types.

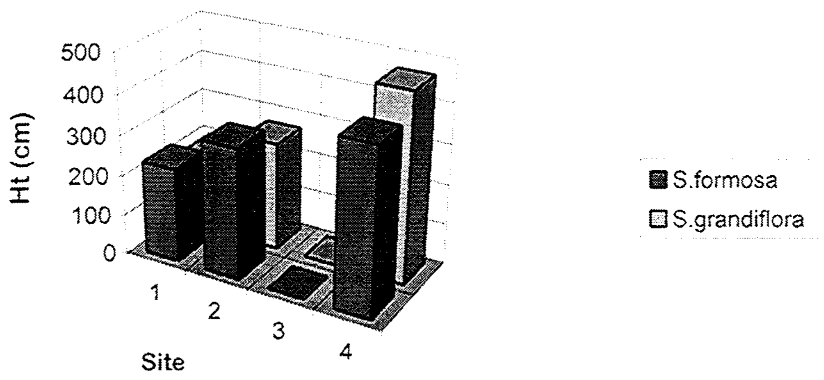
Two Sesbania species at Soe Bobonaro site 8 months after planting. S. grandiflora left and S. formosa right.

Figure 21. Sesbania Species Performance at Soe and Sikumana at Age 1.6



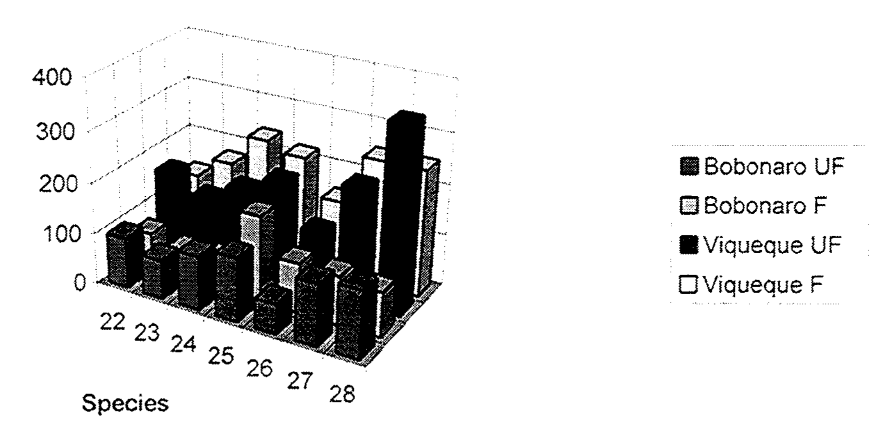
Both species performed extremely poorly at the Soe RCT site, a surprising result. It is possible that the infrequent visits to the site by BPK staff did not detect damage to browsing by native deer, which are common in this area. No consistent trends for a response to fertiliser can be discerned in these species.

Figure 22. Sesbania species Height at Age 1.6 Besi Pae



Sites 1 and 2 are the Bobonaro site, UF and F respectively and sites 3 and 4 are on the Viqueque site, also UF and F. The failure at the latter site may be related to chance location of a termite nest as both species are severely damaged by termites.

Figure 23. Eucalypt Species Height Growth Age 1.6 Years Besi Pae

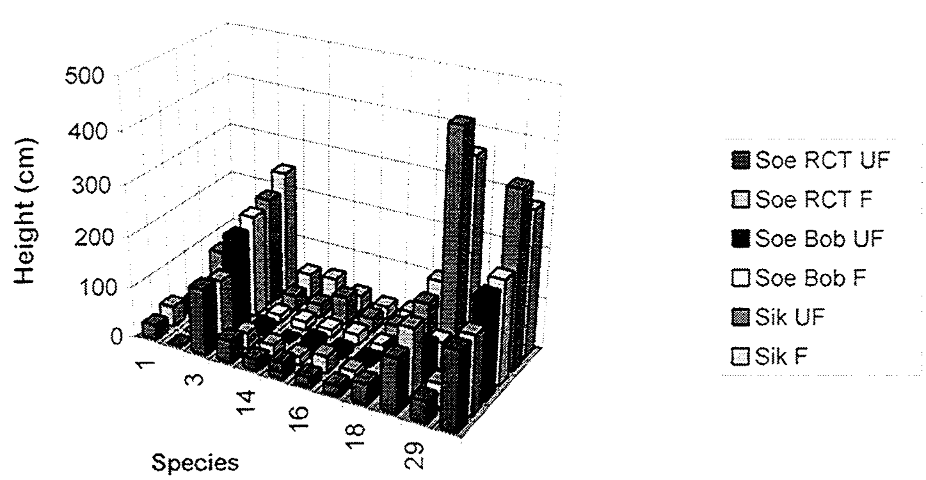


Species Key

22. *E. brassiana*	13997	26. *E. alba*	12993
23. *E. brassiana*	13408	27. *E. citriodora*	14850
24. *E. staigeriana*	13631	28. *E. tereticornis*	14212
25. *E. camaldulensis*	13622		

No consistent trends for a response to fertiliser can be discerned in these species.

Figure 24. Comparison of Misc Species at Age One

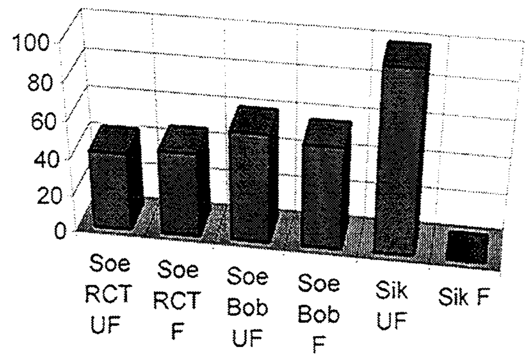


Species List

1.	*Terminalia ferdinandiana*	17442	16.	*Atalaya hemiglauca*	17291
2.	*Casuarina cristata*	15216	17.	*A.hemiglauca*	17107
3.	*C. junghuhniana*	local	18.	*Melaleuca acacioides*	17038
13.	*Parinari nonda*	15661	21.	*Cassia siamea*	local
14.	*Ventilago viminalis*	15468	29.	*Pericopsis mooniana*	local
15.	*V. viminalis*	17719	30.	*Calliandra calothyrsus*	local

Inspection of this graph indicates that only three of the miscellaneous species, namely *Casuarina junghuhniana*, *Cassia siamea* and *Calliandra calothyrsus*, produced good results. All the others were very poor indeed, to the point where they could not be seriously considered for further research in this project. However, the fact that *Pericopsis mooniana* survived reasonably well at most sites (see Figure 25), even though its initial growth rate is poor, indicates this very valuable timber species may repay further silvicultural research. It may well be that this species is not well adapted to growth in an open high light situation.

Figure 25. First Year Growth of *Pericopsis mooniana*



Data Analysis

Turning now to the results of the joint regression analysis, all data was included in an attempt to define better the likely performance of each species over the three sites. Based on the analysis of the 1990 data, the species fall into the following groups:

1. Very poor performers, which did not exceed mean height of 75 cm on any of the experimental sites. These included:

1	*Terminalia ferdinandiana*	17442	Broome WA
11	*Acacia leucophloia*		local
13	*Parinari nonda*	15661	Hann R QLD
14	*Ventilago viminalis*	15468	Augathella QLD
15	*Ventilago viminalis*	17719	Alice Springs NT
16	*Atalaya hemiglauca*	17219	Cable Beach WA
17	*Atalaya hemiglauca*	17107	Alice Springs NT

2. Poor performers, which exceeded mean height of 75 cm on the better sites, but on no site exceeded 175 cm:

2	*Casuarina cristata*	15216	Monto QLD
18	*Melaleuca acacioides*	17038	Beagle Bay WA
29	*Pericopsis mooniana*		local

3. Average performers, which exceeded mean height of 175 cm on one or more of the better sites, but did not exceed mean height of 275 cm on any site:

3	*Casuarina junghuhniana*		local
8	*Acacia polystachya*	13871	Bridle QLD
27	*Eucalyptus citriodora*	14850	Irvine QLD

4. Superior performers which exceeded mean height of 275 cm on one or more sites, generally either the fertilised or unfertilised plots in the Sikumana doline.

4	*Acacia holosericea*	14660	Turkey Creek WA
5	*Acacia auriculiformis*	15477	Morehead R QLD
6	*Acacia torulosa*	14888	Laura QLD
7	*Acacia leptocarpa*	15478	Musgrave QLD
9	*Acacia trachycarpa*	15767	DeGrey R WA
10	*Acacia polystachya*	15860	Lockerbie QLD
12	*Acacia crassicarpa*	15479	Coen QLD
19	*Sesbania formosa*	15439	Maitland R Hwy WA
20	*Sesbania grandiflora*		local
21	*Cassia siamea*		local
22	*Eucalyptus brassiana*	13997	Bamaga QLD
23	*Eucalyptus brassiana*	13408	Musgrave QLD
24	*Eucalyptus staigeriana*	13631	Maitland Downs QLD
25	*Eucalyptus camaldulensis*	13662	Petford QLD
26	*Eucalyptus alba*	12993	Mt Molloy QLD
28	*Eucalyptus tereticornis*	14212	Helenvale QLD
30	*Calliandra calothyrsus*		local

Of these species No. 19, *S. formosa,* was exceptional in that it performed well on the Bobonaro site of Soe, in which most species fared poorly. One possible explanation for this is that this site is in a water gaining situation, and in Australia this species often grows on such sites, indicating that it can tolerate periodic waterlogging.

In addition to the above species, which were planted on all sites, there were several species which were only planted at one or two locations, and for which an adequate picture is therefore not available, particularly as in 1988 they were not planted on the best site, the Sikumana Doline.

They fall into the following categories:

5. Very poor performers at Soe-Bobonaro and/or Soe Raised Coral Terrace which did not exceed mean height of 75 cm:

31	*Terminalia arostrata*	14630
32	*Terminalia volucris*	17444
33	*Terminalia ferdinandiana*	14506

34	*Acacia shirleyi*	14662
42	*Eucalyptus pellita*	11947

6. Poor performers at Soe Bobonaro and/or Soe Raised Coral Terrace - did not exceed mean height of 175 cm:

35	*Acacia plectocarpa*	16182
36	*Acacia plectocarpa*	17499
38	*Acacia stenophylla*	14670
39	*Pterocarpus indicus*	local
41	*Eucalyptus pellita*	16120
43	*Eucalyptus microtheca*	15321
44	*Eucalyptus microtheca*	15322
45	*Eucalyptus tereticornis*	13661
47	*Acacia trachycarpa*	16120
48		

7. Average performers at Soe Bobonaro and/or Soe Coral Terrace, which exceeded mean height of 175 cm but did not reach 275 cm:

37	*Acacia crassicarpa*	13681
40	*Eucalyptus pellita*	13999
46	*Acacia ampliceps*	17052

Acacia ampliceps at Besi Pae Viqueque. Although not scoring well on height growth its biomass production was good and it grows well on alkaline sites, producing good fodder.

8. One species was planted at Sikumana Doline only and proved a superior performer reaching average height of above 275 cm

49 *Eucalyptus camaldulensis* 16720

When the height measurement for 1991 are compared with 1990 the basic pattern that emerges is that those species that did well prior to 1990 have subsequently grown even better, increasing the gap between them and the poor performers. By contrast the bulk of the very poor performers remained stagnant.

In general the gap has also increased, in the case of the good performers, between the two sites for which reliable data is available, namely the favourable Sikumana Doline site and the adverse Soe Bobonaro site.

There were, however, some notable exceptions, which are of particular significance. The most outstanding of these is *Sesbania formosa* 15439, which has largely failed at Sikumana Doline but remained among the top performers at Soe Bobonaro. The closely related local*Sesbania grandiflora* also did well at Soe, but not as well as at Sikumana where at this age it was still the tallest species. Another species that did relatively well at Soe Bobonaro was *Acacia crassicarpa* 13681. Next in order of performance at Soe Bobonaro were *Calliandra calothyrsus* (local) and *Acacia ampliceps* 17052. A number of other species also made fair, though not spectacular, progress at Soe Bobonaro, namely *Acacia stenophylla* (14670), *Pterocarpus indicus* (local) *Eucalyptus pellita* (13999, 16120, 11947), particularly on the fertilised plots. Unfortunately no comparison with Sikumana is available for these species in the 1988 trials. However, they warrant consideration for the adverse Bobonaro site.

The differences between sites and treatments can also be demonstrated quantitatively, by considering the overall means. On this basis, for the height measurements, the overall site-fertiliser means are, when expressed as departures from the mean for the experiment as a whole:

Site-fertiliser combination	*1st measurement*	*2nd measurement*
Soe - Raised Coral Terrace unfertilised	-37.25	-53.26
Soe - Raised Coral Terrace fertilised	-32.23	-50.90
Soe - Bobonaro unfertilised	-62.07	-76.35
Soe - Bobonaro fertilised	-61.09	-80.26
Sikumana Doline unfertilised	+84.94	+128.45
Sikumana Doline fertilised	+109.67	+138.28

Although the second height measurement is affected by the grazing damage within the Soe Raised Coral Terrace site, the difference between the sites persist and are in fact some what accentuated by the passage of time, supporting the conclusion reached with respect to individual species, namely that the gap between favourable and adverse sites widens with time.

Final estimates of the height at second measurement, derived by iterative process gives values which on the whole correspond to the evaluation based on row means for individual species/site combinations, except for the better performers.

There is agreement between the types of analysis with respect to the very poor performers, that is species 1, 11, 13, 14, 15, 16, 17, Sp. 43, which was not planted in Sikumana Doline, is also put into this category. The prediction put the estimated mean (TORS) for this category below 0.5 m.
The next category, that can be labelled as poor performers, contains species 2, 8, 29 and 44. It is defined by estimated means falling between 0.5 m and 1 m. There is only partial correspondence with

the poor performer group based on raw means, i.e. that species 8 in the estimated means is substituted for species 18 in the raw means. The latter has a considerably poorer range of performance on individual sites.

The correspondence becomes even poorer is in the next categories of average and superior performers. The contributing factor to this discrepancy appears to be that in the evaluation on the basis of raw means, outstanding performances on favourable sites in Sikumana Doline, or capacity to cope well with the adverse site on Soe Bobonaro uplands was used to define superior performers. The uniformly poor performance of most species on the Soe Bobonaro uplands was given much less weight. In the estimates all sites were given equal weight, even though the Soe Raised Coral Terrace site had been seriously disturbed prior to second measurement, and was therefore excluded in the evaluation of raw means derived from that measurement. The basic difference is that whereas evaluation of raw means puts only three species (3, 8, 27) in the category of average performer, the evaluations based on estimates of means put the bulk of the species (3, 4, 5, 7, 9, 10, 12, 21, 22, 23, 24, 25, 26, 28 and 30) in the corresponding category.

By contrast, on the basis of raw means of height at three years, a considerable number of species was put, chiefly on the basis of performance in Sikumana Doline, into the category of superior performers, capable of exceeding 2.75 metres in three years on a good site (4, 5, 6, 7, 9, 10, 12, 19, 20, 21, 22, 23, 24, 25, 26, 28 and 30). On the basis of height estimate at 4 years only four species were assessed capable of exceeding four metres over a range of sites and hence fitting into the superior category (6, 20, 27 and 45).

The productions for species 6 (*Acacia torulosa* 1148) appear to be influenced by lack of representation on Soe-Bobonaro site, which tends to pull means down. The error is due to treating a total failure as a missing value. Species 20 (*Sesbania grandiflora*, local) is a superior species on any criterion, at least in terms of early growth. Species 27 appears to have been given a high performance prediction on the basis of good performance at Soe, though it has largely failed at Sikumana in this trial (treated as missing value) and only gave intermediate performance in previous one. Species 45 (*Eucalyptus tereticornis* 13661) was given high predictive overall performance on the basis of good performance at Soe, though it was not tried at Sikumana in this trial. In previous trials at Sikumana it proved a superior performer, so that in this case the adjustment made for the missing value is a correction.

The advanced form of analysis used on this set of data, the modified joint regression analysis, provides an additional, higher calibre view of the results. The output of the analysis is, however, based on the assumption that the species respond equally to site influences on any one site. In light of the non-significance of the species interaction this may appear to be a reasonable assumption, but does not take into account the fact that although the bulk of the species respond to site environment and fertilisation comparably, there are few that go against this generalisation.

The large discrepancies between the raw and predicted value of the means of second measurement in these species are indicative of their capacity to handle the adverse Soe Bobonaro sites better than the bulk of the species. The species falling into this category are:

3	*Casuarina junghuhniana*	local
5	*Acacia auriculiformis*	15477
19	*Sesbania formosa*	15439
20	*Sesbania grandiflora*	local
27	*Eucalyptus citriodora*	14850
37	*Acacia crassicarpa*	13681

Even though the diameters at the first measurement and even the second measurement were somewhat small to give a reliable basis for comparing individual species, the site differences are consistent with height measurements.

Site-fertiliser combination	*1st measurement*	*2nd measurement*
Soe - Raised Coral Terrace unfertilised	-0.25	-0.49
Soe - Raised Coral Terrace fertilised	-0.23	-0.51
Soe - Bobonaro unfertilised	-0.48	-0.58
Soe - Bobonaro fertilised	-0.47	-0.57
Sikumana Doline unfertilised	+0.55	+1.06
Sikumana Doline fertilised	+0.92	+1.15

Discussion and Conclusions

The above observations need to be tempered by the knowledge that the type of site represented by the Sikumana Doline is normally utilised for the production of the staple food stuffs such as corn, beans and peanuts. It would therefore not be normally available for the growing of tree crops, except on a very short rotation. Of the local species investigated, the fast growing but short lived *Sesbania grandiflora* is frequently grown on this site and is retained for a number of years as a sparse over storey over the staple food crops, being utilised as a source of food for both human (flowers used as vegetables) and for cattle and goats (foliage or fodder). The introduced *Cassia siamea* are also frequently grown on these sites, and is slashed and burned prior to planting of the staple crops. The remaining local species tested, namely *Casuarina junghuhniana, Eucalyptus alba* and *Acacia leucophloia* reach their main development on the Bobonaro and Viqueque sites, where they serve as sources of firewood and fencing material, and as a source of temporary soil improvement in the slash and burn agricultural cycle.

The findings can be summarised as follows:

By considering raw means of all individual species-site-fertiliser combinations it is possible to get an overview of the complete interplay of all the factors. The overall superiority of the Sikumana Doline becomes obvious, and there is a tendency to use the growth of individual species on it as the criterion of their growth potential. It is also possible to detect the few species that go against that generalisation, that is those that cope well with the adverse Soe Bobonaro site.

By using the modified joint regression analysis, for incomplete variety x environment data the differences between sites are also identified, but in addition they are also quantified. It is also possible to arrive at a measure of the overall performance of the species irrespective of site, and of its sensitivity to environmental influences. However, as the analysis is based on the quantification of main trends, it has difficulties in dealing with those few species that go against this trend. As a result, some of the estimates of the species performance on the various sites are markedly at variance with the observed raw means. The analysis, whilst designed to deal with incomplete data sets, has its limitations in that the predicted estimates of growth can be distorted by the influence of the missing values in a way that is at variance with earlier trials. It would seem that where a species has failed totally, this should not be interpreted as a missing value.

Section Three - Acacia Provenance Trials

The Acacia provenance trials were intended to explore the variation in suitability for NTT conditions among several provenances of the species shown by the screening trials to have potential for further use in the province. The species considered worthy of further research in this way were *A. auriculiformis*, *A. crassicarpa*, and *A. holosericea*.

The use of the latter species was complicated by the taxonomic revision of the group to which this species belongs, during the course of this project, into three distinct species *A. holosericea*, *A. colei* and *A. neurocarpa*. It was subsequently determined that one of the provenances of *A. holosericea* used in the field trial in NTT is now known as *A. colei*. *A. colei* is a tetraploid while *A. holosericea* is a hexaploid form.

A .auriculiformis is widely planted in NTT mainly along roadsides, but is little used by farmers, and it was hoped to determine whether the new provenances introduced in this field trial were any better suited to NTT conditions than the one already used there.

The trial was established in 1990 on a highland site near Siso, and on a lowland site at Oetium. Both sites were basically Bobonaro Clay parent material, although the Siso site was depositional in nature and Oetium was a drier hilltop site. The standard 25 tree plot was used again, with four replicates of each provenance. We were able to obtain six provenances of *A. holosericea*, six provenances of *A. crassicarpa* and nine of *A. auriculiformis*. Selection of provenances was governed by the availability of seed from the Tree Seed Centre.

Unfortunately, we were unable to procure local seed of *A. auriculiformis* to include in the trial, however this test is one the BPK can easily carry out at a later date, should it need to do so.

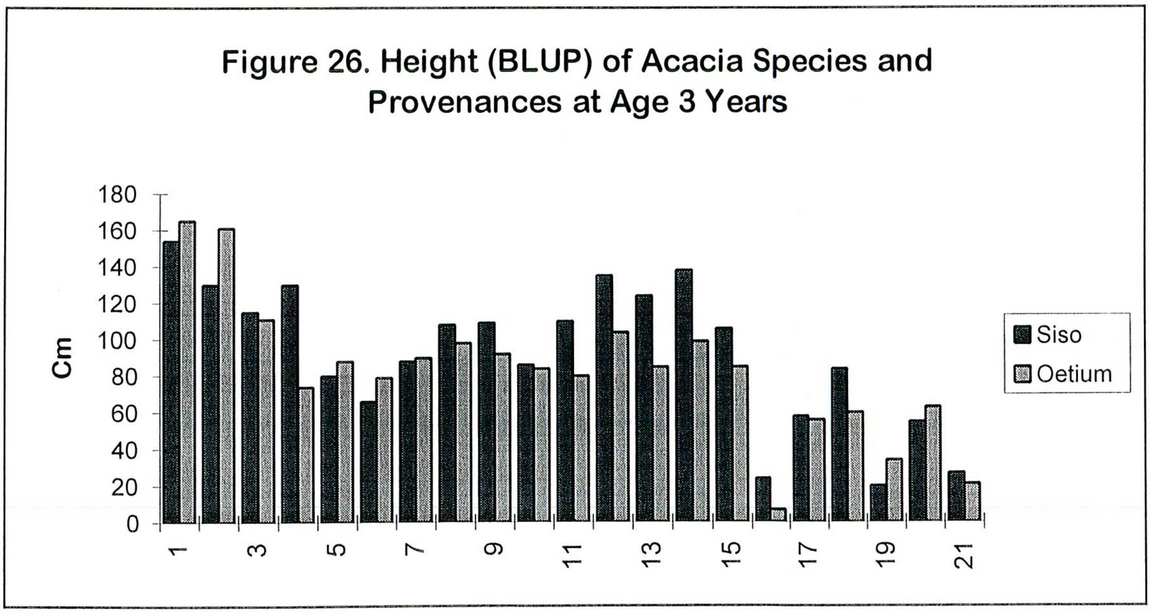
The various provenances and their origins were as follows:

A. holosericea	16389	Coopers Creek NT
	14660	Turkey Creek WA (now known as *A. colei*)
	15366	Cairns QLD
	15732	Edith River NT
	16143	Coen QLD
	16582	Dauringa QLD
A. crassicarpa	16602	Dimisisi Village PNG
	16598	Bimadebun Village PNG
	13683	Woroi PNG
	13681	Mata PNG
	16128	Jardine River QLD
	15949	Laura-Musgrave QLD
	15479	Coen QLD
A. auriculiformis	16484	Morehead River QLD
	16485	Kings Plains QLD
	15483	Archer River QLD
	16152	East Alligator River NT
	16158	Gerowie Creek NT
	16160	South Alligator River NT
	16683	Morehead River PNG
	16106	Mibini PNG
	16107	Tonda Village PNG

Part of the Acacia provenance trial at Siso

Results - Between Species Comparisons

Although the primary intent of the provenance trials was to determine the best performing provenance of several species which showed promise for use in NTT, it is also of interest to examine the data as a whole, comparing all species and all provenances. Figure 26 below shows the BLUPs for age three years for all provenances.



Provenances 1-6 *A. holosericea*

Provenances 7-15 *A. auriculiformis*

Provenances 16-21 *A. crassicarpa*

Although the Best Linear Unbiased Predictors (BLUPs), hereafter referred to as means, form a continuum, it is possible to break the results up into four main categories, on the basis of performance at the more favourable site as Siso.

CATEGORY 1	Significantly superior to categories 3 and 4, confidence limits overlapping with category 2.
CATEGORY 2	Significantly superior to category 4, overlapping upwards with category 1 and downwards with category 3.
CATEGORY 3	Significantly inferior to category 1, overlapping upwards with category 2 and downwards with category 4.
CATEGORY 4	Significantly inferior to category 1 and 2, overlapping upwards with category 3.

Category 1 has mean height at second measurement (at 2.4 years) at Siso exceeding 120 cm. It contains the following provenances:

1	*Acacia holosericea*	16389
7	*Acacia holosericea*	14660
11	*Acacia holosericea*	15366
14	*Acacia auriculiformis*	15483
17	*Acacia auriculiformis*	15483
19	*Acacia auriculiformis*	16106

At Oetium, the mean of some of the provenances fall somewhat below 120 cm, the lowest being 74 cm for provenance 11.

Category 2 has mean height of second measurement (at 2.4 year) ranging from 80 to 120 cm - above average (good) performers

2	*Acacia auriculiformis*	16485
3	*Acacia auriculiformis*	16107
4	*Acacia auriculiformis*	16683
8	*Acacia holosericea*	16582
9	*Acacia crassicarpa*	16602
10	*Acacia auriculiformis*	16152
13	*Acacia auriculiformis*	16158
16	*Acacia holosericea*	15732
21	*Acacia auriculiformis*	16484

In this category there are no major differences between Siso and Oetium.

Category 3 has the height at the time of second measurement (2.4 years) ranging from 40 to 80 cm - below average (poor) performance:

6	*Acacia crassicarpa*	13681
15	*Acacia crassicarpa*	13683
18	*Acacia holosericea*	16143

In this category there are also no major differences between Siso and Oetium.

Category 4 has mean height of less than 40 cm at the time of second measurement (age 2.4 years) - inferior performance:

5	*Acacia crassicarpa*	16128
12	*Acacia crassicarpa*	13681
20	*Acacia crassicarpa*	15479

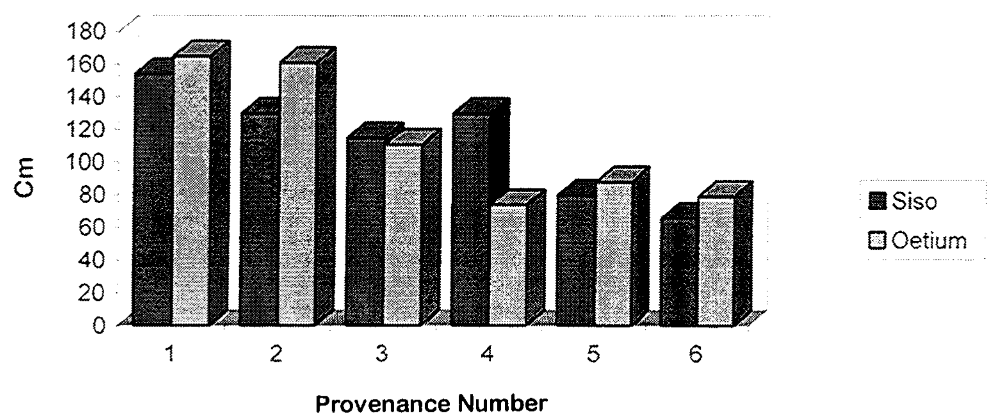
In terms of species, *Acacia holosericea* and *Acacia auriculiformis* thus tend to be superior to good performers under NTT conditions of alkaline soils and prolonged drought, where as *Acacia crassicarpa* tends to be a poor to inferior performers on these sites.

Results - Within Species Comparisons

Acacia holosericea

Looking first at the data for *A. holosericea*, it is apparent that two provenances (16389 and 14660, from Coopers Creek NT and Turkey Creek WA respectively) were superior overall, while 15732 (Edith River NT) and 16143 (Coen QLD) were the poorest performers overall. The other two were intermediate (Figure 27).

Figure 27. Height (BLUP) *A.holosericea* Provenances



1.	S/N 16389	2.	S/N 14660	3.	S/N 16582
4.	S/N 15732	5.	S/N 15366	6.	S/N 16143

The differences in performance of the best and worst groups is of practical significance, as the height at the time of measurement for the best two provenances was double that of the worst two provenances. In terms of biomass production the difference between the provenances would be much greater. This result is particularly important for the type of soil found at Oetium, which is widespread in West Timor and on which there is widespread severe erosion and poor productivity under the ladang for which it is widely used.

There is considerable variation in the form of A. holosericea provenances. This is a spreading form. The one below is more erect.

The two best provenances of *A. holosericea* offer a tree which will be useful in arresting soil erosion, and will improve soil fertility so that improved yields of maize can be obtained when the area is eventually used again for ladang. At the same time, valuable resources of fuelwood will be generated for cash sale by a small farmer or for home use. As this species is not palatable to cattle and also regenerates strongly after fire, it requires little investment of time and care by a farmer-both important considerations in gaining adoption of a new land management practice.

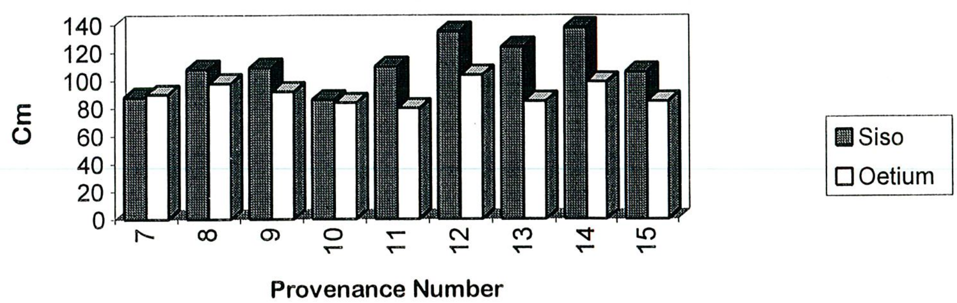
As noted above, provenance number 2 is actually *A. colei*, which has recently received attention for its potential for human food production. If this potential is realised, this species would have an additional value to small farmers in NTT, as the region suffers an annual food deficiency period from September to December when *Acacia* seed could be a useful food supplement.

In *A. auriculiformis*, on the other hand, there was an almost uniform trend for better height growth at Siso compared with Oetium. At Oetium, there was comparatively little difference between the mean heights of the various seed sources, but at Siso there were significant differences, with three provenances (15483, Archer River QLD, 16160, NT and 16106 Mibini PNG) being clearly superior. The remaining provenances were generally similar in height and no worthwhile differences can be seen.

Much better value could have been gained from this trial if it had been possible to test the introduced provenances of *A. auriculiformis* against the naturalised local provenance, but it was not possible to obtain suitable seed at the time it was needed.

Acacia holosericea

Figure 28. Height (BLUP) of *A.auriculiformis* Provenances

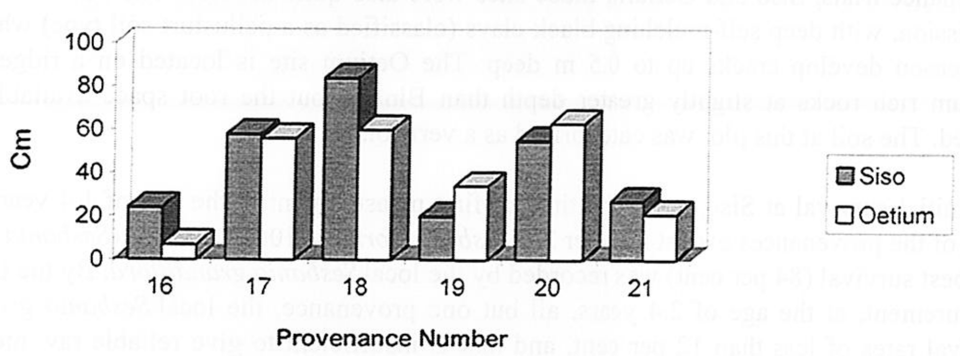


7. S/N 16485 8. S/N 16107 9. S/N 16683 10. S/N 16152
11. S/N 16158 12. S/N 15483 13. S/N 15483 14. S/N 16106
15. S/N 16484

Acacia crassicarpa

This species performed very well in the early species screening trials in NTT and has clear potential for use for the production of high quality timber on soils derived from Raised Coral Terrace.

Figure 29. Height (BLUP) of *A.crassicarpa* provenances



16. S/N 16128 18. S/N 16602 20. S/N 13683
17. S/N 13681 19. S/N 15949 21. S/N 15479

In this species we can see some very clear trends between provenances. Serial numbers 16128, 15949 and 15479, all from Queensland, were clearly inferior in height growth to the other three - 13681, 16602 and 13683, all from PNG. With some variation in the relative growth on each plot, this picture was the same for both field trial sites. The magnitude of the differences between the PNG provenances and the Queensland provenances is also large enough to be of practical importance.

Both plots had very alkaline soils (pH 8+), and tolerance to this factor probably explains the growth differences as the Queensland provenances all exhibited varying degrees of chlorosis, while the PNG provenances usually showed little chlorosis. However, the previous year's trial at Sikumana showed that even on a near-neutral site with better soil fertility, the PNG provenance 13681 was superior to QLD 15479, so there may be real differences in vigour between seed from these two regions.

Section Four - Sesbania Species/Provenance Trial

The provenance trials were planted out at Binaus, near Soe, at Siso and Oetium. In normal years, Binaus would be expected to be cooler and moister than Siso and Oetium, as it is located in the highlands, but in the year that the trial was established, the wet season largely failed in that area. It was estimated by ACIL staff at Soe at the time that the maize yield was only one third of normal for the locality.

In the near total failure of the Binaus segment of the trial the poor rainfall was accentuated by the extreme shallowness of the soils. The site was chosen primarily for safety against local population, which disrupted the near-by earlier Soe-Raised Coral Terrace species trial by cutting the fences and letting in stock for grazing. At Binaus, it was hoped that safety would be guaranteed by the fact that the plot was next to the local forest guard's house, but this did not compensate for the stoniness of the site. In the event, it did not guarantee there would be no grazing either.

Several species and provenances of Sesbania had already failed by the time of first measurement (1.4 years), namely *Sesbania formosa* provenances No. 16175, 16175 and 1065 and *Sesbania sesbans* 875.

Two other species of Sesbania had also failed in the near-by New Species Trial namely *Sesbania erubescens* (local) and *Sesbania cannabina* ex Broome, although the remaining provenances had made some progress. However, by the time of second remeasurement all species and provenances had failed (due again to stock gaining entry), so that comparison is only possible at the first measurement. Although the survival at first remeasurement was better at the other two localities for Sesbania provenance trials, Siso and Oetium, those sites were also quite adverse. The Siso site is located in a depression, with deep self-mulching black clays (classified as a pellusturt soil type) which during the dry season develop cracks up to 0.5 m deep. The Oetium site is located on a ridge underlain by calcium rich rocks at slightly greater depth than Binaus, but the root space available is still very limited. The soil at this plot was categorised as a vertisol.

The initial survival at Siso, up to the time of first measurement at the age of 1.4 years, was fair for most of the provenances except number 26 (*Sesbania formosa* 10650) and 32 (*Sesbania sesbans* 875). The best survival (84 per cent) was recorded by the local *Sesbania grandiflora*. By the time of second measurement, at the age of 2.4 years, all but one provenance, the local *Sesbania grandiflora*, had survival rates of less than 12 per cent, and that is insufficient to give reliable raw means. *Sesbania grandiflora* still had survival rate of 69 per cent and heights averaging in excess of one metre.

The initial survival (age 1.4 years) at Oetium was the most even, no provenance having failed totally, even though some individual replicates did fail. However, by the time the second measurement was carried out, only two provenances, namely the local *Sesbania grandiflora* and *Sesbania sesbans* 874 had survivals in excess of 30 per cent, and further two having survival rates between 20-30 per cent. At this stage the trial was abandoned and the plots reused for a new series of trials.

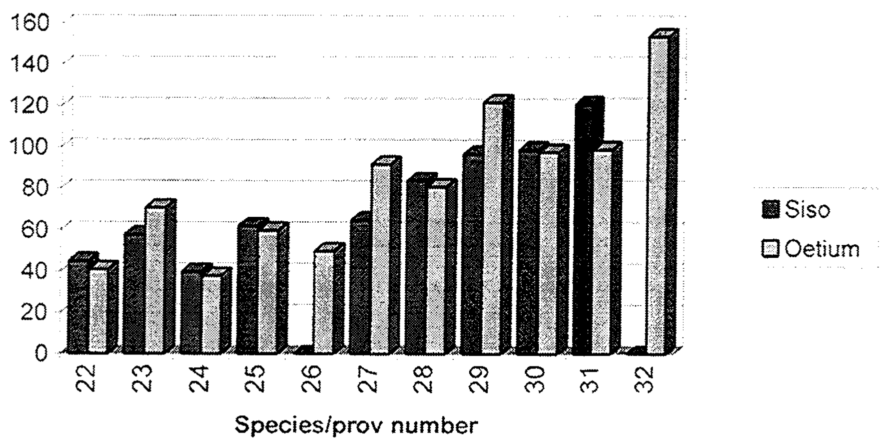
Although the Sesbania Provenance Trial was established as a uniform trial over three sites in terms of the species and provenances trialed, and in the size and design of the three components, comparison across sites is difficult because of the wide divergence in the survival and performance. The fact that relatively poor results were obtained, compared with our expectations, demonstrated how trials carried out in only one season can give results which may not represent the long term situation in the area. Such trials really need to be replicated in successive years to minimise any chance effects of seasonal conditions. As observed in this and the 1990 new species trial, we had the misfortune to strike a wet season with very uneven rainfall.

The Siso site, which tends to be intermediate between Binaus and Oetium in terms of performance over the first year in field, Binaus, in which a number of provenances failed to make the first measurement, and Oetium, in which the confidence limits for the means are very wide, are less suitable for the purpose.

The means referred to above are in fact Best Linear Unbiased Predictors (BLUPs), already discussed for other trials.

At the time of the first measurement, the provenances at Siso fell into two main categories, the shorter (<70 cm) *Sesbania formosa* (16175, unnumbered, 16165, 17662, 10605 and 15439) and the taller (>90 cm) *Sesbania sesbans* (873, 874, 875, 812). The local *Sesbania grandiflora* was intermediate, overlapping the two main categories.

Figure 30. First year height growth Sesbania Species/Provenance Trial (cm)



Species key

22. *S. formosa*	16175	23. *S. formosa*	no num	24. *S. formosa*	16165	25. *S. formosa*	17062
26. *S. formosa*	10605	27. *S. formosa*	15439	28. *S. grandiflora*	NTT	29. *S. sesbans*	873
30. *S. sesbans*	874	31. *S. sesbans*	812	32. *S. sesbans*	875		

Although similar range and grouping of mean heights (BLUPs) was recorded at Oetium, the standard errors were so high that the confidence limits of all species overlapped and no provenance was significantly superior or inferior to the others. However, the broad trend of *Sesbania formosa* provenance being shorter than *Sesbania sesbans* holds except for *Sesbania sesbans* provenance 15439, which is taller than the rest here.

At Binaus, *Sesbania formosa* provenances (17062, 15439) and *Sesbania grandiflora* (local) were inferior to *Sesbania sesbans* provenances (873, 874, 812) in terms of height.

Discussion

The results of this field trial were not as clear cut as hoped for. There can be no doubt that*Sesbania* species have some potential for fodder production on these sites, but further trials are required to prove up their potential. *S. sesbans*, in particular, deserves further work, as its early growth was superior to the widely used *S. grandiflora* on the sites tested here. That some of the species do not survive the first year is not necessarily a disadvantage, as they could be used as annuals to provide a source of quick fodder.

S. formosa was again inconsistent in its performance. It may well be that it is better suited to sites at the wetter end of the scale-not higher rainfall, but soils subject to a degree of waterlogging. The excellent performance of *S. formosa* at the Buat Bobonaro site in the 1989 species trials would support this contention. That this species tends to occur on soils subject to periodic waterlogging in the Kimberley region of Western Australia is also in line with this.

The *Sesbania* trials were unable to thoroughly explore the potential of the various species of this genus under NTT conditions. They have certainly shown that the genus has significant potential for use in this region, most species being well adapted to alkaline soils. Further field trials would have been necessary to carry out a systematic study of the adaptability of two species, *S. sesbans* and

S. formosa to NTT climate and soils. However, the work described here has left a base upon which the Balai Penelitian Kehutanan can build in its subsequent research program.

Section Five - 1990 New Species Screening Trials

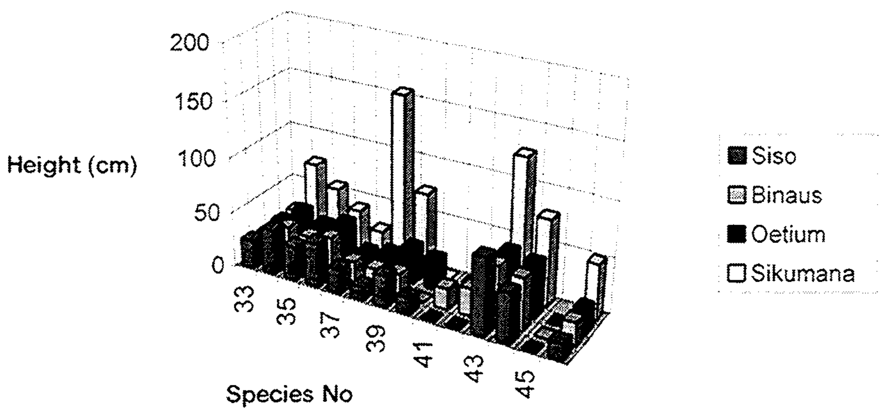
The comparison of the various species in the New Species Trial is made difficult by the small number of species that survived to the second measurement at age 2.4, and the large error term associated with the Siso component of the trial. This trial was severely damaged by cattle deliberately admitted to the fenced area by local farmers.

In addition, there is not the wide spatial separation of the categories that was found in the Acacia Provenance Trial. Overall the performance of the new species is well below that of the *Acacia* species, though better that the *Sesbania* species. In view of this, it may be appropriate to compare the new species with Acacias.

No new species fell into the category of category 1, that is Best Linear Unbiased Predictor (BLUP, hereafter referred to as mean), in excess of 120 cm, that is, corresponding to superior *Acacia* provenances.

There were only two species/site combinations that had a mean exceeding 80 cm, corresponding to good performance in Acacia Provenance Trials

Figure 31. Mean Height at Age One For Four Trial Sites



Species Key

33	*Lysiphyllum cunninghamii*	Broome	40	*A. glaucocaesia*	16809
34	*Pterocarpus indicus*	Benu	41	*A. saligna*	15794
35	*Albizzia lebbek*	Broome	42	*A. mangium*	15589
36	*Pterocarpus indicus*	Amarasi	43	*Calliandra calothyrsus*	
37	*Khaya senegalensis*	Broome	44	*Leucaena glauca*	local
38	*Acacia mangium*	Bogor	45	*Sesbania erubescens*	Broome
39	*Acacia pellita* 15753	Broome	46	*A. aulacocarpa*	15715
43	*Calliandra calothyrsis*	ex Bogor at Binaus	47	*Sesbania cannabina*	Broome

Given the very wide confidence limits of the Siso means, the poorer performance of the species at Oetium and its failure at Binaus, not much significance can be attached to *Acacia pellita's* performance at Siso.

The performance of *Calliandra calothyrsus* at Binaus is offset by only average performance at Siso and Oetium, and consequently not much significance can be attached to it.

Apart from those new species that failed, namely species 40 (*Acacia glaucocaesea* 16809) species 41 (*Acacia saligna* 15794), only three others have given clearly inferior performance of failing to reach mean height of 40 cm by the age of 2.4 years.

33	*Lysiphyllum cunninghamii* ex Broome
37	*Khaya senegalensis* ex Broome
46	*Acacia aulacocarpa* 15715

However, the *Khaya* had very good survival at all sites and has continued to grow slowly but steadily.

Khaya senegalensis at Binaus two years old

The remainder of the new species would fall into the category of poor performers, with mean height at age 2.4 years falling between 40 and 80 cm. They are:

34	*Pterocarpus indicus* ex Pono
35	*Albizzia lebbeck* ex Broome
36	*Pterocarpus indicus* Ex Buraen
38	*Acacia mangium* ex Bogor
42	*Acacia mangium* 16589
44	*Leucaena leucocephala* ex Sulawesi

In addition to the species listed above, several species had largely failed to survive to the second remeasurement at age 2.4 years. They are:

40 *Acacia glaucocaesea* 16809
41 *Acacia saligna* 15794

There were also two species of Sesbania which were a part of this trial.

45 *Sesbania erubescens* local
47 *Sesbania cannabina* ex Broome

Both failed to survive in adequate numbers for second remeasurement and their performance is discussed under *Sesbania* provenance.

The significance of the New Species trial is that it makes possible to relate provenance and species trials carried out in NTT with some key species used in reforestation in Indonesia, such as the local *Pterocarpus indicus* (rose wood), *Albizzia lebbeck*, *Acacia mangium* and *Leucaena leucocephala.* It illustrates the fact that, in the climatic and edaphic conditions of Timor, some of the otherwise rapid growers such as *Acacia mangium, Albizzia lebbeck* and *Leucaena leucocephala,* are only average to below average performers in comparison with the Australian Acacias and Eucalypts. The indigenous *Pterocarpus indicus* and the exotic *Khaya senegalensis,* both of which have timber of outstanding quality, are also inferior to Acacias and Eucalypts in initial growth, which therefore cannot be used as a sole criterion of suitability.

Acknowledgments

The multipurpose tree part of this Project would not have been possible without the wholehearted support of a number of people. In Indonesia, Harisetijono, supported by Dedi Setiadi, was a tower of strength who worked hard and reliably to achieve results. They were strongly supported at all times by the OIC of the BPK, Ir Sutarjo Suriamihardja. On many occasions it was his intervention with Dinas staff that enabled the project team to gain access to field trial sites.

We would have found our work in NTT much more difficult had it not been for the enthusiastic and friendly cooperation we received from staff of ACIL Ltd involved with NTTIADP. We must especially thank Alan Smith, then ACIL Team Leader in Kupang and John Janes, who established the 1989 plots for us at Besi Pae.

In Jakarta, the Project received helpful support at all times from Andrew Elms, the ACIAR liaison officer in Indonesia, and from Sheila Subroto, especially during the purchase of the Kijang vehicle.

From CALM, Roger Edmiston laid the solid foundations at the Sikumana nursery upon which all the field trial work was dependent, and he was ably succeeded by Peter White. Only those who know of Roger's addiction to steak will appreciate his staying power and dedication to work in the early days at the Wisma Cendana. Richard Moore contributed valuable assistance in establishing the trials from 1989. Joe Havel was a tower of strength throughout, bringing his long experience in research and developing countries, as well as his flair for languages, to the Project.

References

Aldrick, J.M. (1985). Phase II feasibility and design study NTT livestock development project, Indonesia, Vol III land resource soils, ACIL Ltd Melbourne.

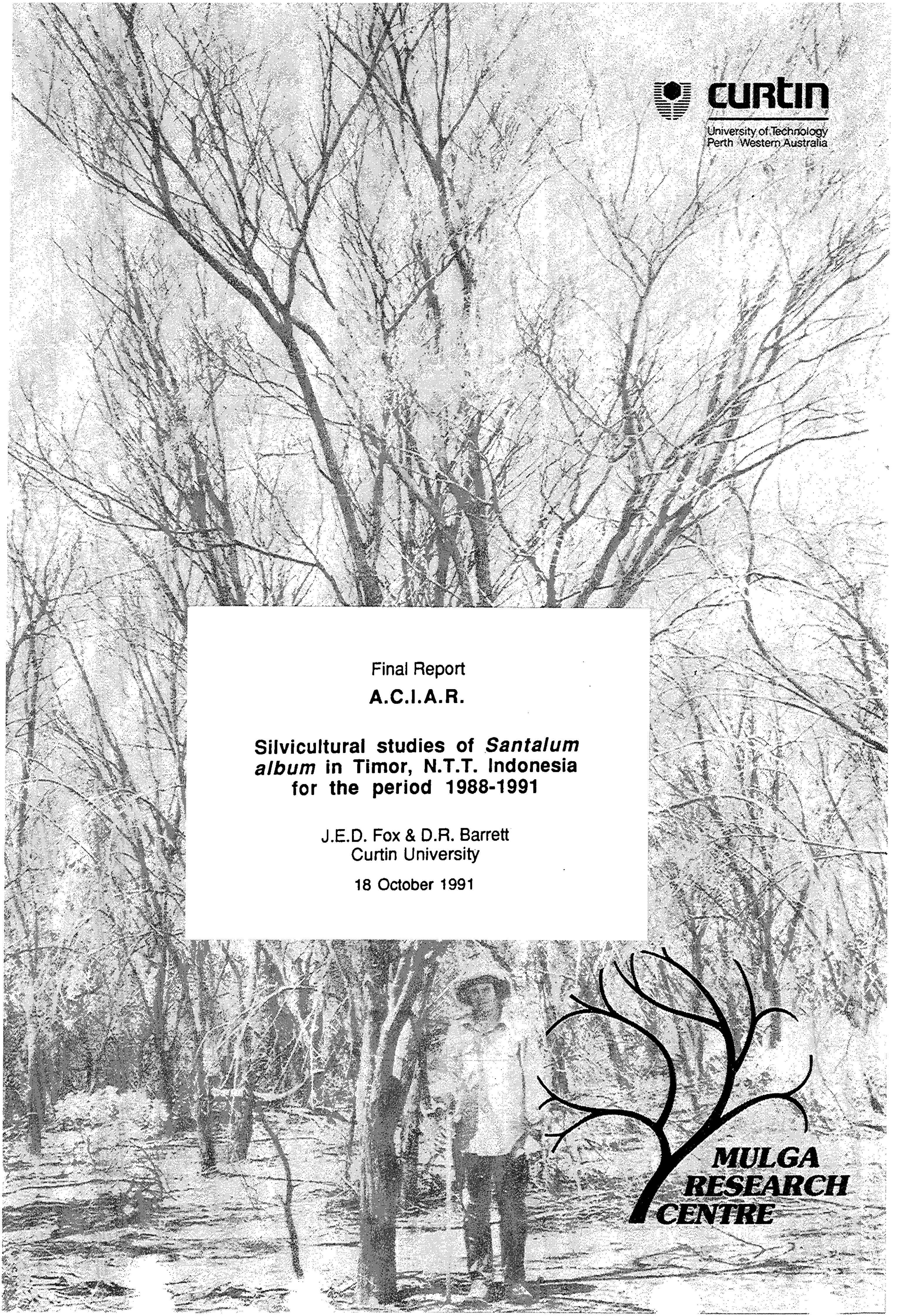
Briscoe, C.B. (1989). Field trials manual for multipurpose tree species. Winrock Int. Inst. for Agric. Dev.

Digby, P.G.N. (1979). Modified joint regression analysis for incomplete variety x environment data. J. Agric. Sci. 93:81-86.

Duggan, K. (1989). Land environment in Nusa Tenggara Timur. Proc. Workshop on Economic and Social Development of NTT, Canberra.

APPENDIX 1

REPORT BY J.E.D. FOX,
CURTIN UNIVERSITY



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Perth Western Australia

Final Report

A.C.I.A.R.

Silvicultural studies of *Santalum album* in Timor, N.T.T. Indonesia for the period 1988-1991

J.E.D. Fox & D.R. Barrett
Curtin University

18 October 1991

MULGA RESEARCH CENTRE

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Silvicultural studies of *Santalum album* in Timor, N.T.T. Indonesia for the period 1988-1991

J.E.D. Fox & D.R. Barrett
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18 October 1991

Introduction to all projects

Research into cultivation of sandalwood, *Santalum album*, under the Australian Centre for International Agricultural Research Programme (ACIAR) has included several aspects. Perhaps the most important has been screening of potential hosts. The most conclusive study to date has been selection of the best soil mixture for use at Kupang. Other studies have involved fertiliser trials, planting methods, selection techniques and provision of early shade.

In some instances, trials have not been successful and the results are indefinite. Sometimes this has resulted from environmental problems such as fire or cattle intrusion. In other cases nursery stock, plastic tubes or potting mixes have not been as good as is possible to achieve. Generally the larger and more complicated experiments have tended to have most problems. When several variables are introduced the background variability of positioning or site, can over-ride the factors being assessed.

Priorities were discussed early on and these have become accepted with time. A step-by-step approach with redefinition of directions has sought to give a sustained increase in the level of success. Particular aspects of the overall programme have been solved but some gaps remain. Future work should logically draw on proven procedures - Eg it is no longer necessary to include 'no-host" treatments and small plastic bags are not the best.

The background to understanding of how to handle the question of establishing *Santalun album* in the field comes from a report produced in 1976 by the Forest Research Institute at Bogor. This was prepared by Zoefri Hamzah (1976). It contains entries under a variety of headings and the report sought to distill earlier knowledge with practices current at the time and a certain amount of circumstantial lore into a complete synthesis. This text includes all prior writings and as it is not selective or critical it cannot be used as a basic manual. A variety of researchers delved into it and sought out topics for research projects. In recent years useful experimental work has been done at Gadjah Mada University by way of undergraduate student projects, by research staff at Forest Research Institute at Bogor and by the Kupang FRI team. Little Indonesian work has been formally published and it has proved difficult to obtain concensus on research achievements. One of the early aims of the ACIAR programme was for the organisation of a seminar to bring together researchers to review the current state of knowledge. A programme of this nature was in fact held at Gadjah Mada University in July 1987. This coincided with the planning stage of the ACIAR programme and Australian researchers were not involved. The papers presented at that "Sandalwood Discussion" have not been collated, critically edited nor formally published. Several contributions do contain useful factual statements. Many follow the trend set by Hamzah (1976) in quoting from Rham (1925) and Kramer (1922). These two papers may be considered classical texts in relation to an understanding of *Santalum album* in Timor. It would be anticipated that a useful international seminar could be held at Kununurra, WA in 1992.

Project 1: Selection of trees for seed collection

The main thrust of this project has been demonstration of selection criteria for trees to be reserved for seed collection.

In India the Sandal Research Centre at Bangalore has surveyed and assessed sandalwood characteristics for both quality and quantity as a gene resource for breeding and conservation. Stands of sandal in Kerala, Tamil Nadu and Karnataka have been selected as seed production areas. Seventy nine individual trees have been designated as "plus trees" because they are of high quality as regards fast growth, maximum heartwood volume and fragrance, straight boles, resistance to disease and pests, and flowering and fruiting ability (Rai 1986). Since many of these desirable characteristics are thought to be genetically controlled, seed from these "plus trees" are preferred.

Two possible sources of variation are particularly important in the first instance. The first is growth rate. It is generally the case that within a species there will be a range of growth potential. For most trees, especially for those grown for timber, selection for fast growth will enable a shorter period between establishment and harvesting. Variation in growth rate is of considerable importance for species, which generally grow slowly. *Santalum album* is usually considered to be a fairly slow growing species so those individuals which show fast growth could be examined to determine whether fast growth has a genetic basis. Whether this is so or not, particular site conditions may influence growth. Different growth rates may be expected when seeds from different places are used to produce plants to be raised in any one place. Some may be more adapted to the site where the trees are planted and others may be less adapted. Thus at one place plants from a particular locality may be fast growers, and at another planting place those from another locality may grow fastest.

The second source of variation considered is in oil content. In the case of *Santalum album* the value of a tree is in its oil. We assume that more heartwood will give more oil, but without laboratory distillation it is not possible to estimate the oil. Thus, of the measurable characteristics of felled trees the amount of heartwood is of most interest. As in India for *Santalum album*, in Western Australia also there is good anecdotal evidence that *Santalum spicatum* varies considerably in oil content. For both species some trees and some areas produce very little oil. Seed collection from such sources is not to be encouraged. A programme may be developed to determine whether it is possible to select trees on the basis of oil content in order to use seeds from superior oil producing trees.

In addition, an area of doubt which may or may not have relevance to oil content and which is capable of being cleared up reasonably quickly, is the question of the existence or not of two varieties based on leaf size. This is widely accepted as being so. The 1987-1988 inventory defined small leaves as 2.2 - 4.8 cm in length and large as between 3.7 and 8.5 cm in length. Several plants were examined briefly and found to have a range of leaf sizes. However there appear to have been no critical studies on the range of sizes likely on a given tree. Clearly some new leaves might be small because they are not fully expanded. There may also be nutritional/environmental causes. Should the largest 20 leaves of a "small leaf" tree be significantly less in mean length than a similar set from a "large leaf" tree, some basis of a genetic difference may exist. A student from Gadjah Mada has written a thesis on leaf variation, based on about 100 samples from Buat (Adriyanti, 1989). Mr Kharisma's experiment at Buat includes progeny from large and small leaf parents. In due course all plus tree progeny may be able to be characterised on the basis of their largest 20 leaves. Initially seed from two contrasting leaf size trees could be sown and their progeny assessed. Shading experiments may also throw light on the variation.

The desirability for plus tree designation in Timor has been recognised for some time. However, the first attempt to come to terms with how this should be done has resulted from the ACIAR programme.

The current method of determining whether individuals are harvestable is to determine the amount of heartwood by boring into the stem. An early field trial compared increment borers with the conventional NTT auger style borer at Kefamenanu and in the Soe area. The conventional borer was superior. The auger style borer could be inserted rapidly, heartwood detected readily from wood frass by scent and colour change. The increment borer was more difficult to insert and remove, some compression of the core was suspected, and it was much more difficlt to estimate depth to heartwood in the field. The only advantage of the increment borer was that the narrow diameter core would be likely to cause less damage. A supply of a tar based filler was suggested as desirable to block off the hole made after testing with the conventional borer.

In mid -1988 a set of harvested *Santalum album* trees was examined from Nilulat/Haumeniana, in Kefamenanu province. Of the 96 felled trees a complete set of measurements was available for 76. The first effort was to examine the characteristics of these typical, conventionally harvested trees. This set represents the currently exploitable range of material and is useful for a number of purposes including the criteria for selection of candidate plus trees. Most trees were between 8 and 15 m in height and 4 of the larger trees exceeded 50 cm diameter at breast height (d.b.h., taken as 1.3m).

Measurements of depth from outer bark to heartwood (sapwood radius), the girth (and hence diameter) of the bole at 1.3 m, and the length of bole and tree height were available for 76 individual felled trees. From the dimensions measured it is possible to work out volume tables which could predict the potential heartwood yield. The heartwood from 42 of the 76 trees was weighed.

From these measurements an estimate of percentage heartwood based on basal area was made (Udi Tiyastoto, 1989). The heartwood content, defined as the cross-sectional area of heartwood expressed as a percentage of tree cross-sectional area at a height of 1.5m from the ground, ranged from around 20% to 70%. The best of the felled tree set had about 70% heartwood as measured at the basal area point. This confirms the notion of considerable heartwood content variation in trees of similar history. Trees with a high percentage basal area (between 60 and 70 percent) fell within the stem diameter range of 20-60 cm. A useful criterion for selection was that if a tree has 60% heartwood (that is % basal area or cross sectional area) at 1.3 m such a tree should be considered for status as a plus tree. An amended technique has been developed to include trees less than 20 cm in diameter. This is based on a trendline % heartwood = 18.6 + 1.56 diameter. Basically any tree of 12 - 14 cm diameter with < 2.5 cm sapwood radius or of 14 - 20 cm diameter with < 3.0 cm sapwood radius can be taken as candidate. It is not known whether many small trees are likely to meet this additional criterion. Figures 1 - 3 illustrate characteristics of the felled tree set.

The volume of heartwood in the 10 'best' trees (Ie. those with the highest basal area content), was significantly correlated to tree diameter, tree height, bole length, low sapwood radius and heartwood weight and total tree volume (Table 1).

TABLE 1 Significant correlations of volume of heartwood for 10 trees with the greatest percentage heartwood basal area.

Measurement	Correlation with heartwood volume	Significance
Heartwood weight	.980	*
Tree diameter b.h.	.848	* *
Total volume	.788	* *
Bole length	.784	* *
% heartwood b.a.	.734	*
Sapwood radius	.696	*
Tree height	.636	*

** correlation coefficients exceed p 0.01 and * p 0.05

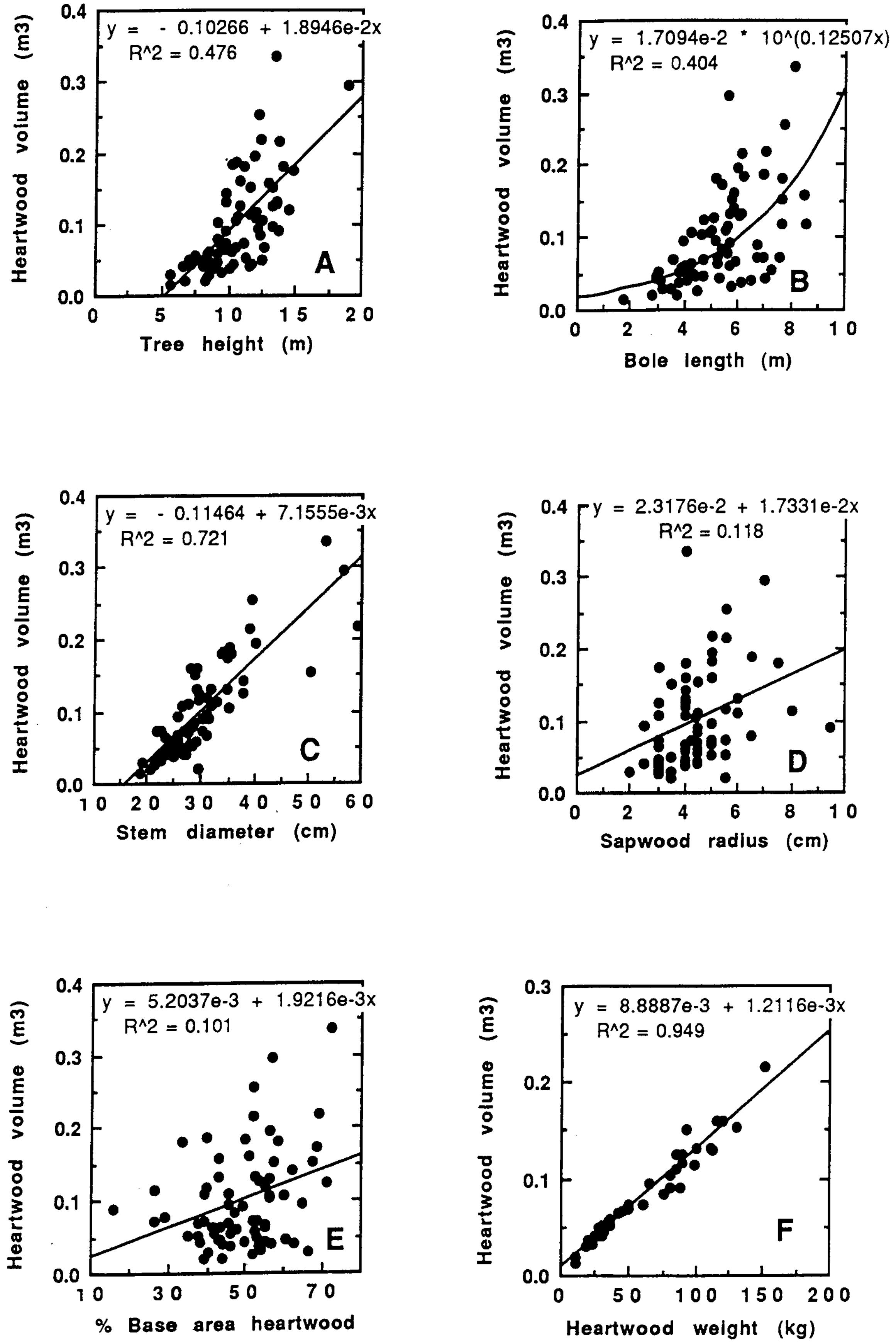

Figure 1. Relationship between heartwood volume and other tree parameters for the 76 felled tree sample from Nilulut/Haumeniana, Kefamenanu Province. (Tree diameter taken at breast height on bole).

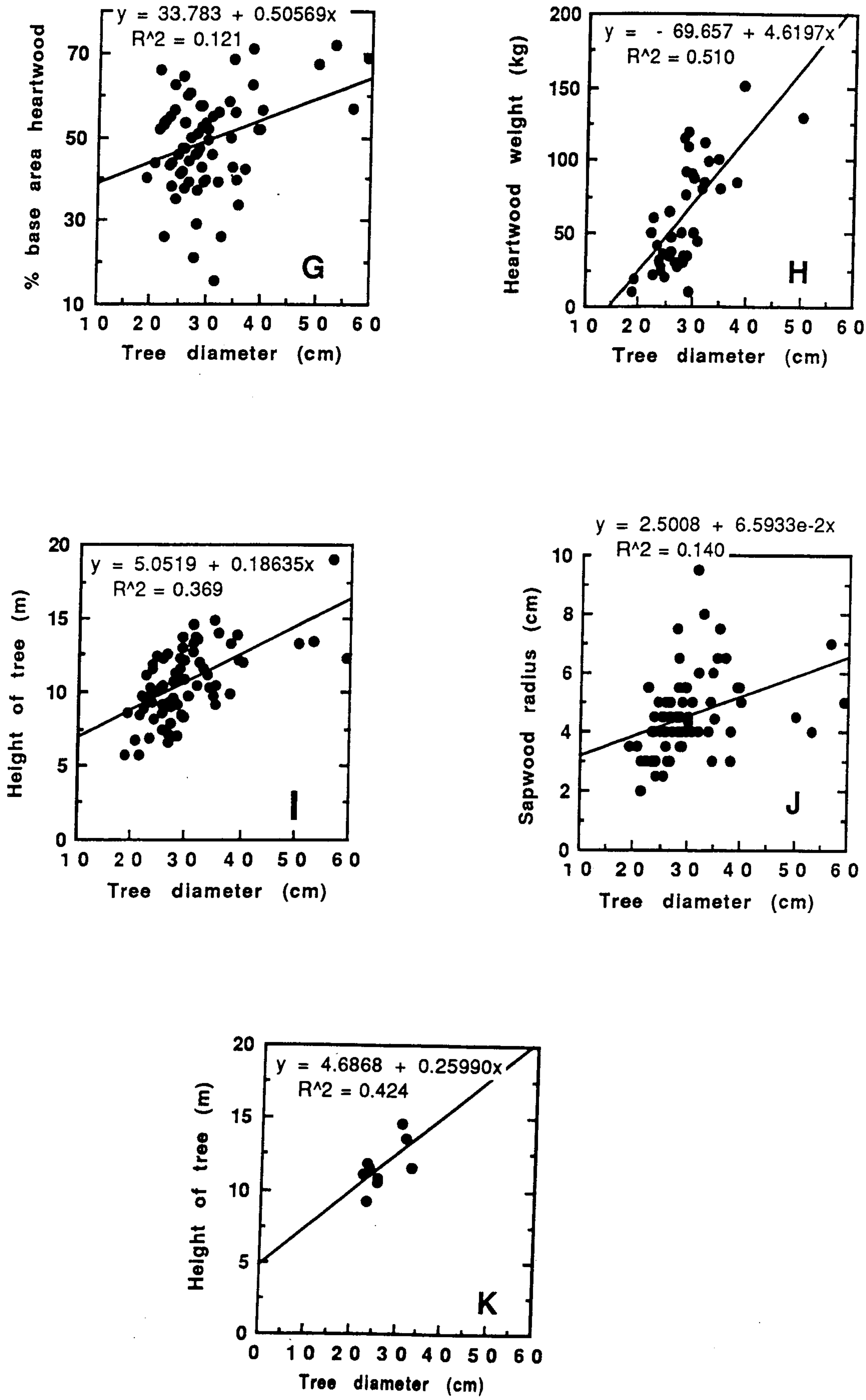

Figure 2. Relationship between tree diameter and other parameters for the 76 felled tree sample (graphs G, H, I and J) and for the 10 'best' trees (graph K) from Nilulut/Haumeniana, Kefamenanu Province. (Tree diameter taken at breast height on bole).

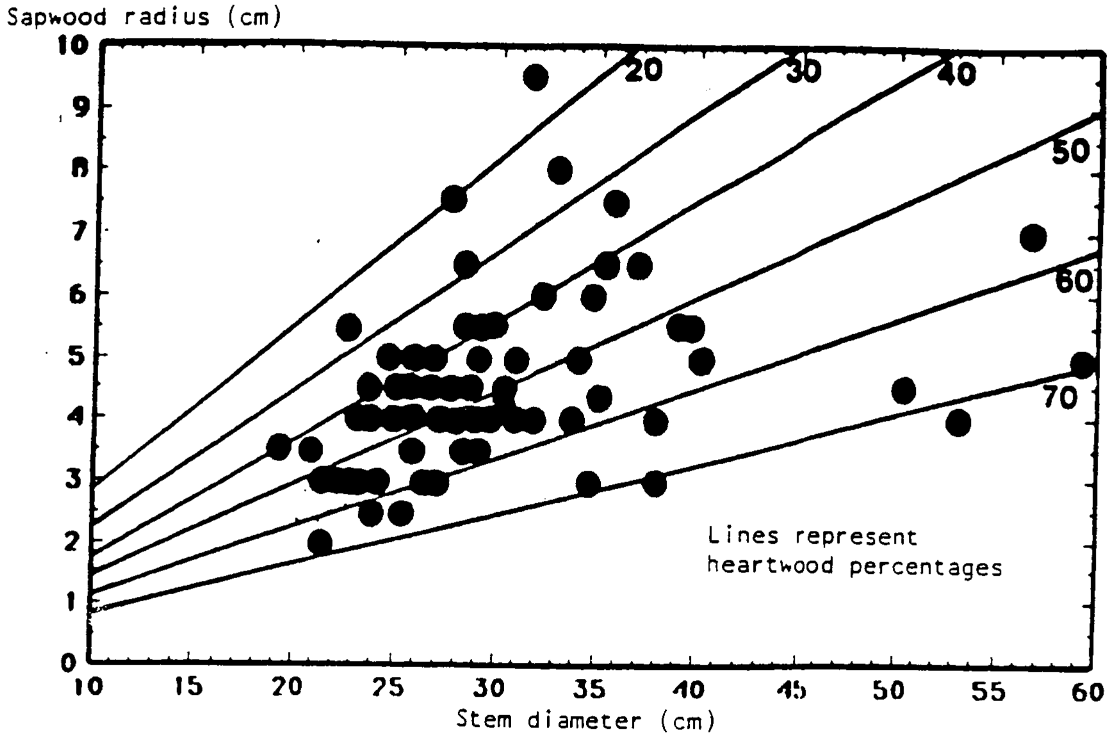

Figure 3. Relationship between stem diameter, sapwood radius and heartwood percentages for all felled trees in the 76 - tree set.

The set of 10 trees selected as having the greatest percentage heartwood basal area were from the set of 76 trees felled on the basis of being superior in quality of heartwood. Before cutting, each tree was tested with the NTT auger. Trees with little heartwood were rejected and left standing. Thus, the overall selection ratio would actually be much lower than 10 in 76 because an unspecified number of trees were rejected prior to felling. Subsequent field sampling of live trees has generally found at least the same number of trees with as without significant quantities of heartwood. Graphs of the type illustrated in Figure 3 have been developed for rapid field assessment of heartwood percentages. It is preferable to paint mark trees as soon as they are known to be candidates for plus tree status.

A programme for testing heartwood for oil will depend on the ability to track harvested material through processing or to test individual standing trees separately. Using already exploited trees rules out the collection of seed but this approach could be used to differentiate areas or stands. Thus if from a given locality it can be determined that trees consistently produce higher than average oil contents, that locality must be given special attention. Trees must be preserved for seed collection on an indefinite basis. This may require special provisions to avoid harvesting, to protect the area from clearing, burning or other changes, and of course to ensure that the people of the area are fully acquainted with the reasons why such trees are to be preserved. Many past efforts at improving the basis of sandalwood cultivation have foundered due to lack of communication with villagers who have not known that the trees are special and should be used for seed collection. Payments to villagers may assist with this.

A second approach to selecting high oil content trees for seed collection is to use plantations where such exist. A non-destructive sampling procedure to test the oil content of a plantation of same-aged trees would first involve mapping and measuring the trees. A combination of fast growth and high oil content would be especially desirable. The following hypotheses could be tested:

- that variation in oil content occurs
- that oil content is proportional to heartwood
- that sampling of trees at, say, 10-20 years from planting can discriminate between superior and inferior oil producers.

Either approach would require a range of trees to be selected for sampling (non-destructive). Sampling should be to provide estimates of oil per unit dry weight of heartwood, (or some similar index), which can be related to tree sizes and/or ages. Some follow up analysis may be required - for example, assuming that testing suggests that larger trees of a given age have more heartwood and more oil content, then the indication would be that within a block, larger trees could be used as seed sources. Confirmation could rest on further analysis from additional large trees of a given age.

As the trees age the quantity of heartwood increases. This implies that wood material that was previously sapwood gradually becomes heartwood. This change is associated with the accumulation of oil in the wood. Since it is known that trees grow at different rates and have different quantities of heartwood at similar ages, it is the proportion of heartwood in the tree that is of interest rather than the heartwood content *per se*. If we simply concentrated on heartwood content then all selected trees would automatically be the larger, older trees.

There is evidence that some large trees are poor in heartwood and some small trees are high in heartwood. This is manifested in the Timor felling rules which provide for a minimum size of 50 cm girth (15.9 cm d.b.h.); heartwood diameter of more than 12 cm and a narrow sapwood thickness. These rules mean that for the felled tree set no trees with low heartwood content could have been included. For the felled tree set examined, age may well have been the dominating factor in heartwood content.

Since exploitation of trees has been going on for a long time, it must be assumed that most of the larger older trees have now gone in most, if not all, localities. The phenomenon is known as "creaming", cutting out the good and leaving behind the runts. It may well be that residual large trees in exploited areas were rejected for removal earlier on as having a low content of heartwood. To use such trees for cultivation is a form of negative selection, a common enough hazard in many tropical forests.

Conversely large trees in remote areas may not have been subjected to exploitation. Location of trees in such locations is considered an urgent priority for securing a wide variety of gene pool material for reservation.

Forest reserves, private lands and plantations were possible areas to search for trees to sample for 'plus' characteristics. An examination of inventory and current production data indicated that the South Central Province (TTS) based on Soe would be the most productive for a starting point. In this region two main plantation origin stands were located. They were examined first because of the ease of access by Timor staff with limited mobility. Without transport to get about to the more remote areas coverage is difficult.

Ajaubaki. At Ajaubaki, near to the town of Kapang in Mollo Utara, the trees occur in a formal plantation. The Soe office records indicate that 12 ha of *Cassia siamea* and *S. album* were planted in 1929 and a further 5 ha planted in 1951. It is believed that the site examined dates from 1951. The origin of the seed used in planting sandalwood is not available, but it is likely that it came from a nearby area. Seventy eight trees were examined over about 8 ha. The soil at this plantation site is grumosol over coralline limestone. A number of the sandalwoods were observed to be leafless at the June 1989 visit. The dominant host is *Cassia siamea* . *Psidium guajava*, which apparently seeded in naturally, is common as a dense understorey. Some farms have encroached into the plantation from the edges. Nine trees were selected as candidates based on borings. One subsequently blew down. The trees with the best form were nos. 1, 4, 7, and 8. No. 6 has 4 trunks at 60 cm and no. 9 has a wide spreading crown with low heavy branches. The area is an example of agroforestry. With very simple management this could provide high yields. Some tethered cattle in the block could continue to utilise grass but cultivation for food crops should be stopped. This is causing damage at several edges of the plantation. The large *Cassia* may have already been thinned out for firewood.

Oenutnanen. The second location is at Oenutnanen, Mollo Selaten. Here the records show that *S. album* was planted over a number of years: 1924 (2ha); 1928 (6ha); 1929 (6ha); 1934 (17.5ha); 1936 (17.5ha); 1937 (7 + 14ha). It was not possible to locate any maps showing where these blocks were, so that dating of the trees has not been possible. Most of the planted trees here are in gardens (or on land that has been gardened) on fairly steep slopes in limestone karst country. Consequently there is a range of host trees present and much damage from past burning for gardening activities. All trees with obvious basal holes were omitted from consideration, so that depth to sapwood was not taken on such defectives. After initial screening using the boring technique candidate trees were measured for total height, length of bole and stem diameter. Notes were made of tree shape, distance from putative hosts and so on. A number of candidate trees had more than one main stem, and these usually only had good heartwood percent on one stem. As at Ajaubaki, several candidate trees occur in clumps of other stems so that fallen seed collection is not always reliable from the numbered candidate.

Another area examined for selection was part of presumed village land, formerly forest land, at Siso, not far from Soe. Here a number of natural trees occur in and near present settlement. A set of plus tree candidates was selected by Udi Tiyastoto. These were not as rich in heartwood as the candidates at Ajaubaki and Oenutnanen. Those in the forest area were mainly deformed by heavy liana growth or heavy shade from nearby large forest trees. In the garden areas trees often had wounds and low forks, the latter perhaps due to open growth. Several had no apparent large woody hosts in the vicinity. Two sets of younger stems (root sucker growths?) around older trees were measured. There were 39 individual stems at Nonmolo, an old grave site on a rocky limestone hill with a large *Bombax ceiba*. Fifty seven stems were measured in an open area around CT No. 24. *Carica papaya* and *Alstonia scholaris* grew in the area which was heavily gardened and in between houses.

Provincial staff at Soe indicated many trees grew in Konohousisi. This area lies beyond Buat. A total of 31 trees were examined and 16 measured in detail. Road conditions were bad in this area due to rain on slippery surfaces (November). A number of trees was also assessed in the vicinity of Nusa and Nefa Nusa on the Niki Niki road in Amanuban Barat. These were on limestone karst and on the whole had poor heartwood. Possibly many of these were of sucker origin. Some of these trees had fruit and flowers in November 1989. Further searches were made for candidate plus trees between Niki Niki and Soe, in the vicinity of Tetaf and Oesena. Komang and Markum also searched for candidate plus trees around the Buat area, near Soe. A total of 24 was examined for sapwood thickness and of these two stems were reasonably good.

With the use of the ACIAR car, it was possible to venture further afield. These forays were not always successful. At the suggestion of the District Forester at Oenlasi, a long journey was made to Kokoi. The road was very difficult. The Kokoi locality was high on a stoney hill with all the land around farmed, including some steep slopes. A large number of badly formed trees were examined and many individuals had basal holes. An area of remnant forest on a hill top was examined. This was preserved by the local people as a sacred bush area (Lunu Hutan Adat). No sandalwood was found in this dense forest, but a number of individuals were present on limestone karst soils below the forest where all other vegetation had been cleared off. Very few trees had appreciable heartwood.

The most remote area thus far visited, Netpalen, yielded a number of very good candidates and may well be the best site of all. There were magnificent stands of *Eucalyptus urophylla* en route to Netpalen (Kaijaob) where the district forester at Kapan had indicated there were good specimens of *S. album*. After walking a considerable distance we were rewarded by seeing a number of good specimens on steep slopes with *Casuarina, Albizia chinensis, A. lebbek* and *Acacia leucophloia*. A number of trees were sampled for heartwood and several with high levels were recorded. A later visit (April 1990) to Netpalen added more trees, shown to us by the local forester, Nicodemus Sole (O-I-C Kapan). Several of these had good heartwood. This location required a longer walk than in November as the access road to the nearby village could not be driven on due to the wet soils following the rains.

The Siso set is generally the poorest on the criterion of heartwood content. Several trees there were selected on the basis of good form. Form is a difficult criterion to allocate in view of the varied growing condition of the trees. One adequate tree was identified from the Kefamenanu area based on testing of some 16 trees over a wide area by Fox, Robie (RFO) and Kharisma and about 30 by Udi at an earlier date. Surveys in the Kupang area have covered a few trees only with no candidates. Time could be saved if regular checks were made with District staff where felling has been scheduled to occur and where the officers who bore trees can also assist with selection. Reports by the forestry staff to the research institute would facilitate matters.

In summary, from October1988, surveys were carried out in 12 different localities (Table 2). The intention originally was to select candidate trees from each of the four Timor provinces. Besides having above average heartwood, the characteristics of narrow branch angle, good height to first major branch, and absence of basal holes or damaged roots are other criteria for selection. Some 50 trees have been selected to date as candidates for plus tree status (Figure 4) and seeds have been obtained from 30 of these. These trees have been pin-pointed on location maps, numbered, given a notice indicating status, and photographed. It is vital that Forestry Department staff are aware of candidate trees and do not permit them to be harvested.

TABLE 2 Plus tree assessment

Location	Date Surveyed	Assessor*	Numbers Examined	Numbers Marked
Buat	October 1988	JF/Kh	6	0
Meneke	November 1988	U	39	0
Nibaaf	November 1988	JF/Kh	14	0
Amarasi	November 1988	W	10	0
Ajaubaki**	April 1989	U	78	8
Oenutnanen	April 1989	U	82	12
Siso	October 1989	U	48	9
Buat	November 1989	Ko/M	24	2
Kokoi	November 1989	U/Ko/M/JF	20	3
Konohousisi	November 1989	U/Ko/M/JF	31	3
Netpalen	November 1989	U/Ko/M/JF	17	6
Netpalen	April 1990	Ko/M/Kh/JF	4	2
Niki Niki-Nule	November 1989	U/Ko/M/JF	56	8

* JF = Fox; Kh = Kharisma; W = Wayang; U = Udi Tiyastoto; Ko = Komang M = Markum

** Originally 9, one blew down.

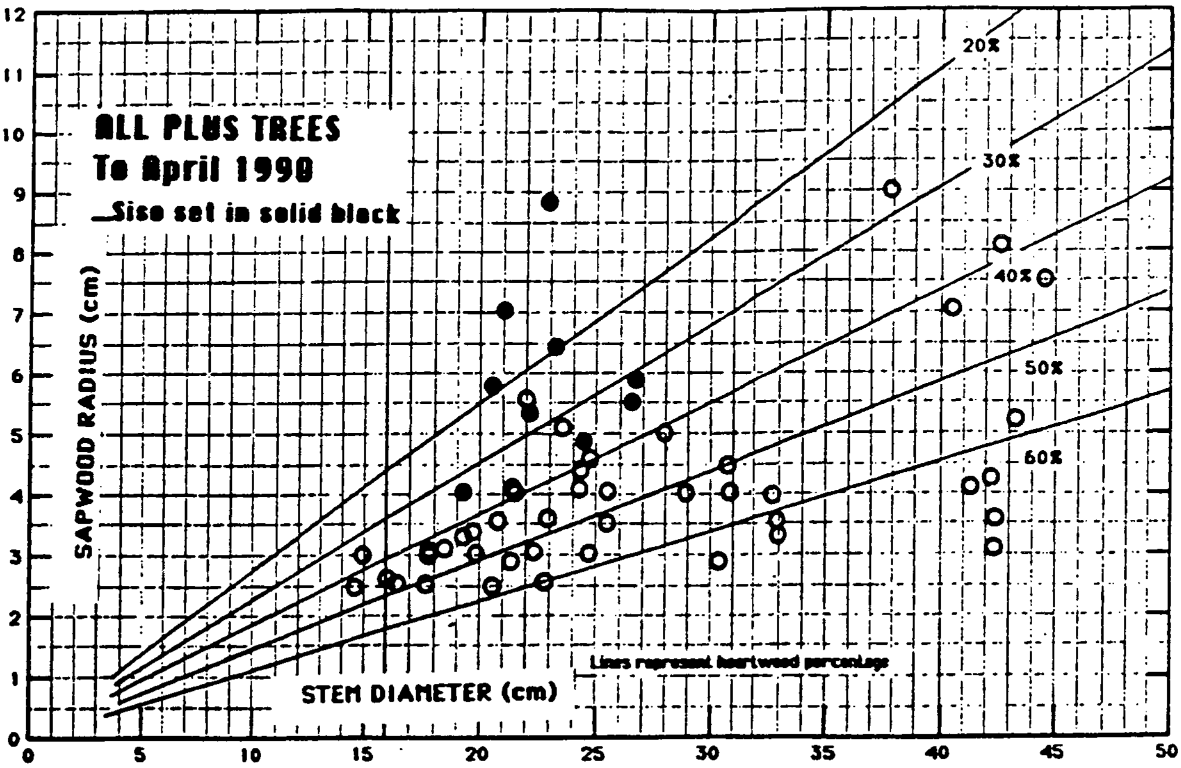

Figure 4. Sapwood radius/stem diameter and heartwood basal area spectrum for the candidate plus trees selected to April 1990. Seven of these exceed 60% heartwood.

An important problem is the frequency of gardening activities. At Ajaubaki, Oenutnanen and Siso, villagers are using the sandalwood areas for cultivation. This is contributing to basal damage to trees and the development of hollows apparently eaten out by termites.

Revision of the selected plus trees may be needed if for instance the selected trees turn out to be slow growing, to have variable progeny or if oil percent is not well correlated with heartwood percent. Work needs to be done on sorting out other characteristics - growth rate straightness and bole length, for example and if there is any correspondence between these and high heartwood percent/oil content. In the first progeny trial sets of 15 plants from 11 separate parents were planted in December 1989. The best progeny set in terms of early growth came from Tree 18 at Oenutnanen. This tree has second heaviest seed weight of the 11 collected in 1989, it germinated sooner and with higher percentage than the others. Seedlings had a taller mean height prior to planting. The parent tree had a stem diameter of 24.5 cm at assessment and 40% heartwood.

The urgency of selection of potentially high yielding trees for retention implies that in the next few years priority must be given to nominations of superior trees. This is best done on a combination of auger boring to test depth to heartwood and observations of tree form. Only for plantation trees can age be reliable. It is possible that some other, as yet unseen areas of plantation exist. If this is so then these merit attention. The main thrust however is suggested as being in more remote and inaccessible areas. For this to be done effectively a dedicated officer is required to be assigned to the selection programme.

Project 2: Seed production from selected trees

In India it is reported that the appearance of *Santalum album* varies according to the conditions under which it grows. If grown in light shade or open situations, the tree rarely has a crown height taller than 6-7 m average, or about 12 m maximum. The foliage is scanty or nearly bare in hot weather, light green tending to yellow in colour. If grown in the dense shade of other trees, sandal may have a bole height of 15 m to 18 m (with a 2.4 m girth) with a high, bushy crown, and a large leaf which is darker green and thicker than those grown in more open conditions, (Hutchins,1884).

Tree height in Timor does not appear to exceed 20 m and a tree of 15 m usually represents good growth. There is much confusion on leaf type with all surveys usually designating a tree as big leaf or small leaf, (see Project 1). This distinction stems from early observations by Dutch foresters but the first attempt at determining whether varieties are involved was made recently (Adriyanti, 1989). Our present opinion is that the position of the tree (whether in the shade or in the open), and the season may well be responsible for differences.

Trees begin to flower and bear fertile seed at 3 or 4 years of age. Some seed has been obtained in Kununurra (WA) from 2 year old trees, (Fox and Barrett, 1988). The seed from these young trees was viable (P. White, pers.). Sandal flowers are purplish brown when mature, unscented and in axillary or terminal cymose panicles. The fruit is a purplish black, globose, succulent drupe, 5 - 8 mm in diameter and normally weighing around 0.16 g. The fertility of seed produced on young trees is uncertain but as trees age seed becomes more prolific, and there is a higher proportion of fertile seed. Abundant good seed is produced each year on nearly all trees over 20 years old.

Flowering and fruiting seasons vary, probably depending on the growing region. In Mysore, which is in the sandal belt, sandal flowers at the end of the hot season (peaks in June) and the fruit ripens in a few months, usually at the close of the rains (September). A second flowering commences in November with fruit ripening about February. In other areas flowering and fruiting may occur at different times of the year. One often finds nascent flowers, buds, flowers at different stages of development and maturation, and ripe fruit on a tree at one and the same time. Although most trees in India usually flower and fruit twice a year, some trees flower and fruit throughout the year, others once a year and some not at all. In Timor it is usual for one main crop to be produced, generally between January and May. However the timing varies. During the April 1990 visit fresh fruit was found at Netpalen but at Siso fruiting was much earlier. Fruit became available in March in localities used for seed collection in early 1990. Time of collection will thus vary with locality.

Seed is dispersed by birds (Rai and Kulkarni, 1986; Fox, 1988).

Seed collection is a fundamental part of all plantation programmes. It must be done efficiently, be cost effective and produce the highest possible proportion of viable seeds. Trees of high oil content should be preferred for seed collection and seed should be measured and weighed to characterise each selected parent, as part of the research programme.

In India seed is generally considered to be viable for up to 9 months when correctly prepared and stored, although Hutchins (1884) reports seeds germinating well after 2 years. Correct preparation and storage entails collecting fresh fruit from the ground or tree, completely defleshing by washing well in water, drying in the shade, treating if possible with an organo-mercurial fungicide and storing during the dormancy period in polythene or gunny bags in a dry place (Rai and Kulkarni, 1986). This storage is inadequate for the hot conditions at Kupang. The first seed bought from Timor was material stored at the Provincial office in gunny sacks for 9 months. At least 90% was rotten.

In Perth, good germination has been obtained from specially collected seed stored in a refrigerator for over 6 months after receipt from India. Commercial stock purchased from Indian seed merchants has given zero percent germination for three separate purchases. Figures 5 and 6, the results of trials at Curtin University, suggest that viability differs little between 2 and 6 months storage.

In Timor both different sources of seed and collections from individual trees, vary considerably in percentage germination attainable and in the survival capacity of seedlings. For example best results for percentage germination and early height growth in Timor were obtained with CT 18 from Oenutnanen at Oilsonbai in 1989.

Careful handling and cool storage should ensure carry over of seed from one year to the next. Care in germination is more important in Australia where we rely on *S. album* seed brought from elsewhere. When adequate seed supplies are available then low germination rates and reasonable nursery losses are tolerable. For seed from selected candidate plus trees special care is needed in Timor to maximise the potential progeny numbers attainable.

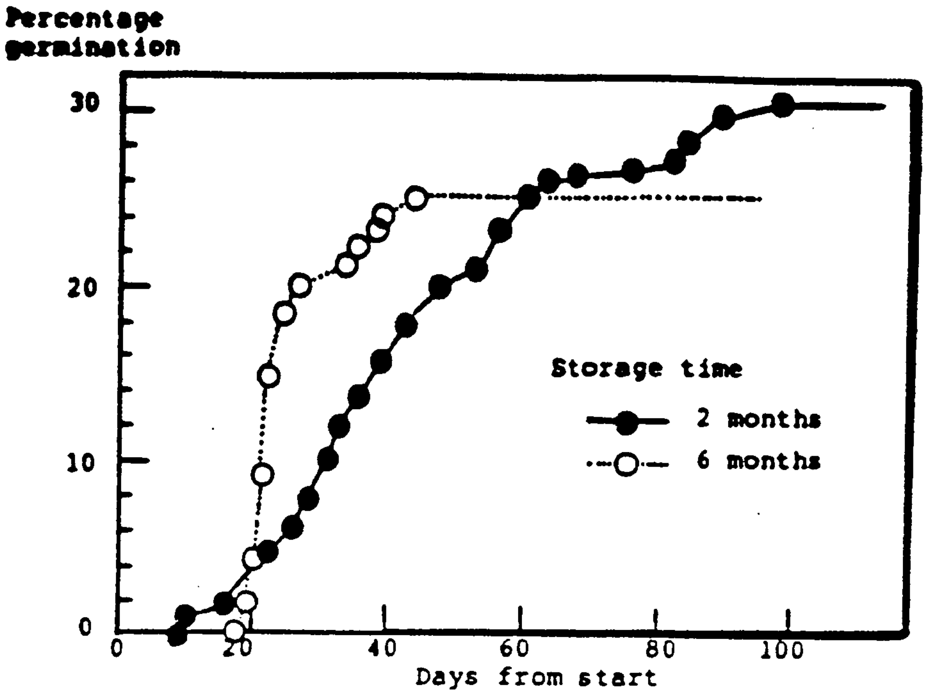

Figure 5. Germination of Marayoor seed after dry storage in a refrigerator at 4°C

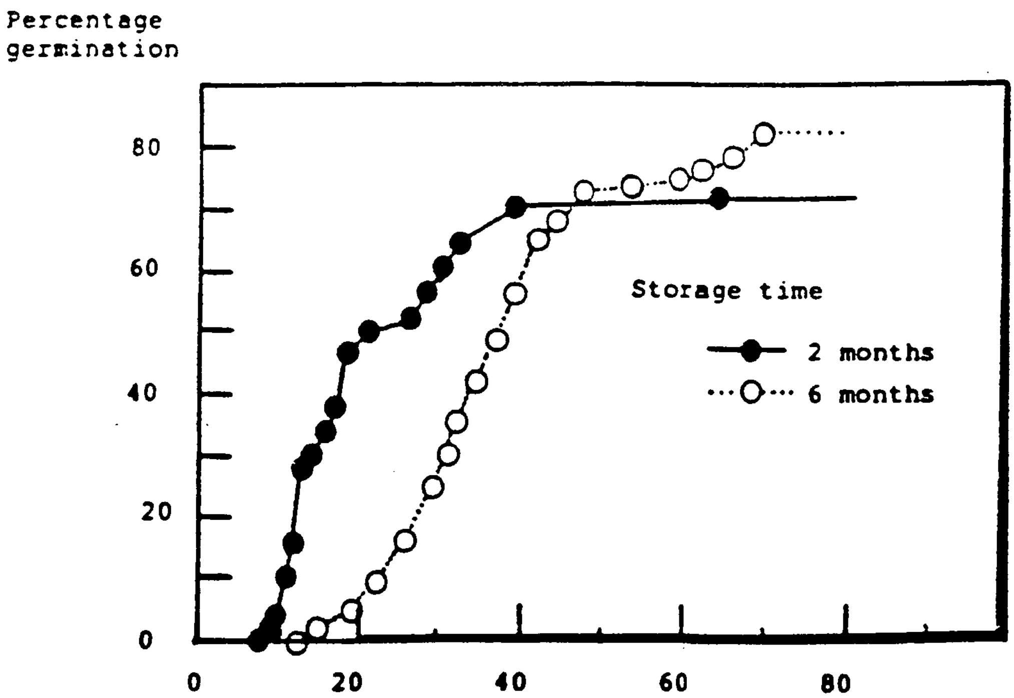

Figure 6. Germination of Ryalpad seed after dry storage in a refrigerator at 4°C

The following procedure has been elaborated in New Caledonia for *Santalum austro-caledonicum.* It fits very well with our own experience in Perth and should suit Timor conditions, (Kagy, 1988).

It is important to collect the seed of only the current year's crop. Do not collect seed from the ground unless the ground has been swept first. Fruits must be depulped very quickly after collection - within about 4 hours. This is done by rubbing the flesh against a wire mesh, while washing with water. A second washing, preferably in agitated water, is made to remove vestiges of the fleshy pulp adhering to the seeds. Floating seed is usually not viable and can be discarded. After the pulp has been removed, the seed is spread out on racks to dry in shade, one seed deep to allow free circulation of air. This process is most important. If not followed much of the seed will spoil. The seed is kept at room temperature if it is to be used promptly, otherwise it should be stored in a refrigerator. In dry, cold storage the seed maintains its viability for at least 2 - 3 years.

The seed is then treated with a sterilising mixture made as follows:

5% mercuryl lauryle

5% Eau de javel

Eau de javel is a local mixture of calcium hypochlorite (CaClO) and caustic soda (proportions unknown). The most important component is the CaClO. Seed is soaked for 3-5 minutes in this mixture and then cleaned thoroughly with water, for say 10 minutes. If only the CaClO is available, then a 10% mixture with water is used - 10% of the commercial mixture as purchased. Other sterilising mixtures besides Eau de javel may also be suitable.

The procedure for *S .austro-caledonicum* is possible for *S. album* . In Timor it is suggested that fruit for collection should be dark brown to black in colour with the pericarp wrinkled. Shaking the tree will allow the fruit to fall (Hamzah, 1976). The next stage is to put them in a bucket of water and squeeze them to dislodge the pericarp. The seeds should then be removed from the water and rubbed against a wire mesh prior to drying in the shade. Depulping has not been well organised in cleaning operations observed to date and sun drying is rife. More rapid washing, cleaning and careful drying would be desirable. A refrigerator is now available at the Forest Research Institute in Kupang to store clean, dried seed. This arrived by mid 1989 allowing the possibility of setting out time of storage trials. Trials are now in hand to test the long term viability of refrigerator stored collections in Kupang. Suitable containers (screw top glass bottles or polythene containers) should be used to store seed. Fungicide and naptha flakes should be added.

After testing and careful record keeping it should be possible to develop a written statement of appropriate handing and storage procedures for *S album* in Timor.

Vegetative Propagation

Should the research programme throw up superior oil producing individual trees and seedling progeny trials prove poor, then the question of vegetative propagation may become important. In India tissue culture of *S. album* has been perfected, and currently work is continuing in Western Australia, where seed supplies are at present limited.

Another method of vegetative propagation is the development of root suckers. The species suckers well and several examples have been noted in the field.

Hussein Mahmood (1983) reported the organisation of root sucker experiments around mature trees. Sites were at Buat (63 trees), Oenlasi (Mollo Selatan) and Amanuban Tengah. Amanuban was the best site. Mr Yos Kuik, Planning Officer from Soe had a file on this but unfortunately the data were missing. There was some sprouting, some 800 shoots were recorded from 1076 holes. Two to three cm pieces were cut from roots. Some 30 - 40 cm of growth occurred in the first year. A visit was made to Noelea where root sucker growth was seen. Many shoots were grazed by cattle and the present status is not known.

The philosophy of this method of regeneration is difficult. At present the roots are dug out in the year following cutting of the tree. Several years careful husbandry prior to exploitation would be required to ensure sucker regeneration. A suggested experiment at Soe should be delayed at least until earlier results can be obtained.

Another method is to cut out pieces of root and place them into pots. Mr Kharisma trialled this at Kefamenanu. A survey of the success of this trial was made. Many pieces had rotted and many pieces that did produce epicormic shoots died either due to a change in watering regime or to the combined effects of nematodes and bacteria from over moist pots. Should the plus tree programme yield very few plus trees, then this method may be of value. However in the presence of adequate seed supplies then seed production from selected trees is clearly more productive in terms of improving the growing stock.

Experiments undertaken with root cuttings (prior to the end of 1988) became badly infected with nematodes and bacteria at Kefamenanu. While it is interesting that sandalwood can be propagated from root cuttings, there is no current problem with seed supplies nor are there any individual elite superior trees which have been identified and would merit vegetative propagation.

Height records of root suckers in the first fenced enclosure at Oilsonbai should be numbered and measured. These had grown rapidly after first observed and since cattle were excluded from the area.

STATUS

Some of the topics which remain to be elucidated further include those which follow. Much of this could be tackled by a graduate student stationed in Timor for an extended period.

**Is there an optimum time for maximum seed harvest from fruits on the tree? What proportions of the fruit-crop become mature at different times of the year in different zones? Zones may be, for example, based on altitude, latitude, longitude or soil type.
It is known that seed should be collected fresh so times of collection will vary with locality and possibly year by year.

**Do fruits ripen over an extended period?

**Is loss to birds high if picking is delayed? Can seed that has passed through birds be used?
Evidence from the University of Gadjah Mada's experimental forest at Wanagama suggests that seed which has passed through birds could be used.

**Does collection of fallen seeds produce seed of lower viability?
Indian experience suggests that for maximum viability fruit must be picked or collected from the ground when fresh. In Timor at present, seed collection is largely from the ground. Construction of simple make-shift pole ladders could allow collection from trees. If remote plus trees carry unripe seed at inspection, then the ground beneath could be cleared to facilitate fallen seed collection later.

**Does viability vary with time of picking and length of storage?
The germinative capacity and quality of sandalwood seed has been the subject of conflicting reports over the years. It is accepted that an initial dormancy generally exists, so fresh seed may not give as many plants as seed held for some months. The conditions of storage are important, and there is a wealth of anecdotal evidence relating to seed storage. Seed can retain its viability for some time in dry, cold (refrigerator) storage. Seed not refrigerated can deteriorate quite quickly. A current experiment at Kupang is investigating retention of viability with seed held in cold storage. At Perth cold storage (~6^{o}C in a refrigerator) has maintained good viability levels over 1-2 years. We have not managed to examine this for freshly collected material as yet.

**Do trees which produce heavy crops in one year produce light crops in the succeeding year?

For practical purposes in Timor liaison should be maintained with the district forestry staff regarding the readiness for collection of seed from selected trees. Mr Kharisma should be responsible for work on seed quality, provision of superior seed stock and related matters.

Project 3: Nursery techniques - handling and hosts

Nursery germination and seedling health

Much of the literature refers to problem areas that various researchers have encountered. Losses of seedlings have been variously attributed to fungal attack, nematodes, nutrient deficiencies and under/over watering. The Forestry Research Institute (F.R.I.) staff at Kupang have used 3 main nurseries for raising seedlings over the past three years; Oilsonbai, Soe and Kefamenanu. Some plants have also been grown at Sikumana. At Oilsonbai there is a perennial stream providing water, a dense shade house and a small enclosed area. At Soë there is a piped water supply and a large glass house newly constructed. At Kefamenanu the water is of poor quality in the dry season and there is much encroachment by cattle frequently entering the nursery. The nursery at Sikumana has a good shade house courtesy of the ACIAR programme, but here water has to be carted in. Improvements at all sites have been made following interactive discussions with F.R.I. staff. Kharisma and Komang oversee nursery handling and hosts. A number of Forest Department activities (other than the Forest Research Institute) have inputs to sandalwood. Liaison was maintained with District Forest staff at Soë and Kefamenanu.

Nursery trials have included soil amelioration and nutrient experiments, (dealt with under project 4), length of time in the nursery and the value of different periods of shade and sun prior to planting. These kinds of experiments are very difficult to set up without a very vigorous protocol and arrangements for preplanned testing of significance. In all areas where improvements are sought through trials one important consideration must be to minimize the number of losses. Whether these are due to a treatment effect or are spread through an experiment is often difficult to ascertain unless an adequate control is set up and all other procedures used are conducive to survival.

A number of germination techniques and potting practices are used in different places. The following account describes practice in New Caledonia for *Santalum austro-caledonicum*, (Kagy, 1988).

A period of 6 months is necessary to break seed dormancy in *S.austro-caledonicum*. Before germinating the seed, it is scarified by cutting off the point of the seed, where the flowering parts were attached, just removing the seed coat. The endosperm should not be damaged. The seed is then soaked overnight, either in water alone, or in a mixture with gibberellic acid (GAA). Whichever is used, it is important to ensure the seed is laid out on a tray one seed only in depth and the seed is immersed to only half its diameter. After soaking for one night the seed is soaked for 3-5 minutes in a solution of 1 gm Benlate (fungicide) in 2 litres water. Seed is germinated in a special bed of crushed coral made to fulfil the function of vermiculite. It is heated from the bottom to maintain the germination temperature at 28-30 degrees C. Seeds are kept moist by a mist sprayer. As soon as the root emerges, the seed is transferred to another tray filled with a mixture of one part sand and four parts peat moss. After 10 days in the peat moss trays the seedlings are transferred to a plastic tube filled with a free draining soil mix, and kept under shade, using a screen of giving 50% light reduction. After 20 days alone in the tube the first stage (Ie. the pot or intermediate host) host is introduced. A cutting about 5 cm in length, containing two "eyes" on the stem of the host plant, *Alternanthera sessilis*, is placed into the tube near the edge. All leaves of the host are trimmed off. Two months after transplanting into the tubes the shade is removed. At about this time the host plants will require pruning back as they are very vigorous. The growth of the sandalwood seedlings is also rapid and two months after transplanting they can be 20-30 cm in height.

An industrial forest plantation area in Oelbiteno, (Timor) was visited in June 1989. The officer in charge was Andi Purwadi. Here *Santalum album* had been tried in a variety of containers with long, black, tapered hard plastic currently favoured. This style is similar to the Queensland Forestry Pot, but narrower and scarcely able to contain the *Capsicum* host as well as the *Santalum*. Germination is undertaken in compost several cm deep. This leads to many seedlings being potted with extraordinarily long hypocotyl growth. The aim is to have plants potted for 8-12 months. The potting mixture is 1 river sand: 1 topsoil (loam): 1 compost. The compost is partly rice straw, other vegetable matter and manure, but not very well rotted down, with much fungal activity. Plants are kept under 80% Sarlon shade for up to 6 months, then in 55% Sarlon shade for 4 months, then 2 months in the open for hardening off.

The long tubes can be reused 5 times, and stand in wire mesh raised tables for air pruning of roots. Also being used are hard plastic trays of 45 cells, 5 x 5 x 7 cm which can be reused 3 times. A larger tray of 28 cells appeared even better. Losses due to damping off were discussed (watering twice a day may be too much) in relation to the compost which may not have been adequately cooked. Slug damage was also noted.

Varied lengths of dormancy are reported for *S. album* in India but 2 months is generally accepted as being the minimum dormancy period (Rai and Kulkarni, 1986). Germination under appropriate conditions may not begin in treated seeds for about 30 days after the break of dormancy. Then a further 140 - 150 days may be required for 80% germination. Germination of *S. album* was found to be most rapid and complete at 25°C in trials conducted at Curtin University (Figure 7 and 8).

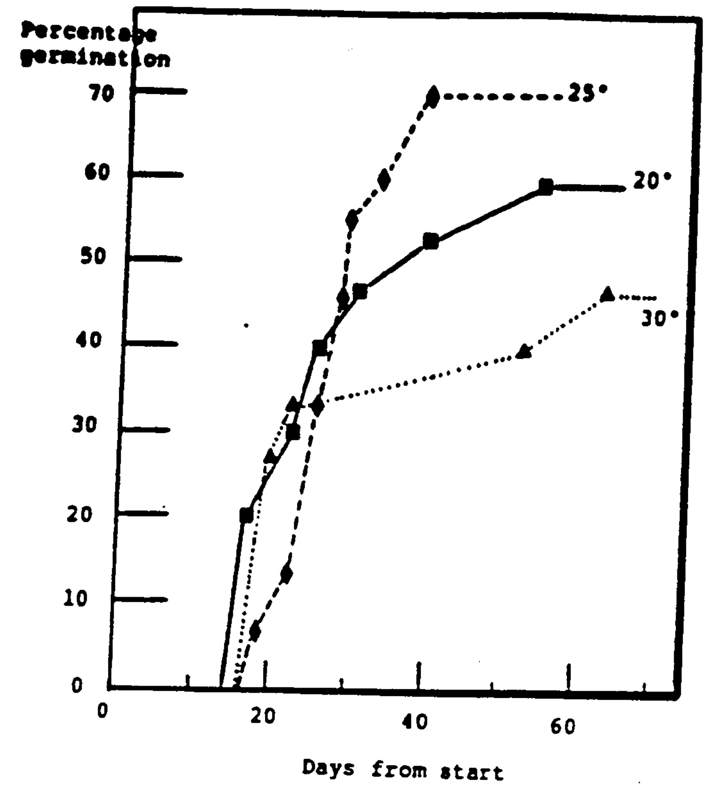

Figure 7. Germination of nicked bangalore seed at three temperatures.

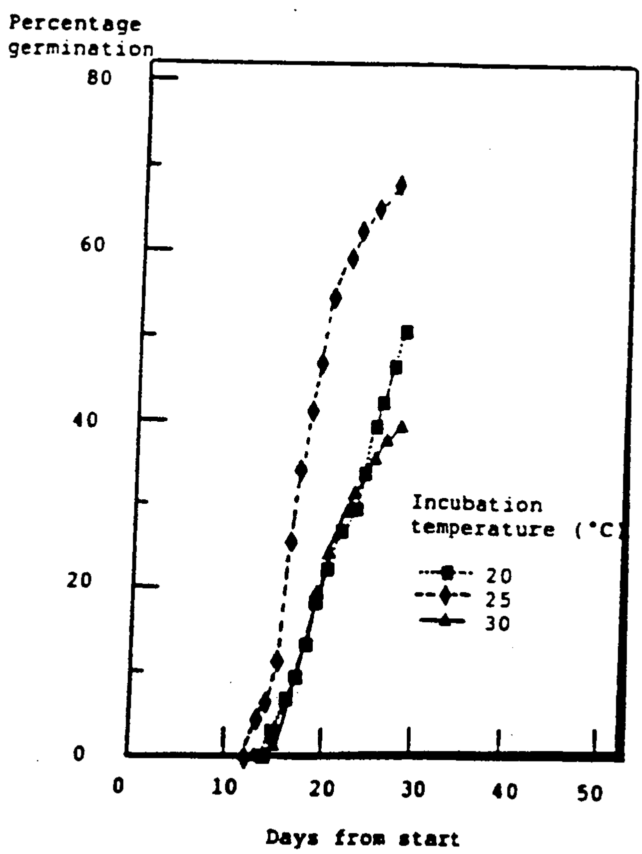

Figure 8. Germination of GA soaked Bangalore seed at three temperatures.

In practice, in Timor, good germination can be obtained at ambient temperatures, with seed covered, in sand trays which must not be allowed to dry out (Figure 9). The soaking of seed in gibberellic acid (GAA) hastened germination in trials in India (Nagaveni and Srimathi, !980/81) and at Curtin University (Figure 10).

A trial at Kefamenanu in 1989 was unsuccessful. Lack of germination was attributed to poor seed quality. For routine purposes GAA is not required when seed supplies are adequate.

Present practice at Oilsonbai may be summarised as follows. Seed is sown into germination trays with coarse river sand in the mixture about June - July. Too much organic material in the tray results in loss due to fungal attack. After about 3 weeks germinated seedlings can be transplanted into pots containing a pre-sown and just emergent host seedling. Daily watering is required at the cooler times of the day but plants should not be kept in over moist conditions. This is best attained by standing plastic bags on shingle or raised cement beds to allow air circulation and root pruning. Protection from the sun is essential in the early weeks, but hardening off is desirable towards the time of planting out. In the absence of a definitive result to testing it is suggested that plants be fully exposed in the final three weeks. If a type of shade is used which can be thinned (e.g. grass thatch) then thinning can commence when sandalwoods have 4-6 good leaves. Rigour is required in culling out weak plants at the time of planting: conversely for most field trials adequate spares should be prepared at the seeding stage. By December, planting time, it is possible to have seedlings > 30 cm high, with good basal wood development at five months from initial sowing.

STATUS

Careful handling and cool storage should ensure carry over seed from one year to the next. Care in germination is more important in Australia where we rely on seed brought from elsewhere. When adequate supplies are available then low germination rates and reasonable nursery losses are tolerable. For seed from selected candidate plus trees especial care is needed in Timor to maximise the potential progeny numbers attainable. Continuous attention is required for many procedures and the early provision of a technical note to outline simple, but robust, practice for the wider scale cultivation of *Santalum album* is seen as a priority for FRI staff to produce.

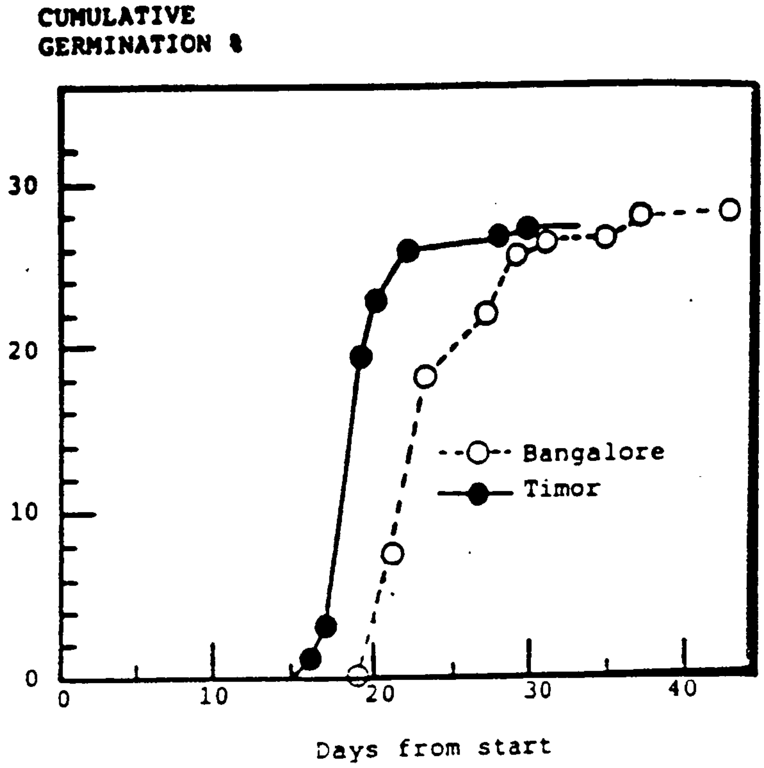

Figure 9. Cumulative germination percentage of seed of *Santalum album* from Timor and Bangalore. All seed pre-nicked and incubated in coarse sand in a humid, well watered shade house.

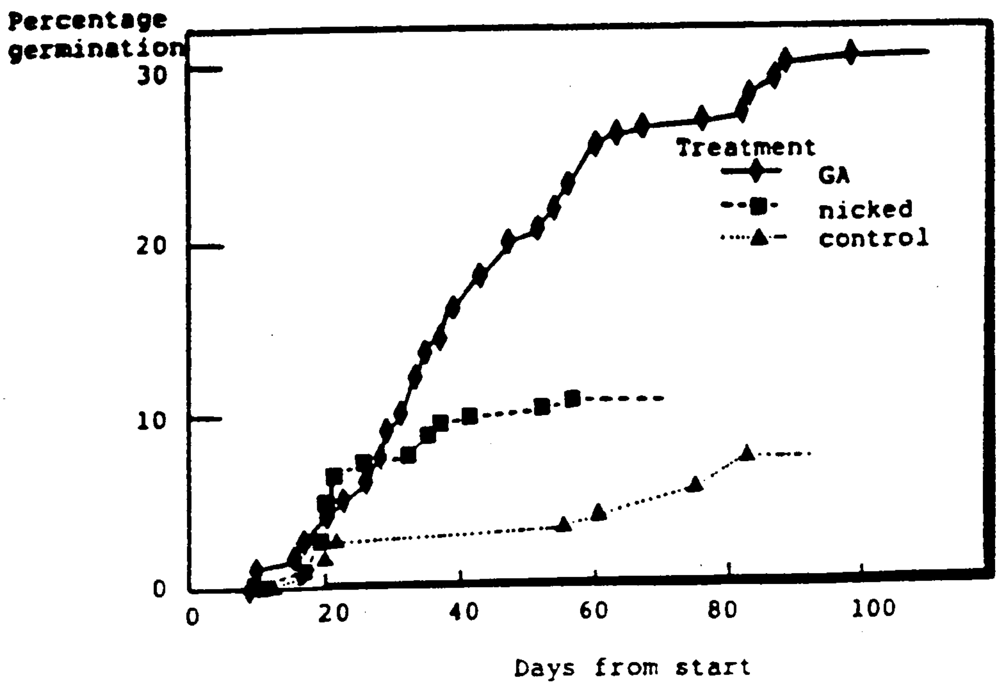

Figure 10. Germination of Marayoor seed after different pre-treatments.

Intermediate/pot hosts

In the nursery *S. album* can persist without a host for some time. However, it is generally accepted that growth is better with a host. Characteristics of an intermediate host of general utility would include:

- no competition interaction with sandal
- little starvation of the sandalwood by the host
- ability of host to survive transplanting into the field
- enable field hosts to attach satisfactorily

An excellent host would be one which can be raised economically, can be pruned back, will supply nutrients readily and which can persist on outplanting until field hosts are effective. Some short stature *Acacia* or other leguminous plants may be useful if actively nodulated. These can then be expected to supply nitrogen to the *S. album*. Most sandal seedlings (70%) initiate haustoria within 30 days of germination and 97% have haustoria after one year, (Nagaveni and Srimathi 1985).

The selection of suitable intermediate hosts is on going. Zoefri Hamzah (1976) indicated *Capsicum* as the generally preferred host. By the end of 1988 *Breynia* was favoured in all nurseries. However *Capsicum, Calotropis and Cassia sophorae* had also been used. At the time of this review *Desmanthus virgatus* and *Crotalaria juncea* were the favoured species.

Following the Department of Conservation and Land Management (CALM) success in Western Australia using several species of Acacia to avoid intermediate hosts at Kununurra, a pilot trial under the direction of Ir. Kharisma, at Sikumana, was seeded (8.10.88) into germinated *S album* pots. Unfortunately these pots were rather small and this contributed to the lack of success of the trial. It was recommended that these hosts could be tried:-
(a) low habit: *A translucens, A. hilliana, A. tumida* (prostrate variety)
(b) intermediate size, light foliage: *A. bivenosa, A. ampliceps, A. eriopoda*
(c) taller species: *A tumida, A holsericea*

Subsequently seed of the following was taken to Kupang, given hot water treatment, and sown using distinctive coloured labels to distinguish between hosts:
*Acacia aneura 2750 Weeping foliage tropical WA - tree 15 m
*Acacia aneura 8A Central WA - small tree 10 m
*Acacia holosericea Tropical WA - tree to > 15 m
*Acacia pachyacra Tropical WA - shrub to 4 m
*Acacia hamersleyensisTropical WA - small tree 5 - 6 m
*Acacia maitlandii Tropical WA - shrub to 3 m

*Acacia citrinoviridis Tropical WA - tree to 15 m
*Acacia amplicepsTropical WA - tree to 10 m
*Acacia dictyophleba Tropical WA - shrub to 4 m
*Acacia tumida (normal) Tropical WA - tree to 15 m
*Acacia tumida (prostrate) Tropical WA - shrub < 1 m
*Acacia retivenia Tropical WA - small tree < 15 m
*Sesbania cannabina Tropical WA - shrub to 4 m
*Tephrosia rosea Tropical WA - shrub 1.5 m

It was hoped to record time and number of germinations, measure hosts and *S. album* at 1 monthly intervals and to plant out additional pots during rainy season 1988/89. Any additional plants were to be moved to larger pots for December 1989.

Notes applicable to the species used: - both *Acacia tumida* and *A. holosericea* are somewhat similar in appearance to *Acacia mangium* used as a host in Northern Australia (Kununurra) with flood irrigation. *Acacia aneura* has been used at Perth with great success and more recently has been the best host at Kununurra. *Acacia retivenia* is not well known as a planting possibility but is believed to favour climatic conditions not too dissimilar to that of Kupang. *Acacia pachyacra* is believed to be an efficient nitrogen fixer and grows very rapidly from seed after fire. *Acacia citrinoviridis* is a tall tree of creek lines, and *A. ampliceps* favours the same sites but is shorter in stature. It also appears to nodulate readily and to fix nitrogen well. *A hamersleyensis* occurs on iron rich acidic rocks and tolerates low rainfall. It probably grows less fast than the other species and may not endure alkaline soils. *A. maitlandii* and *A. dictyophleba* have short life spans, usually less than 5 years. *Sesbania cannabina* grows as an annual at Kununurra with a similar dry season to Kupang. *Tephrosia rosea* is a small perennial shrub and is extremely drought tolerant. The prostrate form of *A. tumida* was included as it would not shade out the *Santalum album* yet would provide good ground cover to mitigate the heating of the sun. The seed of this species is not as viable as that in most collections, perhaps suggesting that its varietal status may represent an aberrant genetic form.

A comparison of *S. album* heights for plants grown with a range of Australian *Acacia* species in small diameter pots is shown in Figure 11. In this illustration, sandalwood mean heights are shown after 4 months in the pot. These pots were too small to allow any real validity to differences in performance. Most of the *Acacia/Santalum* experiment commenced at Sikumana, ended up in a planting block at Kefamenanu in February 1989.

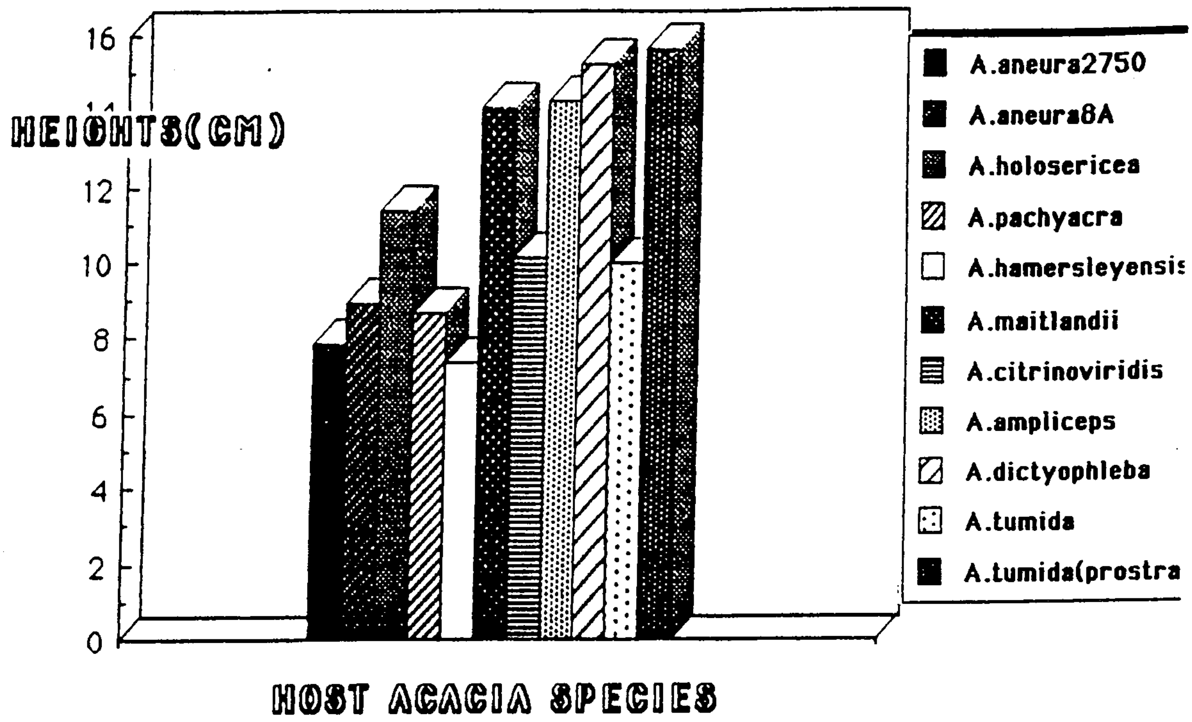

Figure 11. Heights of *Santalum album* seedlings after 4 months in pot with *Acacias.*

Six left-over pots from the *Acacia/Santalum* trial were planted outside the nursery house at Sikumana on 21.11.88. All plants were given `Osmocote', balanced NPK fertilizer pellets. One plant with *Acacia maitlandii* grew well, but all plnts had died by April 1991.

The balance of *Acacia* not used at Sikumana (*A. aneura, A. ampliceps, A. oraria* and one each of *A. hamersleyensis, A. citrinoviridis, A. auriculiformis*) was taken to Oilsonbai and repotted on 10.6.89 into 1: 3 mix. Of these hosts only *A. ampliceps* showed any promise.

Some residual pots which contained live *S. album* plants were fertilized with `osmocote' and provided with *Capsicum seedlings* in order to test whether *S album* will re-host and persist in pots to the second year. They were planted at Kefamenanu in May 1989.

This ambitious trial was not sucessful for a number of reasons. It did however, provide valuable lessons in the conduct of subsequent cooperative work, and a part of it may be repeated later. Of the species used only *A. ampliceps* showed promise, but it cannot be conclusively dismissed that the Australian species will not make good hosts.

In a large pot host trial established during 1989 the small acacia-like legume *Desmanthus virgatus* was found to be an excellent pot host. This appears to be a New World species which has some weedy/opportunistic characteristics in the Old World. Other useful hosts, in that significant height improvements over *Capsicum* were achieved in the trial were:- *Crotalaria juncea* and the non-legume ornamental herbaceous *Alternanthera*. *Sesbania grandiflora* was also good, but this plant grows too large too rapidly for use as a standard pot host. *Cajanus cajan* (pidgeon pea) another legume, also achieved better height growth on sandalwood than did *Capsicum*. However *Cajanus cajan* becomes woody fairly quickly and may not take top pruning too well. The most promising *Acacia* was *Acacia ampliceps* but this poses similar problems to *Sesbania grandiflora*.

In November 1989 root development in the above pot host trial was examined. With *Duranta repens* from cuttings, sandalwood had good roots and haustorial development but the hosting effect on foliage was slow to work. Grass species were also slow to start. The roots of the grasses had large nodules. A rosette Asteraceae *Elephantopus scaber* had very long roots with no haustorial attachments at all. The small local legume *Desmodium* sp. was similar but some nodules were present. The roots of *Acacia holosericea* had gone directly to the bottom of the pot, nodules were present but no attachments. Root/haustorial development was not examined on the better sets so as to avoid reducing the numbers of plantable individuals.

Mean height development of *Santalum album* in November 1989 was as follows:

Pot Host	**Mean heights**	**20 weeks**
	All	**Best 5**
Desmanthus virgatus	23.4	41.4 b
Crotalaria juncea	22.3	52.8 a
Alternanthera sp	21.2	40.2 b
Sesbania grandiflora	17.6	27.4 c
Cajanus cajan	16.9	27.1 c
Acacia ampliceps	16.6	23.1 cd
Lycopersicon esculentum	16.0	26.6 c
Acacia oraria	14.5	20.4 def
Capsicum frutescens	14.5	23.8 cd
Breynia cernua	14.3	21.2 de

A trial incorporating a number of pot hosts (local legumes and also the local *Alternanthera*) was commenced at Oilsonbai 10.6.90. A large quantity of *S. album* seed was sown, sufficient for up to 20 hosts of 50 pots each. Pots were prepared of 1:3 mixture (Sikumana sand/loam

- the best from the 1988/89 trial, project 4) in large plastic bags. *Desmanthus virgatus* again performed well in this trial and can be confidently recommended for wider use.

OTHER TRIALS

Several minor trials were set out at Kefamenanu. In May 1989 *A. oraria* and *S. album* , were sown under the direction of Komang in large plastic bags with about 2 kg soil, for planting out in November. It was arranged that at the same time in November a set of one month old seedlings were to be planted out as well. The idea of this trial was to test the ability of smaller seedlings to persist.

In June 1989, old nursery stock was planted into thirty two 2 kg bags using 1 sand: 3 loam, with river gravel on top. Four containers had advanced *Capsicum* hosts; 24 had old stock *Sesbania grandiflora* ; 4 had younger *Capsicum*. These containers were all stood out in the nursery in full sun. They were subsequently planted out into a nearby grassed area but did not survive the open, hot conditions.

Kharisma managed 2 large experiments which were still ongoing in November 1990.

No1. Age of seedlings trial. Sets of plants aged 6 months (sown June 1989); 8 months (sown April); 10 months (sown February); 12 months (sown December 1988); 18 months (sown June 1988) were raised in separate beds. These all had *Calotropis gigantea* as host; this needed pruning back. By November 1989 there were a number of big individuals in the older set but losses appeared greater with time. Plants of 10 - 12 or more months in the nursery may be too large for conventional planting with no watering in.

No 2. Effect of Shade on 10 month old seedlings. Three beds of seedlings were sown in February 1989. It was planned to have 6 treatments of these seedlings (with *Calotropis* as hosts), that is 0.5 of a bed for each treatment.

Treatment	50:	In July remove shade, so plants have 5 months shade, 5 months none
	60:	In August remove shade, so plants have 6 months shade, 4 months none
	70:	In September remove shade, so plants have 7 months shade, 3 months none
	80:	In October remove shade, so plants have 8 months shade, 2 months none
	90:	In November remove shade, so plants have 9 months shade, 1 month none
	100:	Keep these plants in shade, so plants grow in shade for 10 months.

It was recommended that prior to commencing treatments in July it would be desirable to:

1. Standardise beds - remove zero plant pots, repot no host to host.
2. Measure heights of *S. album* so that equal numbers of very tall, medium tall and short plants were in each of the 6 half beds which would constitute the treatments.

3. Equalise numbers of pots between half beds.
4. Draw random numbers to decide which half of each bed becomes the 50, 60, 70, 80, 90 or 100 treatment.
5. Prune back host growth.

In November 1989 this experiment was examined. The set with 50% of the time shaded and 50% of the time open looked good with strong plants, tall and good brown wood. The 100% shade set was very leggy with leaves dark green and thin. Large numbers of deaths in all sets made this trial difficult to analyse.

Sets of 100 were counted for numbers of good plants.

Treatment (% shade)	50	60	70	80	90	100
Good survivors (%)	68	59	35	43	20	53

A number of those in 100% shade would wilt on planting.

Seed of *Santalum acuminatum, S. lanceolatum, S. murrayanum* and *S. spicatum* requested by Komang in November 1989 was taken to Kupang by F. McKinnell in December 1989. The seed was sown by Kharisma on 15.12.89 at Sikumana into local lithosol in seed trays with no drainage. When inspected on 17th April 1990 there was no germination at all.

STATUS

Pot size used so far is variable and has depended on what can be obtained. No formal trial of pot sizes has been undertaken. The main choice is between a large pot with a long lived host (as in Kununurra) and a smaller pot with an intermediate host. However the latter should not be so small as to allow the host to break through. Very thin gauge pots at Kefamenanu had shown signs of sunlight damage in October well before planting time. *Calotropis* had grown through small pots. Long tubes may have an advantage over short ones. Further work is required on hardening off prior to planting out - all plants should be exposed to sunlight and reduced watering prior to planting.

The target is a plantable *S album* of 20 - 30 cm height with some brown bark and good, green leaf development, after about 6 months in the nursery. From the first seed of the year's crop a maximum of 6 months is available, June to December, to produce transplants for the start of the rains. It is necessary to determine whether seed is better stored until say, April of the following year. For example, if Timor seed exhibits a dormancy period, or if germination is higher after refrigerator storage, then sowing of the previous year's seed in a given year may be advantageous.

Project 4: Nursery techniques - potting mixes and fertilizers

At the start of the ACIAR programme it was evident that some of the potting materials used were heavy alkaline clays. These may not allow adequate root development or transfer from pots without root breakage. FRI staff held the perception that growth of *S.album* would probably respond to fertiliser, but there was no evidence for this. In New Caledonia a free draining soil mix receives NPK 17:17:17 fertilizer at the rate of 3 kg per cubic metre of soil. It was also noted that harvest measurements should account for root distribution, haustoria development and cohesion of materials. In the past height measurements alone have been used to contrast host treatments. Whether this is sufficiently related to subsequent out-planting success to avoid dry weight analysis need testing. Even so dry weight analyses should be done for experimental results. Preliminary observations suggested that chlorosis was common. Heavier applications of foliar micro nutrients appeared to provide some relief. Perhaps iron chelate would be beneficial if iron is the problem and attention would need to be paid to availability of N, P, K . The 'sand' used in trials appeared to be very alkaline and it was suggested that other sources of river sand should be available with some searching. A set of plants at Soe showed about 2% albino plants. This was probably genetic, rather than nutritional. A similar problem appeared at Curtin University in 1982 with some Kalgoorlie seed of *S. spicatum.* All seedlings died after exhausting the endosperm.

Subsequently it was possible to arrange for the natural soils in the areas of interest to be analysed at Bogor for nutrients (Table 3). As a general principle it would appear that most of the naturally available soils are reasonably fertile, with the Kefamenanu soil least good in a nutritional sense. Some concern has also been expressed that the natural water source used at Kefamenanu may have appreciable dissolved carbonates, especially in the dry season.

A number of experiments have been undertaken by F.R.I. Kupang staff on soil amelioration using the nursery at Oilsonbai. The most successful experiment was one designed to contrast different proportions of sand in the potting mixture. No fertiliser was added. This experiment was written up for publication and is attached as Appendix 1. The addition of Taurus sand to both Oilsonbai grumosol and the Sikumana lithosol has been conclusively shown to improve growth of *Santalum album* (Komang, Sutarjo & Fox, 1989). In both cases 3 parts sand to 5 parts local soil produced greatest stem diameter, greatest height and dry matter in *S. album* over a 6 month nursery period. As the texture of the Soe soil analysed is similar to that of Sikumana, the addition of sand to the Soe mix should produce equally enhanced sandalwood pot growth. It is therefore recommended that a potting ratio of 3 parts sand to 5 parts loam be used for basic potting mixtures. The Kefamenanu material is sandier than the others and while therefore easier to work, would not benefit from as much dilution with sand. The available sand is also rather coarse at Kefamenanu, and also probably calcareous. In each case, the next best performance was with 25 percent sand. Loam from Sikumana gave better growth than that from Oilsonbai and if Sikumana material is used then both 25 and 75 percent sand are better than all other mixtures. In practice it may well be easier to use a mixture of 1 part sand to 3 parts loam. There was a significant correlation between mean dry weights and seedling heights overall for *S. album* grown in both local soil bases.

An investigation of early shoot/root development was undertaken at Curtin University, (Figure 12). Graph A shows values for 5 replicates at each of 2, 3, 4, 5, and 6 weeks. In graph C a linear relation is shown between total plant dry weight and time and also for shoot dry weight. Root dry weight is much more variable with a falling of after 4 weeks a strong correlation was evident between height and plant dry weight as shown in graph B. Thus we may conclude that height can be used where it is inconvenient to harvest the plants.

TABLE 3. Main soil properties of materials used to raise Santalum album (F.R.I. Bogor data)

	LOCATION OF SAMPLE				
Property	Kefamenanu	Soe	Sikumana	Oilsonbai	Taurus sand
Percentages					
sand	31	21	21	18	78
silt	59	41	40	19	9
clay	10	38	39	63	13
Soil pH (water)	7.5	6.5	6.5	7.2	8.2
Bases me/100 g					
K	18.9	8.4	8.5	18.6	21.4
Na	15.5	18.8	37.5	23.8	93.8
Ca	122.4	135.7	58.5	151.3	65.6
Mg	22.3	42.8	29.7	63.1	33.2
C.E.C.*	2.7	6.2	6.9	10.3	2.2
N%	0.05	0.25	0.15	0.16	Nil
P(mg/kg)	1.86	2.69	16.72	2.98	1.58
Description	Silty loam	Clay loam	Clay loam	Clay	Sandy loam

* Cation Exchange capacity

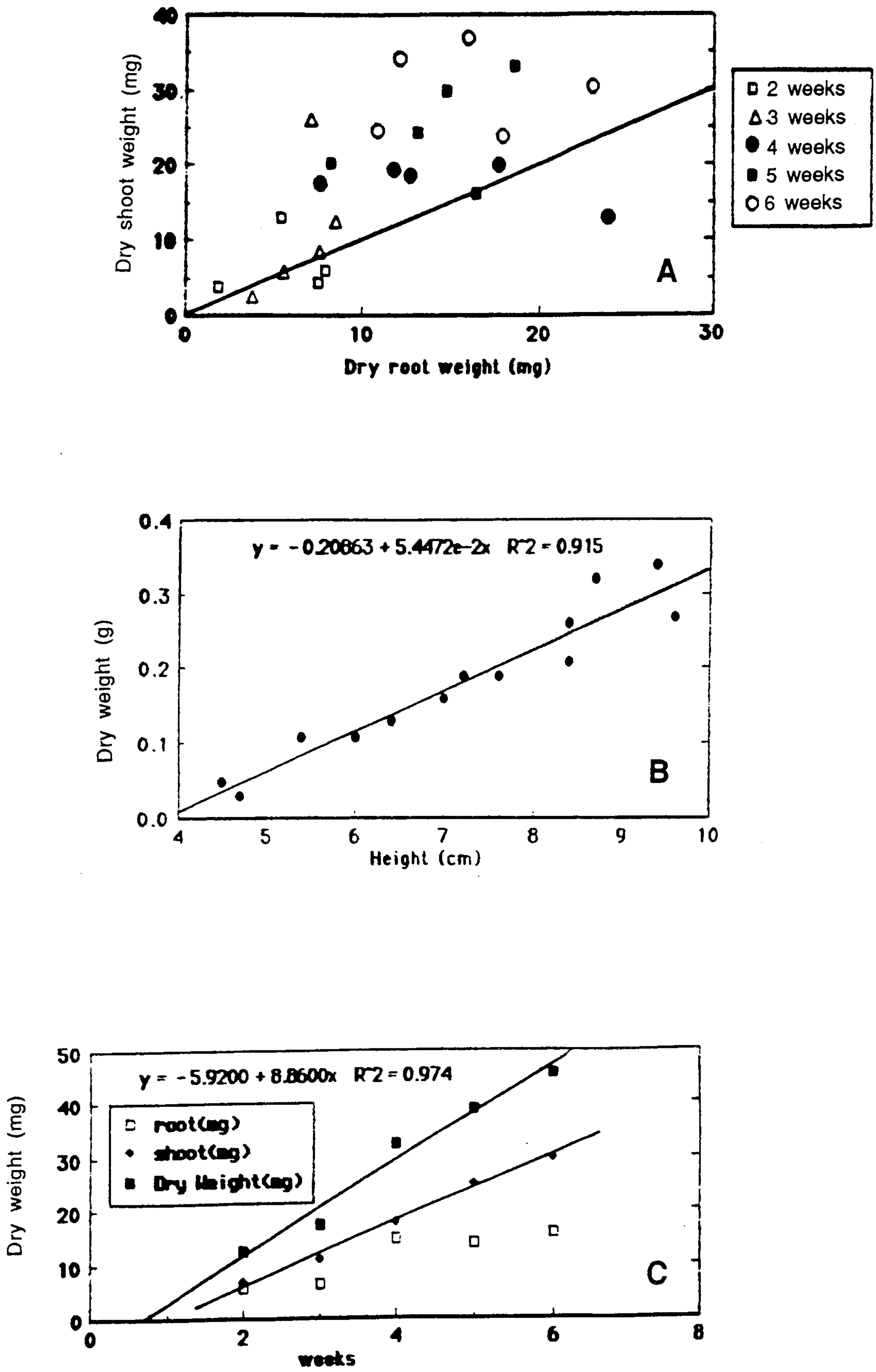

Figure 12. Relationship between dry weight and (A), dry root weight; (B), seedling height; (C), time from germination.

Other experiments attempted to contrast two local soils with various levels of foliar nutrients and of cow manure and other organic composts added to the basic local soils. They were replicated and fairly elaborate trials with *Breynia* as host. Harvesting of the plants was not undertaken and results based on heights were inconclusive.

Another nutrient experiment was undertaken at Oilsonbai prior to receipt of the soil analysis data given in Table 3. This used 4 levels of each of N, P, K with the local vertisol. This was also largely inconclusive and resulted in mainly chlorotic foliage.

A very elaborate trial to cover an estimated 5 ha at Soe was drawn up by Kharisma. This sought to simultaneously contrast urea fertiliser, hosts, planting method and seedlings from large and small leaf sandalwoods. This was also done before the Bogor analyses were available. The heavy clay soil at Soe necessitated careful attention to planting preparations. Holes were dug well in advance of planting so that presumably any nitrogen mineralisation was very rapid on commencement of the rains. Extra *Cassia sophorae* seed (which seems to colonise cracks and holes very rapidly at the start of each rainy season) was added to the holes. The trial was planted with *S. album* in 1988. It involved the following set of treatment combinations:-

A. Urea -1(0), 2(2 g), 3(4 g), 4(8 g)

B. Hosts - *B. cernua, C. sophorae*

C. Shade/planting spot: Hole + no shade; Hole + shade; No hole + no shade; No hole + shade

Fertil-izer level	i(cm)	[%]	Large leaf	[%]	Small leaf	[%]
0	.635	[99.6]	.644	[99.2]	.627	[100]
1	.190	[94.6]	.117	[92.5]	.260	[96.7]
2	.339	[91.5]	.252	[89.7]	.420	[93.2]
3	.144	[74.2]	.110	[76.1]	.178	[72.3]
Hosts		all	large leaf		small leaf	
no host	.263	[89.8]	.206	[91.2]	.323	[87.9]
Breynia cernua	.339	[85.6]	.332	[84.4]	.346	[86.9]
Cassia sophorae	.419	[95.2]	.356	[92.3]	.479	[96.9]

Table 4. Urea trial summary. Percentage survivors and mean height increment 15 days from 29th October to 12th November 1988

Inspection of the nursery plants in October 1988 indicated that urea was affecting plant health. All seedlings were assessed and measured after 15 days, (Table 4). Before outplanting it was evident that the following effects had occurred:

No fertilizer gave best growth and best survivals. Large leaf plants grew slightly better than small leaf ones. Level 3 fertilizer gave least survivals and least growth. Growth with no host was lower than with host. *Cassia* was the best host: it allowed greater growth and more survivals of *S. album.*

Only live *S. album* were planted out but the affect of urea was carried over into the field trial with clear cut results. Of 3072 planting spots, 433 (14.4%) had survivors at November 1989. At all levels of urea application there were losses and depression of height increment. Control plants survived and grew better. Urea is not a good treatment for the cultivation of *S. album* on the Soe (Bubonaro clay) soil. Despite the losses this fenced plot is a valuable trial, which merits filling in and re-assessment from time to time.

A water capacity experiment was initiated by Kharisma at Sikumana in which *Santalum album* and *Capsicum frutescens* were planted into pots containing the local soil (lithosol) at Sikumana nursery early in 1990. The pots were 12 cm in diameter and 15 cm in height. Thus the approximate volumes of the pots were 1700 cc. It was calculated that a pot of dug soil material would hold 520 ml of water. It was proposed to water daily with the following:-

Amount (ml)	% of 520 ml	% of 1700 ml
130	25	7.7
260	50	15.3
390	75	22.9
520	100	30.6
650	125	38.2

This trial used the local soil, rather than a sand mixture as currently recommended.

STATUS

It can be confidently given as a general nursery aim that plants can be grown in containers to 25-30 cm height in 6 months. Grumosol and lithosol clays or clay loams should be mixed with sand in a ratio of 5:3 parts soil:sand.

No important pests or disease symptoms have been evident at the nursery stage so far. Equally no obvious nutrient deficiencies have come to attention. With the ever present threat of cattle, all nursery areas require to be effectively fenced to keep stock out.

Since Komang has had training in soil science, he should cooperate in all trials involving record keeping of potting mixtures and fertilizers. Emphasis must be placed on record keeping for all existing trials: any existing soil survey and fertilizer trial reports have not been sighted. It would be useful if FRI staff had access to Department of Agriculture results.

Project 5: Planting techniques

Sandalwood will grow under a wide range of conditions. Literature sources reviewed in Barrett(1988)mainly from India, indicated that it can tolerate rainfall from 500 - 3000 mm per year, temperatures from near zero to over 40°C (once established), elevations from sea level to 1800 m (except where it is very cold), and many different soil types - sand, clay, laterite, loam and even poor, rocky, gravelly soils. The soils are sometimes low in nutrient status. There is some indication that trees suffering spike disease tend to be found on more calcareous soils with lower available nutrient levels, especially phosphorus. Sandalwood is not normally found in saline habitats. Under Timor conditions the present day distribution of sandalwood seems to be more associated with vegetation type than with characteristics of the soil. It is absent in *Eucalyptus alba* and *E. urophylla* stands of natural forest, possibly being unable to tolerate fires, to which the former, at least, seem to be frequently exposed. It also seems to be absent in very tall, old stands of semi-deciduous forest. In these habitats, of which few have been noted, presumably either all pre-existing trees have been removed or the life span of sandalwood is out of phase with very long-lived tree species.

Santalum album is able to parasitise a wide range of plant species, including itself. Hosts, however, appear to be of varying benefit to sandal and this has been evaluated by various workers. Typically assessment has been based on the number of haustoria formed on different host species under controlled experiments. In addition observations have been made on the size and appearance of sandalwood with different hosts; resistance to spike disease conferred by the host on the sandal; and also amino acid composition in sandalwood has been examined for plants hosted to different species. There is no doubt that some hosts are more suitable than others in that they promote better growth but the reasons for this are unclear. It is considered that hosts able to symbiotically fix atmospheric nitrogen may have advantages. In choosing hosts for sandal, host size, potential size, shade giving properties and economic importance should be considered along with their growth promoting capabilities. Different hosts may be required for different stages of growth.

The most successful plantation seen to date in Timor (Ajaubaki) is with *Cassia siamea*. This species is not palatable to stock, an important consideration when cattle grazing is currently the dominant land use for much of the land areas available for cultivation of sandalwood.In natural areas the large leguminous trees *Albizia chinensis*, *A. lebbek*, and *Acacia leucophloia* together with *Casuarina younghouniana* are often seen near sandalwood. At Oilsonbai *Acacia auriculiformis* is being tested as a well-established host. Perhaps the most promising species which could be brought into forward planning is the faster growing species *Albizia (Paraserianthes) falcataria*, successfully used in New Caledonia. Other candidates include some of the tropical Australian species trialled in the fuel component of ACIAR project 8613. Of those species *Acacia crassicarpa* appears worth trialling.

Planting should be done with a pot host (see project 4 report) which will carry the sandalwood through the first dry season at least. Numerous observations and some planned experiments have shown that *Santalum album* definitely requires host plants after it is about one year old. Nonetheless, sandal will survive without a host for 2 years, other conditions being favourable. Most *Santalum album* seedlings (70%) initiate haustoria within 30 days of germination and 97% have haustoria after one year. Trials over 2 years have shown that sandal seedlings planted side by side in the same pit with a host (with the vegetation removed) grow very well. If planted in the midst of naturally occurring herbs and shrubs, growth is poorer and is worse if host and sandal are planted as much as 2.2 m apart or if no host is present.

It is necessary to make a distinction between short-lived hosts for the seedling stage and longer-lived plants for the field. There appears to be little scope for short cuts, and the best method would be to pre-establish the longer lived hosts prior to planting sandalwood. Trials of intermediate species should be continued as the Kununurra experience has shown that several species of *Acacia* can be raised in the pot with sandalwood, and both can then persist in the field. This observation is clearly not applicable to long-lived species, nor to those which can grow very rapidly. In either of those scenarios there would be insufficient room and mutual competition for space. Preferably new trials should be initiated where suitable longer lived host species are established prior to outplanting of *S. album*. In addition to *Acacia/ Albizia/Paraserianthes*, several species of timber trees have been used in India. Selection of suitable long-lived species for hosting is not a difficult problem so long as those selected are from among species known to grow well under Timor conditions, and, preferably where the silvicultural techniques are understood..

Planting holes need to be thoroughly cultivated and the sandalwood plus host carefully placed into the hole so that it occupies a small depression rather than a mound. Taking advantage of the slope layout may enhance water conservation on sloping sites. Weeding of ground cover competition is essential to avoid sandalwood being completely shaded. Available studies and reports indicate that when young, perhaps to about 2 years old, *Santalum album* thrives best in the shade of bushes and trees, and about 50% shade is ideal. The crown should be open to the sun and allowed free expression. In very dry climates a light overhead shade is beneficial. Side shade is helpful at all stages. In the case of *Santalum spicatum* we have found that some shade is desirable initially. We also find good persistence of *S. album* in shady conditions where host *Acacia* trees provide both roots for the parasite and some overhead cover. However, in the seasonally dry conditions of Timor grass growth may compete with sandalwood for scarce soil moisture. Regular cutting of grass, which can be used as a mulch around sandalwood plants, is recommended as an interim measure until grass competition/control can be effectively analysed. Side and top shade have been tested by both Kharisma and Ida in the Soe area, at Sikumana and Kefamenanu. For the first dry season a light thatch of grass supported on sticks serves to protect the young plants from direct sunlight. These huts must be maintained as when the plants are as tall as the thatch they will be damaged if the grass is not removed. It is not recommended that sandalwood should be planted into grassy areas devoid of trees. All the trials undertaken to date clearly demonstrate that such a procedure is extremly hazardous. Areas of grass are prone to fire, they require extensive, regular cutting or other control. If the grass were to be eliminated by severe cultivation or herbicide spray the sandalwoods would then be fully exposed at a sensitive stage and also lack any woody perennial hosting arrangement to see them through the dry season. There is considerable doubt about the value of some of the sites which have been made available so far for the sandalwood research program. As stands of *Eucalyptus alba* tend to provide little opportunity for villagers to make simple and productive gardens, such stands seem to form a major component of the available forest estate. Where these have been converted to open grasslands then it is essential to undertake pre-planting of hosts on a broad scale.

There were no records of field fertilization on sandalwood noted in the literature review, (Barrett,1988). Limited trials at Curtin University, Perth showed ammonium sulphate and a liquid NPK application to foliage had no effect on seedlings. Humus and leaf litter are considered beneficial to growth. There is evidence that sandalwood obtains nitrogen, phosphorus and basic amino acids from its hosts whereas it probably obtains potassium from the soil and may also be able to take in calcium. The question of field fertilisation of established plantations can be left until later on, if and when any obvious deficiency symptoms materialise, or when the extent of plantations is sufficiently large that adequate areas of *Santalum album* are available to lay out such trials as would be necessary to statistically test the value of any fertilisation techniques.

At the start of the first phase of Project 8613 it was felt that the most important requirement was to have some planted *S. album* about the place. On the whole there is very little to be seen at present and most prior projects must have been less than successful. In October 1988 an excellent 4 m specimen was observed in the garden of the house then occupied by John Janes, another hosted to *Acacia oraria* was growing well in the ditch outside the nearby Canadian residence. In 1987 Mr Kharisma had provided 5 to Wisma Cendana, one of which had survived. Twenty five were planted in the grounds of the Governor's residence after the Governor launched the Sandalwood Revitalisation Programme (S.R.P.) in November 1983. It is not known whether any of these survived. A small number of straggly plants were planted outside the F.R.I. at Kupang with heights of < 1m in 1988. Most of these survived and at the last visit were 2.5m tall, despite the only probable host being teak, a species not extolled in the literature as particularly useful as a host. Perhaps as a consequence of being very open, and fully exposed to the sun, these plants seem to have suffered a great deal of insect attack to the foliage. Jones (the Canadian aid official, then resident in Kupang)noted in 1983 there was a Forest Department planting programme of 30 ha for 1983/4. He indicated that sufficient seed had been collected for 700 - 1000 ha. A grove of 75 trees was reported by Jones to have been planted at Sopo, TTS Kabupaten in October 1983, part of the S.R.P.launched by the Governor, but it is not known whether these survived. In 1986 a major exercise in direct sowing was undertaken, with sites in all provinces of N.T.T. There was no indication of any research prior to this exercise, the procedures for successful direct sowing of *Santalum album* are not documented for large scale work and enquiries later revealed that no seedlings were reported to have eventuated from any of the 12 areas which had been sown.

The question of where to experiment with research into plantation establishment is difficult. The Kupang F.R.I. may not have sufficient mandate and discretionary power to negotiate directly with private landholders. The Kg Oenutnanan stand in Molo Selatan, outside Soe, appears to be second generation progeny from a planting made in 1938 after exploitation. In this private land area many trees have parang damage, burn wounds, basal holes and exposed roots. Heartwood depth was not particularly good. The main research effort must be on forest reserve land controlled by the government, where it is possible that fire and grazing can be managed. The first planting trials undertaken were at the research area locations of Sikumana, Oilsonbai, Buat and Kefamenanu. For the 1988-89 planting season some stock ex hosting trials was available. Reasonable options at that time, providing that early planting was done at the start of the rains, that good rains came, and that good stock was available, appeared to be:-

1. Large pots with both *Santalum album* and an intermediate host and, from another pot, a longer term host (e.g. *Acacia*) host, all go into one hole in the ground - possibly at Sikumana.
2. Plant *S album* with intermediate host adjacent to an established secondary host (*Acacia* etc.). This secondary host may have been planted one year earlier, or if longer then some thinning may have been required. Stands of *A. auriculiformis* at Oilsonbai were suggested as being suitable.
3. In a cleared area plant out secondary hosts on a grid (firewood/timber/fruit trees), then place *S. album* with its primary host in a hole, say no more than 25 cm from the secondary host. This method was to be used at Buat, Soe and with *Calliandra* at Oilsonbai.

Following some success with these initial efforts it was expected that more elaborate layouts could be tested in subsequent years. At that time it was not clear exactly what existing examples could be used to review past planting successes and tending requirements. During the period of the first phase of Project 8613 a number of field plantings were made. These are mentioned by locality.

Oilsonbai

1988/1989 Field Trial. It was planned in October 1988 to plant *S album* under and among existing *Acacia auriculiformis*; some with simultaneously planted *Calliandra calothyrsus*. A fence was required, preferably covering a large area. It was possible initially for a 1.5 ha area to be fenced off. Planting in January 1989 incorporated the existing *Acacia auriculifomis* as well as newly planted *Calliandra* as potential field hosts. The *S. album* plants were relatively small, reflecting the need for a longer period in the nursery prior to planting. A number of survivors were present at a June 1989 inspection, and it was hoped to get some early indications of the value of proximity to extant shade on seedling development of *Santalum album*. Unfortunately this fenced block was burnt in October 1989 and practically all experiments were a total loss. The area has been used again to incorporate replicates of later trials set out in January 1991 testing height of planting stock, and the effects of mulching treatments with grass mulch.

1989/1990 Field Trial A second area of about 1.5 ha was selected for the 1989/90 trial. This incorporated a range of nursery, first stage pot-hosts (Project 3) and also different levels of shade and nearness of established hosts. Planting spots were marked out on a grid of 3 x 3 for planting under extant *Acacia auriculiformis*. This utilised the better survival and height growth sets from the large trial of pot hosts, with the remainder being *Capsicum* hosted. A separate area was laid out for planting sets of plus tree progeny. An attempt was made to categorise sites by degree of shade using a portable light meter. This was not entirely satisfactory, and it was decided to record all *Acacia auriculiformis* trees (and others). These were plotted onto a scaled map of the block.

A time of planting trial (*Capsicum* hosts) was commenced in November 1989 at the south western edge of the block convenient to the water supply. These sets went in at fortnightly intervals for sets of 10. They were hand watered until the rains set in. Inspection in April 1990 indicated better height and survival in the earliest planting time block.

In April 1990 the whole area showed massive growth of grasses, a range of several species with very dense cover, mainly headed out and flowering. Planting spots were often bare with a radius of about 20-30 cm bare soil, cracked and very dry. All grass needed to have been cut some 2 months earlier towards the end of the rains. All planting spots could then have been mulched with cut grass rather than left bare of all surface cover. Mulching was demonstrated. Many planting spots had dried out severely so that annual pot hosts had gone and the *S. album* had begun to wither. The grasses on the other hand were still very green and stood over moist soil. The immediate task instituted was to cut all grass, mulch all planting spots with cut grass and to simultaneously clear a five metre fire break each side of the fence all round the block. The cut grass from the firebreak was heaped for later use in a formal mulching trial in the next block.

Pot Host Trial. An important observation was that those *S. album* of superior growth in the nursery had persisted longer into the dry season than had smaller plants. This reinforced the notion that plantable *S. album* should be considered as individuals > 25 cm. Although this was attained on average in the three best hosts (at 23.12.90 - *Desmanthus virgatus* 34.3 cm; *Alternanthera* 33.6 cm; and *Crotalaria juncea* 29.7 cm, with *Sesbania grandiflora* also exceeding 25 cm, at 26.1 cm), many other plants were put out at a much shorter height. It was anticipated that a correlation between planting height and survival to mid April would show that survival ran in the order best to worst :- *D. virgatus, Alternanthera, C. juncea*, etc. Most of the material planted had grown for about 5 months in the nursery. Perhaps 6 months is a better target period for average growth. The 1990/91 follow up trial was therefore suggested as being set out in early June to ensure that 6 months pot growth would be available.

Detailed observations by host type were made in April 1990. These were as follows. *Desmanthus virgatus.* Sandalwoods with this host appeared to be the best. In many cases the host was still doing well. Its spreading habit was unlikely to interfere with vertical shoot growth of *S. album.* Where this host had been put into the time of planting trial, *S. album* was also doing well. Larger hosts may need pruning later on. Some of the *Alternanthera* sp. hosts had disappeared. Despite the prostrate growth of this host, most *S. album* with this species continued and were in good condition. No tending treatment is necessary, and the host is also a living mulch. *Crotalaria juncea* as a host had mainly dried off though some still persisted. It was earlier observed at Kefemenanu that *Sesbania grandiflora* as a host is aggressive and in many cases the *S. album* had died due to competition from the host. This was despite good survival in measurements at 10.3.90 and 10.4.90. A useful treatment could be to top prune the host, which can then side shoot. With the tropical Australian species *Acacia ampliceps* as host the *S. album* was slow in starting. However at the April visit both host and *S. album* were persisting well. A major problem may be leaning if the host continues to grow. In the case of *Cajanus cajan* few hosts were left, but those that had persisted looked good. *S. album* appeared very patchy with this host. Other hosts were *Breynia cernua* where the hosts rarely showed good growth, and sandalwoods often had few leaves or recent leaf falls. *Capsicum frutescens* hosts formed the bulk of the plantings across the block. Where the host was good (and in fruit) the *S. album* was also good, with the proviso mentioned above that larger nursery stock appeared to have grown better and persisted longer than smaller stock. A large number of small stock with this host was planted so failures may have been proportionately high amongst the sets. With tomato(*Lycopersicon esculentum*) all hosts were dead, not a good sign as the sandalwood may not have hosted to the *Acacia auriculiformis.* Many sandalwoods were still in good condition however and pot hosting may have provided sufficient impetus for adequate field hosting. *Acacia oraria* as a host was growing well (better than *A. ampliceps*) and *S. album* was persisting well despite earlier poor (relatively) height growth. This combination may have similar potential leaning problems, as with *Acacia ampliceps. Erigeron* *linifolius* [Asteraceae] - very few hosts persisted and this one was difficult to assess. Although *S. album* got off to a poor start the combination with *Duranta repens* showed considerable prospects. Hosts were generally good and *S. album* showed high persistence. It may be necessary to top prune the *Duranta repens*; the species is amenable to pruning.

Plus Tree Block. Many failures were probably associated with small planting stock, survivals from hosts other than the *Capsicum* used may have been higher. Sets of 15 plants from 11 separate parents were planted in December 1989. The best progeny set in terms of early growth came from Tree 18 at Oenutnanen. This tree has second heaviest seed weight of the 11 collected in 1989, it germinated sooner and with higher percentage than the others, and had a taller mean height prior to planting. This block had adequate space for the addition of new progeny of 1990 material from the same parent trees. Instead of *Capsicum* as the pot host, as in the first set, it was suggested that the refilling be with stock hosted to *Desmanthus virgatus*. Additional unplanted land to the west was allocated to the plus tree progeny planting for additional parent sets.

1990/1991 Field Trial. A third block, adjoining the 1989/90 area to the east also of about 1.5 ha was fenced for the 1990/91 trials. Experiments established in here include mulching trials and tests of the most suitable size of *Santalum album* planting stock. All plants were hosted to *Desmanthus* and all plants were raised in the recommended potting mixture. Replicates are also planted in the first block fenced for 1988/89. These trials were set out elegantly with good stock and represent an excellent research investment.

General Observations. It is much more difficult to establish plants of *S. album* on the Oilsonbai grumosol site than on the 1988/89 Buat site where higher rainfall, extending further into the year, has the potential to maintain soil moisture at a higher level. The *Acacia auriculiformis* hosts at Oilsonbai will, of course, have contributed to soil moisture depletion. Despite this, grass control is of primary importance.

Buat (Soe)

1988/89 Field Trial. This large trial area of about 5 ha was set out to test a combination of nursery fertilisation, provision of shelter at planting, hole versus slit preparation of planting spot, pot host and leaf type. Fenced cattle managed to get into the nursery where *Acacia villosa* pot hosts were preferentially grazed to *Breynia* or *Cassia sophorae*. Further incursions into the planting area resulted in later decapitation of many surviving *Santalum album*.

Topographical surveys of the site were made in April 1989 with Mr Kharisma who was shown how to use a clinometer. An inspection in June 1989 showed that all plants had been planted in their plastic bags. There was evidence throughout the experimental site of frequent, dense cattle stocking. Nearly all the planted *Acacia villosa* were eaten off. Despite these problems a large number of *S. album* were still alive. The value of thatched shade houses was clear. As the area was largely grass (with a few large *Casuarina younghouniana* and *Acacia leucophloia*,and some thickets of lantana) it was recommended that survivors be weeded and provided with pulled/cut grass mulch, cattle excluded and the external firebreak cleared and maintained. All plants should be kept free of grass growth, particularly at the start of rains. In the NW corner several *S. album* were growing from natural regeneration, presumably from root sprouts. The fence, plus firm exclusion of cattle, should lead to more natural regeneration. Observations could be made around existing *S. album* trees inside the fence to see whether seedling regeneration can be encouraged, e.g. clear grass/lantana, alang-alang (*Imperata* grass) and instead plant *Acacia*. The dense patches of alang-alang should respond to *Acacia mangium* which is known to suppress this noxious grass. It is difficult to envisage successful direct establishment of *S. album* into *Imperata*. Survivors of the 1988 planting using 2 pot hosts (*Cassia sophorae* and *Breynia cernua*) and a field host, *Acacia villosa* were measured in November 1989 , in March 1990 and April 1991.

The main results from this trial were related to nursery preparation and handling (mentioned earlier on in this report). Continued maintenance and observations are highly desirable as the planting area represents the most ambitious trial in recent years. Sub areas can be utilised for smaller trials and where sufficient survivors from the first planting do persist then useful information on growth and silvicultural responses can be derived. Blank patches could have *Acacia* species planted in advance of *S. album*. Blocks of dense *Acacia* could suppress grass growth and make fire protection easier. Selection of species from the ACIAR firewood trial complemented with those known to grow well, e.g. *A. auriculiformis, A.crassicarpa* and *A. oraria* would be a useful demonstration of broader scale plantings.

Binaus

A new experimental block was commenced at Binaus north of Soe (altitude 774 m) where three experiments were put out in December 1989 by Kharisma and Ida Rachmawati. These trials were examined in April 1990.

A. Length of time of S. album in pots Planted 21.12.89. Plants had different times in pots prior to planting in the field. i.e. 4, 6, 8, 10, 12, 13 months. Each plant of *S. album* was planted with an *A. auriculiformis* in the same hole. Survival of *A. auriculiformis* was better than *S. album*. There were many instances of one or the other surviving but not both. Assessment of this experiment was complicated by the fact that most of the *S. album* were shorter in height in April 1990 than they were when planted in December 1989. The area had been recently weeded and lightly mulched.The main problem was that the vegetation was mainly grass, which prior to fencing had been heavily grazed for some considerable time. The scattered nature, and incomplete cover of woody perennials provide an overriding site complication factor masking treatment effects, despite replications. A year later the ungrazed grass was very vigorous, as at the Oilsonbai site, and survivors were extremely scarce. Some problems need to be considered in relation to this trial. The length of time in the pot is compounded by the pot host/*S. album* connection. If the pot host is effective then *S. album* is likely to be taller. In this case pot hosts were not evident in the field so the transition to *A. auriculiformis* as an early host was not particularly useful. In addition at this site (Binaus) *A. auriculiformis* has no prior history. The initial growth since December 1989 appeared to have been poor, but perhaps the stock was also poor. It was suggested that a possibly useful analysis would be to contrast mean heights of *S. album* at planting with April measurements i.e. 4 months "growth" and survivals.

Possible hypotheses include:

longer time in pot	results in	larger *S. album*
older/larger *S. album*	results in	better survivals
older/larger *S. album*	results in	better mean height at 4 months
older/larger *S. album*	results in	better mean height increment at 4 months

B. Relative time in shade/sun. Planted 21.12.89. All plants were 10 months from sowing in a pot with *Calotropis gigantea* as pot host. The variable treatment was months in shade/months in sun. These treatments were 10/0, 9/1, 8/2, 7/3, 6/4 and 5/5. This experiment was planted mainly in an area of heavy grass competition. Although recently weeded it seems that during the rainy season (December - April) most planted individuals had suffered from grass competition by April 1990. Part of the trial was also located in an area of shrub growth - here the shade/competition from shrub growth may have affected performance. In many cases either the pot host, the *S. album* or both were dead. Earlier trials indicated *C. gigantea* to be a strong competitor with *S. album*, especially if in a small pot. Several *S. album* individuals appeared to be in good health at April 1990, but as with A, there were very few in 1991. As with A several conceptual problems need consideration. Were the individual host/S. *album pots* comparable at the time of planting? Were both present at the time of planting? Survival will depend on this initial pot/host connection, and in the longer term on the access to a new, longer term host. It was not clear whether a longer term host had been planned for this experiment. As with trial A above, a possibly useful analysis would be to contrast mean heights of *S. album* at time of planting with those at 4 months, and survivals.

Possible hypotheses include:

Longer time in the sun gives better "growth" and survivals.

5/5 were better *S. album* at the start and better overall

5/5 were better *S. album* at the start and better mean height at 4 months

5/5 were better *S. album* at the start and better mean height increment at 4 months

and conversely 10/0 plants (i.e. entirely grown in shade) give poorer performance for the above parameters

C. Top shade/side shade/control (Ida Trial). All *S. album* had a pot host of *Capsicum frutescens*. All were planted in the same hole as an *Acacia villosa* second stage host. The shade material was a metallic fly screen material, galvanised light coloured, mesh size about 1-2 mm. Each was 1 m X 1 m . The top shade was a horizontal screen placed at 1 m above ground, the side shade consisted of 1 m high strips on each of 4 sides around the planting holes. A comparison of light meter readings using the camera indicated little effect of the top shade. The side shade was not much different from the surrounding grass/shrub growth. Visual impressions were that top shade depressed *A. villosa* and side shade increased height of *A. villosa*. There were very few survivals of either *S. album* or the *Capsicum* pot host. Problems in relation to this trial include possible lack of early weeding control. The shade mesh may not have cut out much sunlight. Treatment was compounded by grass and shrub growth being variable. If all planted *S. album* were of similar size, with an extant *Capsicum* host, then analysis may distinguish between treatment effects. However it must be noted that several *S. album* survivors were yellow foliaged, indicating no effective pot host/parasite connection. As with trials A and B it would be best to restrict statistical analysis to the first 4 months of growth and survival. Hypotheses could include:

Top shade enhances early *S. album* growth
Top shade depresses early *A. villosa* growth
Shade is more effective than control planting
Top shade enhances survivals
Top shade enhances 4 months growth

All 3 experiments may suffer from the absence of a "level playing field" in that initial planting stock needed to be comparable. An analysis of the mean heights of planting stock by treatment needs to be done using analysis of variance. This should show no significant differences between the treatment sets for overall mean heights in C, but may indicate treatment effects in A and B. Stem diameter in B is also worth analysis as shade removal may decrease height growth but increase stem thickness.

As observed in April 1990 the level of field survivals was poor. It is of interest to consider whether survival level is due to treatment or not. For A and B above where the "treatments" in the experiments were nursery procedures then a main result of the experiments is survival and growth up to the time of planting. Clearly if a particular nursery treatment is more wasteful in terms of plastic bags than another, then this needs to be known. Did the available nursery stock meet the criteria for normal successful planting?

i.e.
- soil mixture 37.5% sand
- minimum size of 25 cm height
- attachment of sandalwood and host
- suitable pot host

Of these only the fourth is able to be tested for the experiments. For any field survival experiment there is an inherent problem if any of the following plants are included:-

S. album with no pot host	- must then find one in field
Small *S. album*	- may not persist, has grown poorly to date
Large *S. album*	- may not persist - its demand for water may not be met in the field leading to top death.

In future unless uniform planting stock is available then field planting must involve:-
similar site for each plant, similar preparation, similar soil, similar host availability, similar pot planting treatment : weeding, mulching, and provision of water where necessary.

Kefamenanu

This site is in open woodland of *Eucalyptus alba*, mainly grass ground cover. Several large trials were planned for 1988/89. When first inspected in October 1988 the main problem was water supply coupled with few surviving nursery plants for the planned trials. In April 1989 it was observed that a fire had destroyed part of the nursery and also burnt the fence. Cattle had re-entered the area and replanting awaited their exclosure again. On this visit topographical surveys of the Kefamenanu site were made with Mr Kharisma. It was recommended early in 1989 that blocks and strips of *Acacia* for future hosts be planted and that the area be blocked off for fire control. By November 1989 the location had not burnt again as there was a successful fire break all round, but grass built up inside. It was suggested that blocks or strips be burnt inside the fence line.

Australian Acacia species as Hosts.

The *Acacia/Santalum* experiment commenced at Sikumana in 1988 ended up in a planting block at Kefamenanu in February 1989. Mean heights of surviving *Acacia* species (at 8 months from seed sowing) are shown in Figure 13. At assessment in November 1989 their heights in cm were: *A. retivenia* 30, 38; *A. ampliceps* 13(+*S. album* 13), 15; *A aneura* 11(+*S. album* 13); *A tumida* (prostrate form) 15, 9; *A holosericea* 120, 88 (+*S. album* 10); *A dictyophleba* 22.

That few survivors persisted was due to the following:

1. small plastic bags, plants not repotted into larger bags
2. travel from Sikumana to Kefamenanu by road
3. all plants planted in their plastic bags

In such work, large bags must be used. Labelling must be adequate. Hosts or sandalwood deaths should be replaced. In May 1989 the block was reworked to achieve the following:

1. at each spot a host and a *Santalum album*
2. each extant host plastic bag was cut away on the side of the *Santalum*
3. use was made of old stock of *Acacia oraria* (c. 20-45 cm tall) for filling blanks, with old *S. album* 5-10 cm tall. All planted free of bags, and covered with a light grass mulch.

In April 1990 this *Acacia* trial had only 3 sandalwood survivors, all with *Acacia auriculiformis.*

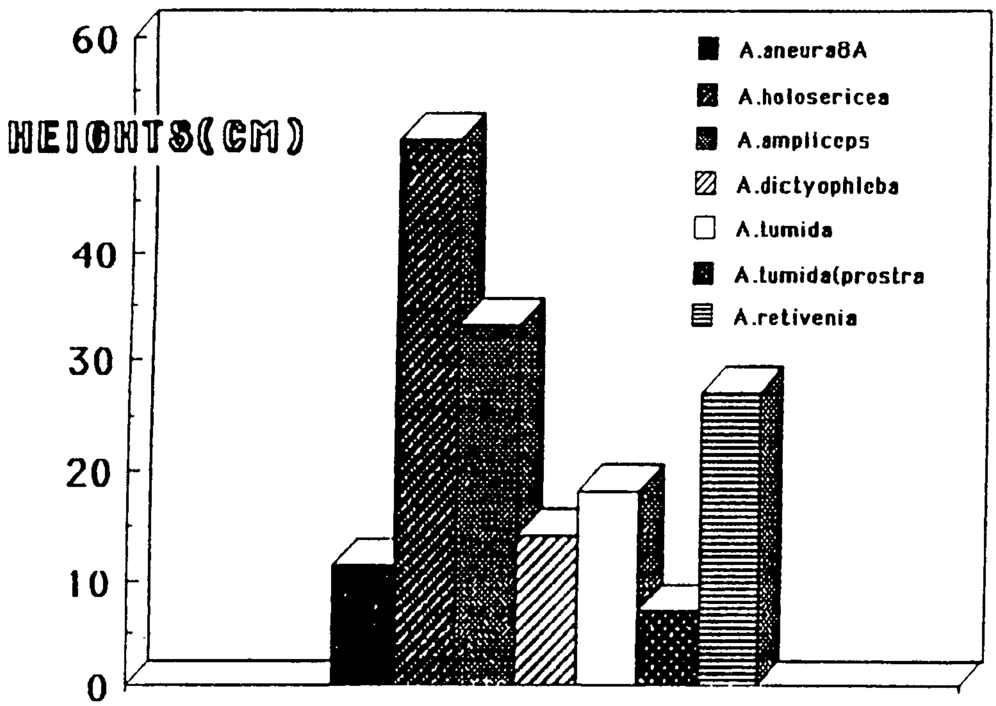

Figure 13. Acacia heights at Sikumana 8 months from sowing of seeds.

NPK Addition to Capsicum Hosts.

In the Sikumana nursery, sandalwoods hosted with *Capsicum* had been in 2 treatment sets, one of 10 with NPK 5 g Osmocote, the other 10 with 10 g. These plants were also planted at Kefamenanu with the *Acacia* set.I n May 1989 the surviving *S. album* were good and had been covered with overhead grass shade. All *Capsicum* were then more or less dead, so second stage hosts of *Acacia oraria* were planted alongside these *S. album.* Little or no difference in height of *S. album* was observed between the two fertiliser treatments.

S.album under Sesbania grandiflora

In a minor trial at Kefamenanu 9 *S. album* were planted in June 1989 into the house area with *Sesbania* using *Santalum* of > 40 cm (3 plants); about 25 cm (3 plants); 10-15 cm (3 plants). These had mainly *Capsicum* pot hosts. All were watered in. The *Sesbania* had been planted in the preceeding wet season, i.e. only 4 months or so before but these were well over 2 m tall at this stage. As it is located just next to the house these plants were able to obtain RollsRoyce attention. The *S. album* were remeasured in November 1989. They were 39-81 cm tall, several looking quite good. These continued to make good growth, and indicate that the species can be grown in the area.

Year of Planting S.album to Secondary Host

A complicated trial was planned in which 4 field hosts were planted and *Santalum album* was to be planted in the same year, after 1 or after 2 years each with a starter, or first stage host. In addition some different spacings were to be incorporated. This was commenced in the rainy season 1988/89. At inspection in June 1989 it was noted that all plants were planted in their plastic bags, and this inevitably reduced the value of the experiment. However, a number of additional *S. album* seed were sown in February and many seedlings were then growing. All *S. album* planting spots were being regularly watered every second day. Each spot was provided with a grass shade hut. The standard spacing 2 x 3 was examined first.

1988 planted blocks. Hosts heights were :- *A catechu* to 50 cm tall, *A. oraria* to 55 cm, *Adenanthera pavonina* much smaller, about 20 cm and *Sesbania grandiflora* the tallest with plants up to 1.35 m. In some cases planting spots had 3 bags intact, one from the field host, one from the first stage host, a first *S. album* + pot host, and another replant of the same. When seed was sown in February, 3-4 were put in each spot. There was thus a range of conditions with, in some cases, an original *S. album* in its pot (often drying off) in other cases 1 or more smaller but thriving seedlings. Pot hosts may or may not be present. It was recommended that at grass weeding, grass be placed inside the shade houses to provide a surface mulch.

1989 planting blocks. Here hosts were planted in December 1988 in their plastic bags. Large holes were left exposing half of the plastic bags to the sun. Growth of hosts was less than in the 1988 blocks due to this and also because no watering was done. It was recommended that holes be filled in to allow root protection and that bags be cut. *Acacia catechu* and *A. oraria* survived well; *Adenanthera* suffered a number of losses and *Sesbania* fared very poorly. The latter clearly demonstrates the value of watering to the 1988 block.

1990 planting blocks. Some have holes dug in preparation, others do not. Acacias again showed the best survival, fewer *Adenanthera* and hardly any *Sesbania* survived.

When the spacing was 2 x 6 m for hosts, 3 x 3 m for *S. album*, the hosts were generally smaller than the standard spacing set as only *S. album* pots were watered. Many *S. album* had persisted but often only as a sprout from a dry stick. *Acacia catechu* had made best growth in the absence of water, with *A. oraria* second best. *Adenanthera* survivals were good but heights were poor. There were very few *Sesbania* left at all.

It was clear that *Acacia* species were the best for establishing 1-2 years ahead of *S. album*. On this site *Sesbania grandiflora* grows well with water but scarcely persists without. *Adenanthera* can persist well but grows poorly. Several examples of *Capsicum* pot hosts had good seedling growth, whereas *Calotropis* pot hosts had many *S. album* losses.

The major objectives of this trial were not met, it was far too ambitous, too remote from HQ and field conditions perhaps the most difficult of all those used to date for sandalwood. It was recommended in June 1989 that *Acacia auriculiformis/A. mangium* or some other fast growing grass suppressing species should be used in future plantings, prior to introducing sandalwood.

1989/1990 Field Trial

An experiment used *A. oraria* and *S. album* sown in May 1989 (plus a set of 1 month old seedlings) planted directly into the ground in November1989. The treatments used were:

	Mulch			**No mulch**		
6 month plants	No shade	Top shade	Side shade	No shade	Top shade	Side shade
1 month seedlings	No shade	Top shade	Side shade	No shade	Top shade	Side shade

Few plants survived beyond one year in this trial.

Sikumana

The Australian *Acacia Santalum album* trial was intended for this near Kupang location.This did not eventuate and plants were taken to Kefamenanu.It was hoped in October 1988 that at least 20 *S. album* could be planted near the nursery complex. Six *Acacia/S. album* were planted on in November 1988 by Kharisma. One of these survived 2 years.

Acacia auriculiformis as field host

Seven month old seedlings grown with *Calotropis* hosts were planted out by Ida in February 1989. *Acacia auriculiformis* was used as the field host. This was planted 10-15 cm from the sandalwood. All spots were provided with small shade houses. Survival at inspection in April 1989 was virtually 100% with sandalwood about 50 cm tall. The good rains well into 1989 undoubtedly favoured the success of this trial.

Multi-purpose Tree Species Hosts

A second trial of Ida's with *S. album* planted on 10th April 1989 into a multi-use plantation trial established in December 1988, also had good survivals to June 1989 with field hosts of *A. oraria, A. villosa* and *A. leucophloia*. The latter host was very small so that a shade effect may become important with respect to longer term survivals. Half of each was to receive no weeding. There is a strong relationship for seedlings of *S. album* between height and weight, as shown in the soil mix trial (Project 4 and Figure 14). Thus heights of small trees are reliable indications of overall success. This trial, particularly with *A. villosa*, continued to show promise in April 1990 and again a year later.

For future plantings it will be useful to use *Acacia crassicarpa* as field hosts. This is the best *Acacia* in the firewood blocks. It was well nodulated in June 1989.

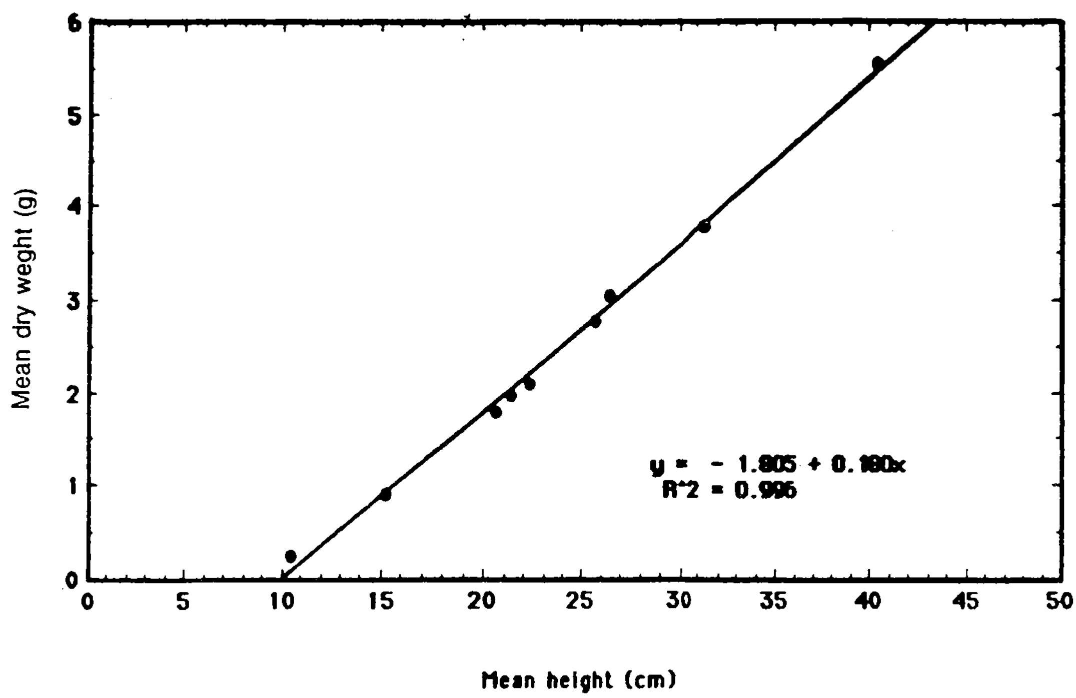

Figure 14. Relationship between mean dry weights (g) at harvest and heights (cm) at harvest for plants grown in both Oilsonbai soils combined.

Lelokasi

At Lelokasi there is a large area of planted (12 years) *Casuarina junghouniana*. It was suggested to the Timor staff that an underplanting trial here would be most useful. This trial was put in by Kharisma in January 1991

Direct seeding

No research trials into direct seeding have been undertaken, nor are any considered desirable at present. The following is a summary of Indian reports. Direct seeding can be done in a number of ways - by dibbling, broadcasting and by pressing seed into the earth by hand. Seed is often treated with a poison (gamaxine, *Acoris calamus* or red lead) to discourage predators. Dibbling is the most widely used method. Seed is passed through a long hollow tube of metal or bamboo, into the chosen site. Dibbling is useful for planting in open, scrubby country or semi-evergreen forest where seed is put into and around bushes (especially thorny ones which act as protection against hot sun, excessive drought, predators and fire). Sometimes known good hosts are grown first so that they provide both protection and host benefits to a sandal planted later. Dibbling is also used to plant sandal and host seed together in worked pits. A third and successful method is to use the trench-mound techniques. Typically 3 m long trenches are dug 30 cm deep and 30 cm wide. The soil removed is piled up 30 cm high along the side of the trench to form a mound. Into this mound are dibbled both sandal and host seeds together. Hosts are often *Albizia* and *Acacia* species, *Cassia siamea* or *Pongamia pinnata*. *Eucalyptus* are sometimes planted in the trenches.

Broadcasting seed generally gives poor results. This is probably because seed does not necessarily fall in a shaded and protected spot and because predators eat the seed. There are records of seed being simply pressed into the ground by hand, often beneath parent trees, but this method does not appear to be practised on a large scale.

Seedlings will not survive the hot weather if they are not well established when the dry season begins. For instance, in the western Mysore sandal zone they should be planted by May (early monsoon), so that they are 6 months old by the time the dry sets in. If they are not well established, or if the rainfall is low or erratic, seedlings may have to be artificially watered if they are to survive. Direct-seeding undertaken in Timor in 1987 was a complete failure despite 10 localities and large areas sown. At an operational scale when the Regional staff have a well-defined planting programme in place it is possible that direct-seeding could be used in a taungya arrangement. However this seems rather remote at present as the institutional barriers to taungya may take some time to change.

Abundant natural regeneration from bird-ingested seed is evident at Wanagama. This is undoubtedly due to the more humid climate of Central Java compared with Timor. The absence of cattle may be another factor as numerous root sprouts have been observed at both Oilsonbai and Soe fenced experimental areas. These were absent before and are not seen outside the fences.

General

In July 1990 the research programme was largely confined to land ceded by the Provincial Forest Department. Two main requirements for all trial areas are:-

Fencing	-	adequate and regularly maintained.
Firebreaks	-	all perimeters to be cleaned off.
	-	if necessary patch or strip burns inside only in cool weather

Planting should be done on available land, representative of areas where larger areas of land can later be used. Preferably it should be wooded, not grassy and fenced to exclude grazing animals where these are present. Other things being equal Forest Reserve land where sandalwood has grown in the past is to be preferred. Extant blocks of suitable hosts if present in prior planting areas, or carefully planned blocks started up 2-3 years prior to sandalwood trials, are desirable.

Selection of additional sites which can be serviced by the existing set up would be useful. If not then a detailed planning of the soil and vegetation status of existing land areas could be a useful preliminary stage. Liaison was maintained with District Forest staff at Soë and Kefamenanu. More cooperation with the other sections of the Forests Department which have inputs into sandalwood could yield more sites in the short term. Insufficient time was available to inspect Forest Department field plantings but with 55 ha tried in 1988, clearly the research team should liaise more strongly with this set up.

Time of planting in relation to the rains is being tested. One of the best percentage survival experiments was the trial planted by Ida at Sikumana in February 1989. As a general principle however it is clearly better to plant out in late December at the beginning of the rains when soil nitrogen is at its highest. For luxury treatment hand watering should be considered. In many parts of India even humble firewood species are hand watered to ensure survival. How much more important for the very valuable sandalwood to ensure that it is established!

Spacing of trees is currently at 3 x 3 m for most trials. In Java much closer spacings have been used. There is an area of trade off between nursery costs, planting losses and the quality of post-planting care. In Western Australia (Kimberley) planting at 5 x 5 m is preferred to allow mechanical grass control. It would be useful for a number of host blocks to be available to test out different spacing regimes.

The following points need elucidation:

- what shade conditions are appropriate for *S. album* plantings in the first 1-2 years
- effect of soil type on growth
- growth of *S. album* with particular host plants

A planting programme should precede a direct sowing programme:-

- to ensure success
- to obtain some areas where growth can be observed.
- to confirm soil types, shade, host assemblage, persistence through dry seasons.

Later on sowing may well be worthwhile and if successful could obviously be much more economical. At the present time planting is to be preferred.

Project 6: Tending requirements

For this project a distinction is made between the cultural techniques needed for planting and establishment and subsequent tending. Those matters associated with planting are covered in Project 5, and include preparation, physical planting and immediate post-planting care. Thus any attention to removing grass competition in the immediate post-planting period should be covered by the requirements for the planting effort. In subsequent years those plants which survive may also require tending to remove grass, at least until the plants have grown sufficiently tall such that the main crown area is free of shading by any grass and herbage present. Should hosts or other competing species provide too much shade/root competition then some thinning may be required. At the initial stages some host plants may require cutting back.

It had been anticipated that some leads could have been derived from observations of existing young stands. For example Jones (1983, page 134) referred to a 20 ha plantation at Butin, Kecamatan Fatulen, established in 1968 (see also Jones 1982, p16, 23). Here teak, sandalwood and *Leuceana* were reportedly grown in alternate rows and the latter were noted as shading out the sandalwood. Jones mentioned a system of cutting and light burning was giving some good results in releasing the sandalwood. Mr Sutaryo reported that this area had subsequently failed. It had been suggested that someone could write up this as a case history, and similarly with Sopo, TTS mentioned in project 2. It is problematical as to whether this is a good idea or not. Valuable lessons have certainly been learnt from observing established areas of sandalwood. All suffer from too much cultivation for crops. At each of Kwaliu, Oenutnanen, Ajoubaki and Oenasi frequent maize cultivation has hindered host development, growth of second generation seedlings, and damaged the butt area of otherwise valuable sandalwood trees. Cultivation round trees (for food crops) should be stopped because this damages trees. Also, if land is cultivated, hosts tend to be cleared and become scarce leaving the *S. album* largely exposed. Some mango trees in the area at Kwaliu suggest that a better management strategy than the present one of an annual maize crop taken every year for at least four years from sandalwood establishment would be as follows:

Year 0 - preparation for *Santalum,* do not clear all potential hosts
Year 1 - cultivate maize, *Capsicum*, plant mango and *Santalum*
Year 2 - a little corn only, tend *Capsicum*, mango and *Santalum*
Years 3 - 6 - tend mango and *Santalum*

After the sixth year plants would be allowed to grow without attention.

Whereas sandalwood does not appear to occur under dense shade, and it must be presumed that establishment in dense shade would be unsuccessful, some side shade or light canopy appears to promote growth. Conversely establishment in full sun is virtually impossible. Much of the available literature on *S. album* indicates that young plants survive and grow better if shaded to the extent of about 50%. The value of thatched shade huts is clear and this technique (project 5) has been frequently adopted in trials. It is necessary to inspect plants so protected during, or just after, the second rainy season to ensure that remnants of thatched huts are not hindering, or distorting, the vertical growth of sandal. Where unmaintained thatch is combined with uncut grass many plants die off or grow poorly.

The importance of cattle and fire exclusion has been continuously stressed. All fences must be maintained and firebreaks (5 m wide) made around all fences. They must be regularly checked. Fire and/or cattle ingression have caused much damage at each of the three main experimental locations. It is recommended that excess dry grass material be harvested from inside fenced areas to reduce the risk of fire. If necessary, controlled patch or strip burns should be made inside trial areas, but only in cool weather. All plants should be kept free of grass growth particularly at the start of the rains. Cut or pulled grass could be used as a mulch around sandal wherever possible. Formal experimental evidence of the value of this technique for the first dry season may be available shortly (project 5). No areas have been observed where it would be possible to grow sandalwood in plantations without fencing to keep cattle out. Present fence design is *ad hoc* with locally cut bush poles sunk into the ground and 3-4 strands of barbed wire then wrapped along the poles. Branchwood is sometimes draped across forked bush wood as an added deterrent. Farmers who grow rice often cultivate bushy shrubs as live fences whereas the maize cultivators, who move their cultivation about, use cut materials heaped against poles and forked branchwood. Whatever the system, and it would be anticipated that ingenuity will develop innovations in fencing styles, it is necessary for the boundary fences to be inspected frequently and any cattle found dealt with. As a concession to local people it may be possible to encourage controlled, tethered grazing inside plantations after about the 3rd year from establishment. Part of the success of India in cultivating sandalwood lies in the many formalised ways in which the forestry staff are able to interact with the rural populations by way of permitting access and use of forest lands. In Timor clear boundaries are uncommon and cattle seem to have total freedom to graze wherever they wander. There is also a lack of respect for the integrity of the forest ecosystems and it seems that only the exploitation of mature sandalwood, its demarcation and periodic inventory, bring the people into the sphere of formalised management of forest lands. Successful cultivation of sandalwood on government forest land will require a greater degree of respect for the integrity of forest boundaries. These considerations are management matters. Their resolution by way of forest research projects will likely be via collaborative sandalwood efforts on private land. This may take the form of long-term renting of suitable blocks, or by encouraging landholders themselves to maintain and manage growing sandalwood trees. Research into these options has not been undertaken in Timor. It is possible that management companies associated with the processing of sandalwood oil will take the initiative, and this is to be encouraged. One can foresee considerable enthusiasm generated as soon as a few contemporary, well managed plots of sandalwood exist and can be visited by community leaders from a range of localities.

Another approach to the difficult problem of fire control would be to put a lot of effort into establishing blocks of dense *A. auriculiformis/A. mangium* or other fast growing grass suppressing species (also useful as firewood). Dense *Imperata* grass (alang-alang) and lantana growth, besides being a fire hazard, inhibit both the natural regeneration of sandal and of desirable woody perennial host species. No examples of natural regeneration from seed have been observed in Timor. In Java, in the absence of cattle and fire, there is abundant regeneration. Examples of resprouts have been observed in fenced areas at both Buat and Oilsonbai. The inference is that prior to fencing cattle would have preferentially grazed such sprouts. Cattle grazing then is probably responsible for the marked absence of small *Santalum album* in all areas where larger trees are seen.

The use of watering as a tending technique merits examination for the first dry season post-planting. At Kefemenanu watering of sandal plants also assisted the trialled field host species *Sesbania grandiflora* and *Adenanthera pavonina* to grow well. These barely persisted without. Watering of firewood plantings is done in many Indian locations where tree planting is used to reverse severe land degradation. For the extremly valuable sandalwood the cost of watering, especially if essential in obtaining good establishment, would be a small investment relative to the rewards of obtaining good yields in the future.

In some cases it may be necessary to control pests. This is not a priority at present, but researchers need to keep their eyes open and it would be useful for the future if samples of insects found on the foliage of sandalwood to be sent to Bogor for identification. Experience to date indicates that it is not necessary to fertilise in the field, although humus and leaf litter are beneficial to growth. An iterative approach is required such that observations on foliage may lead to diagnosis of nutrient imbalance. Should this occur then remedial fertiliser application experiments would be undertaken.

Project 7: Allelopathy

Under Timor conditions sandalwood presence seems to be more associated with vegetation type than with characteristics of the soil. Thus its absence in *Eucalyptus alba* and *E. urophylla* stands has given rise to speculation that these species may produce allelopathic effects. This has been investigated by Forestry Research Institute (F.R.I.) staff at Kupang. Ida Rachmawati examined the possible allelopathic effects of *E. alba* on *S. album* . Plants were hosted to *Calotropis* and subjected to leachate of *E. alba* at Sekumana and Kefamananu - the latter suffered due to water problems and was partially lost to fire in early 1989. .

To date it is understood that trials have been inconclusive but it is an interesting line of research from which some useful data could accrue. Some additional studies could be based on those planting trials where *E. alba* occurs. A major problem in putting sandalwood into *E. alba* stands is that the species is difficult to remove prior to planting in the absence of the availability of heavy machinery. *E. alba* sprouts readily from damaged roots, and is presumably aggressive in its demand for soil moisture, evidenced by a lack of understory woody shrubs where it is dominant. Hosting trials of *Santalum spicatum* in Australia demonstrated that this species did not readily parasitise *Eucalyptus* species when grown in joint pot arrangements. This lack of hosting was considered due to the aggressive nature of the *Eucalyptus* compared with other species of potential host.

Thus far in the Timor program allelopathy is not seen to be a problem. Too many other complicating factors in plantation establishment techniques and planting stock quality effectively mask any expression of allelopathy that might be present.

It is considered that this topic should take a low priority in terms of the efforts of senior F.R.I.staff. However as a student topic it is worth pursuing, and possibly a staff member at Gadjah Mada University may be interested in supervising a student project.

Project 8: Growth Plots and Yield

Growth in India under forest conditions is often of the order of 1 cm yr^{-1} in girth. Under favourable soil and moisture conditions it can increase in girth at 5 or 6 cm yr^{-1}. Sandal growth is not uniform and in an 8-year old plantation, tree diameters varied between 7.2 cm and 14.3 cm. In a 14-year old plantation the diameters ranged from 9.7 cm to 16.1 cm (Srimathi and Kulkarni, 1979).

A number of stands of known age were examined in Central Java (Fox 1988). Under the higher rainfall regime there than in Timor it was postulated that planted *Santalum album* could attain mean diameters of 40 cm in 40 years, with some 26 trees ha^{-1}. The stands could also support 50 ha^{-1} at 30 cm diameter. There are not the same opportunities for yield calculation available in Timor at present.

At Oenasi (near Buat, outside Soe) an area of about 16 ha was recorded in the Soe Forest Office records as having been planted 1972/1973. A later inspection suggested that about 9 ha had failed, leaving some 7 ha with 50 percent survivals. This area was examined in June 1989 although the currently stocked area seemed much smaller than that recorded. Trees were somewhat mixed with other trees of about the same size as the sandalwood. Some particularly tall trees were observed in a cattle byre. Occasional *Eucalyptus alba* persisted in the area. Five temporary plots were established. Figure 15 summarises the height and stem diameters of this stand at 16.5 years from planting.

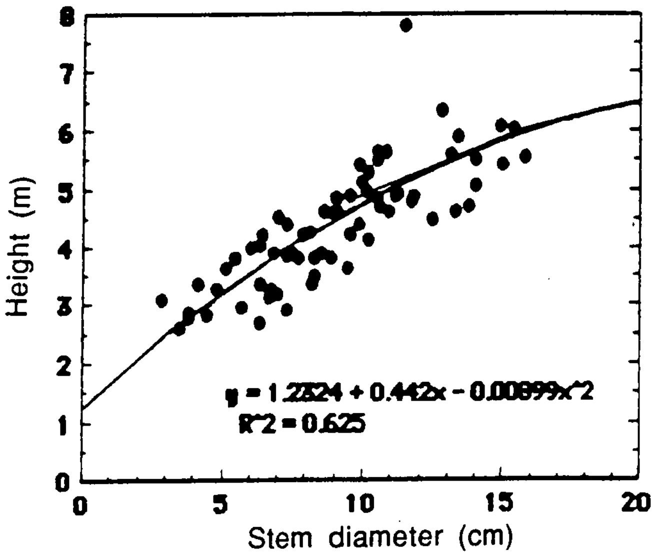

Figure 15. Height and stem diameters for all measured trees in 5 plots at Oenasi age 16.5 years at June 1989. The area was planted in 1972-1973.

At this age trees were 10 cm diameter and 4 - 5 m tall. Heights ranged from 3 - 6.5 m and diameters from 3 - 16 cm. Unfortunately this valuable stand is being cultivated for maize annually and few host trees are available.

Soë office records, seen in June 1989 indicated the following plantings were undertaken with farming in Kwaliu:

1969/70	6 ha
1973/74	25 ha (68% successful)
1974/75	15 ha
1975/76	5 ha
1977/78	55 ha (18.4% successful)
1978/79	50 ha

Unfortunately no maps were available and the percent successful may have been spots or area. From discussions with the Soë staff it appears that seed of *S. album* was sown into cleared bush cultivated for maize. This cultivation appears to have continued at least until 1988-89 as corn stems were still evident in places at the June 1989 visit. Two temporary plots were measured at Kwaliu, Figure 16. The precise age of these two plots could not be ascertained, but if it is assumed that the area of larger growth dated from 1969/70 and the smaller from 1973/74 then the mean annual increment in diameter growth is 0.6 for both. This is very similar to the Oenasi set of measurements.

Two other temporary plots were established at Siso where the abundance of pole size trees suggested root sucker growth.

The literature indicates that heartwood, containing the fragrant oil, can occur in small trees as well as large trees. Most do not develop heartwood until they reach 15 - 20 years. Some trees never develop heartwood. Larger trees may put on 1-2 kg of heartwood a year. Heartwood is at its prime between 30 and 80 years of age in India, with different authors giving different times, probably depending on environmental conditions.

Heartwood is dealt with under project 1 in terms of plus tree selection. In the past, heartwood formation, its colours and its oil content, have been variously attributed to edaphic factors, elevation, geographic location, climatic factors and the nature of the host plants. Heartwood formation is now definitely believed to be largely genetically controlled. In mature Mysore trees the root (which in all trees is richest in oil), contains 10% by weight of oil. The stem contains 5-8% (Sinha,1961).

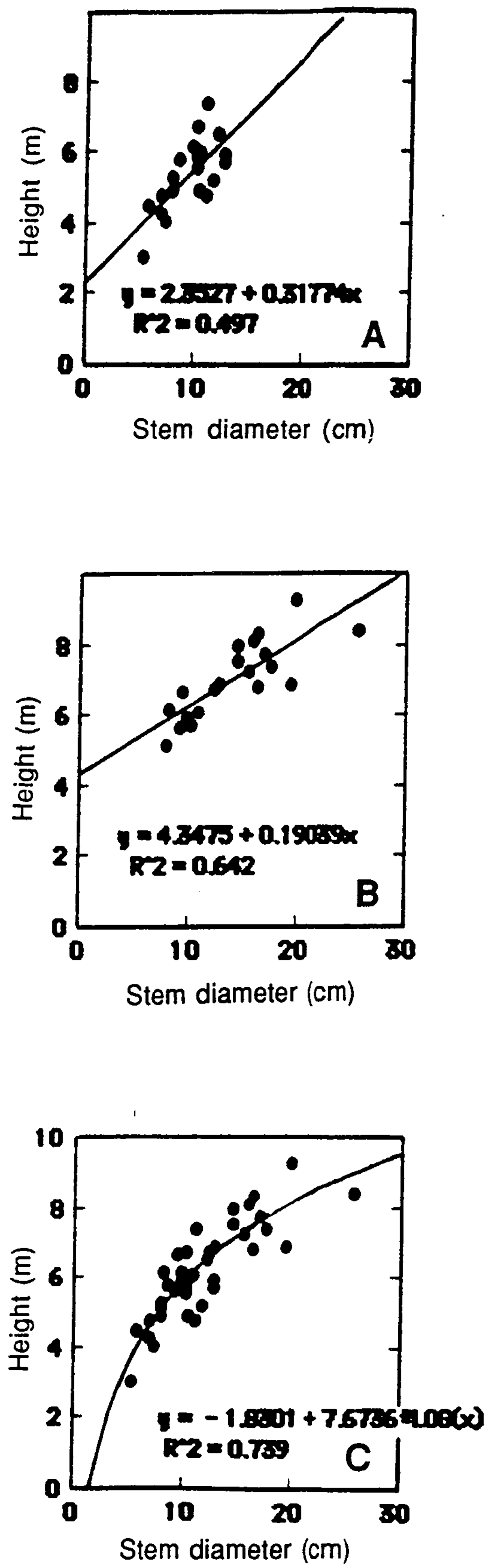

Figure 16. Height and stem diameters in June 1989 for: (A) Kwaliu plot 1, presumed tree age 15.5 years; (B) Kwaliu plot 2, presumed tree age 19.5 years; (C) Both Kwaliu plots combined.

Sandalwood oil has three main components: santalol, santalyl acetate and santalene. The relative proportions of these vary with the age of the tree, the santalol content increasing from 72-83% in 10 year old trees, to 86-91% in mature trees. The other components decrease with age. As the extracted oil ages it changes from pale yellow to golden brown.

Colour of wood	**% Oil**	**% Santalol in oil**
Yellow	1.3-3.5	90
Light brown	2.5-6.2	85-90
Dark brown	<2.5	75-85
Deep chestnut brown	2.5	<85

Favourable environmental factors allow the best expression of a good genetic oil content trait. Indian literature suggests that the colour of the heartwood varies from yellow through brown to deep chestnut-brown. Light brown wood contains the most oil (Venkatesan, 1979).

In mid 1988 a set of harvested *Santalum album* trees was examined from Nilulat/Haumeniana, north of Kefamenanu. Of the 96 felled trees a complete set of measurements was available for 76. A representative sample of 20 1 kg pieces, taken from some of the 76 trees was sent to Bogor to determine oil content. A sampling strategy was devised to select trees from size classes and to cover the range of heartwood present. From the set of 20 samples it was possible to characterise 10 samples with felled tree data (Table 5).

It had been planned that the 20 samples would have included the largest trees with heartwood > 40 cm and those with > 60% basal heartwood at b.h. Of the 20 pieces, 6 could not be correlated with field measurements (one of these was lost). Of the remainder, 10 trees were sampled, 7 with one piece, presumably the butt section; 2 with two pieces and 1 tree had three samples sent (specimen nos. 7, 9 and 16). The latter tree did not have a total weight of heartwood recorded so that actual oil yield could not be determined. The percentage yields of total oil (and santalol) were 1.33(96), 1.28(94), 2.41(90) for the three pieces. The total tree heartwood volume of 0.075 m^3 corresponds to an estimated weight of 55 kg. Thus an estimated mean total oil yield is 0.92 kg, with a santalol yield of 0.86 kg. With this corrected value it was possible to estimate the probable oil yields from the 10 trees, knowing the heartwood weights and oil contents. This is given in Figure 17 and Table 6.

Table 5. **Details of 10 trees (from the set of 76 trees) analysed for oil content.**
K(Kechil) = small B (Besa) = large

Sample no.	Sapwood radius (cm)	diameter (cm) breast height	Base area %	Bole length (m)	Heartwood volume (m3)	Total tree volume (m3)	% heartwood volume	Weight of heartwood (kg)	Tree height (m)	Leaf size
1	2.5	23.87	62.5	6.53	0.041	0.176	23.3	25	11.53	K
2	3	25.62	58.65	5.13	0.1	0.226	44.25	78	10.83	B
3	5.5	22.6	26.35	7.6	0.073	0.23	31.73	60	11.1	K
4	5	25.78	37.47	4.68	0.068	0.14	48.57	48	10.48	K
5	4	30.88	54.89	8.54	0.119	0.334	35.63	80	14.54	B
7	3.5	29.6	58.3	6	0.075	0.294	25.48			
13	4	23.55	43.61	4.72	0.046	0.128	35.94	32	9.22	B
15	4	31.83	56.05	6.07	0.129	0.318	40.57	112	13.57	B
18	8	32.79	26.21	5.58	0.114	0.28	40.71	99	11.58	B
19	4.5	23.55	38.18	7.08	0.044	0.145	30.34	30	11.83	K

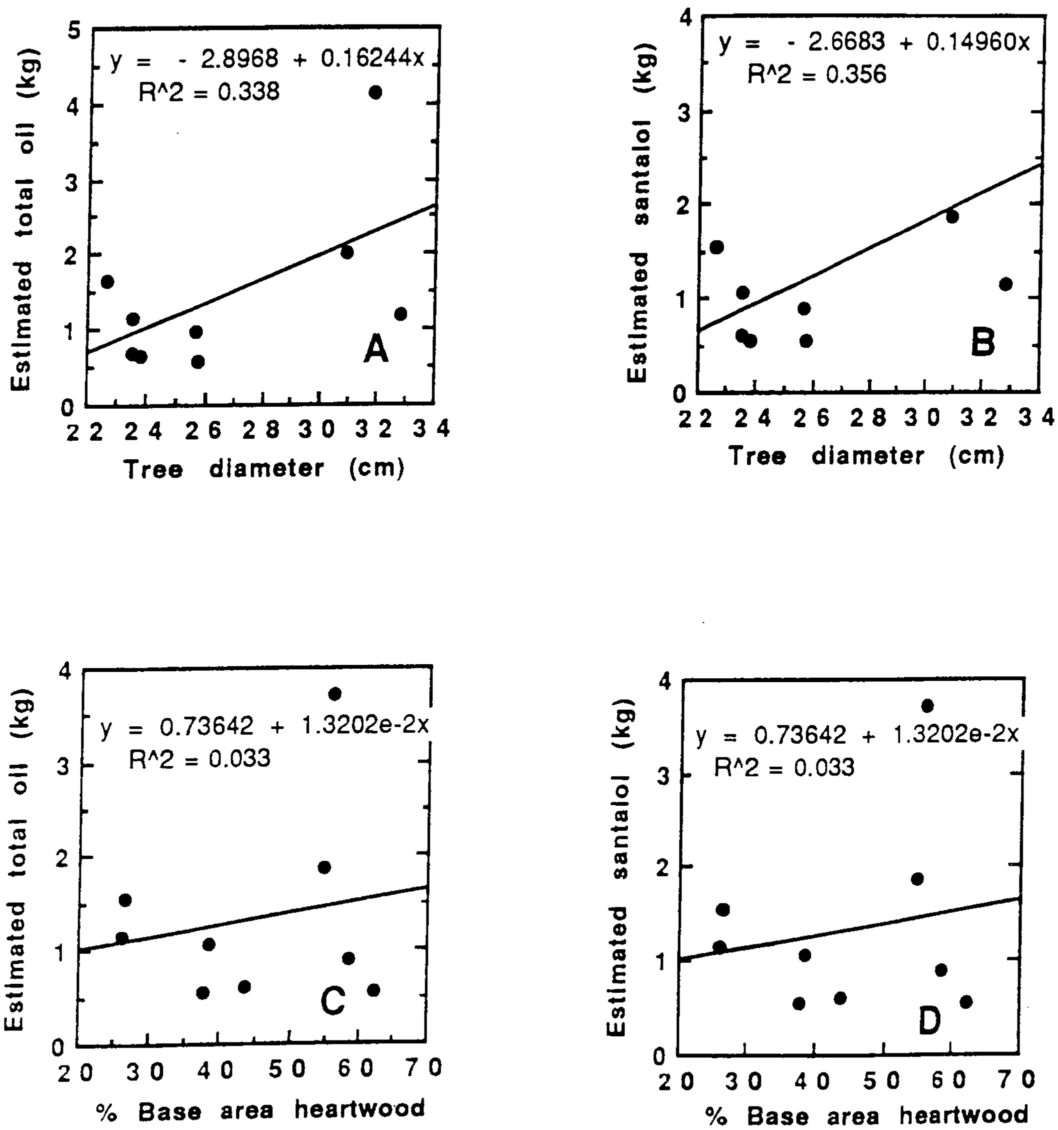

Figure 17. Estimated yields (kg) of oil from 10 tree samples analysed for percent oil at Bogor. Graphs A and C depict total oil yield and graphs B and D santalol yield.

TABLE 6 Estimated oil yields from 10 felled trees Nilulat/Haumeniana

Sample No.	D.B.H (cm)	Heartwood Vol.(m^3)	Heartwood Wt.(kg)*	% Oil	% Santalol	Kilogram yield Oil	Kilogram yield Santalol
1	23.87	.041	25	2.53	88.6	0.63	0.56
2	25.62	.100	78	1.24	91.3	0.97	0.88
3	22.60	.073	60	2.75	93.2	1.65	1.54
4	25.78	.068	48	1.23	93.3	0.59	0.55
5	30.88	.119	80	2.51	93.4	2.01	1.88
7	29.60	.075	55*	1.33	96.3	0.92	0.86
13	23.55	.046	32	2.08	91.2	0.67	0.61
15	31.83	.129	112	3.69	89.6	4.13	3.71
18	32.79	.114	99	1.20	93.1	1.19	1.16
19	23.55	.044	30	3.84	93.1	1.15	1.07

*Weight of heartwood estimated from regression (Figure 1F, project 1) and percentages of oil based on mean of 3 separate samples. Only butt pieces shown in table.

These 10 samples encompass the total range for all 19 pieces analysed and may be taken as representative of the current material. Specimens 19 and 15 may be considered of interest in terms of value yield. The results suggest no clear relationship between bole diameter and estimated oil yield. As noted above for specimen 7 there is variation within trees. The two trees with two samples each had % oil contents of 1.20 and 1.26, and 2.08 and 1.22 respectively.

The overall mean values are somewhat less than reported by Togo Silitonga (1988). He gave a range of 3.94 - 5.19% total oil of which 82.2 to 86.3 was santalol, for trunk and root sent from Kupang to Bogor, presumably from an earlier set.

A correlation matrix for the 10 tree sample is given in Table 7. The correlation for diameter breast height and estimated weight of both total oil and santalol just failed to reach significance at 5%. However oil was correlated with both height and total volume both of which can be estimated in the field. In addition santalol and total oil yields were highly correlated.

TABLE 7 Significant correlations for the 10 measured trees with butt samples analysed for oil

	Volume of heartwood	Weight of heartwood	Total Volume	Height	Length of bole
Estimated oil yield (kg)	*	*	*	*	NS
Estimated santalol (kg)	*	*	**	*	NS
DBH	***	***	**	*	NS
Weight of heartwood	***	-	***	*	NS
Total volume	***	***	-	**	NS
Tree height	*	+	**	-	*

Where *** p 0.001; ** p 0.01; * p 0.05; + almost 0.05; NS not significant.

An area of related work, which has influence on growth and yield, is the question of loss of weight in harvested material. Both laboratory analyses to estimate oil yields and raw material sales of harvested wood can be affected by moisture content. In 1989 Udi Tiyastoto undertook some studies on loss in weight of felled trees. Samples of 20 g were taken of both heartwood and sapwood from debarked material in the field a month after cutting. The mean loss in weight for 20 samples after 3 months was 20%. The following values were obtained:-

	Mean wt loss %	**SD**	**Minimum**	**Maximum**
sapwood	20.16	14.83	5.33	34.99
heartwood	19.74	6.54	13.20	26.28

Should this aspect warrant further investigation then larger wood samples would be required and determination of moisture content at cutting could be useful.

It is important that permanent yield plots are established in as many stands as possible, preferably where the age of origin is known. This will allow growth over time to be followed, taking into account presence of host trees. To some extent marked candidate plus trees (Project 1) can give useful information on growth. There are too few documented plantations to warrant any destructive testing for oil yields at present so that emphasis must continue on non-destructive sampling of young trees. For old growth material it is a distinct possibility that currently harvested material is now lower in oil content than in earlier times. The eventual introduction of superior seed from India may become necessary. Maximum stocking and minimum host density require elucidation for Timor conditions.

Management implications require to be considered in terms of long-term sustained yield. It may well be necessary to preserve from exploitation designated areas so that the gene pool is not further depleted.

References:

Adriyanti, T. (1989). Studi Dendrologis cendana (*Santalum album* L.) di Pulau Timor, Nusa Tenggara Timur. Student thesis, Fakultas Kehutanan, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Barrett, D.R. (1988). *Santalum album* (Indian sandalwood) literature review. Mulga Research Centre, Curtin University, Bentley, Western Australia, Australia.

Fox, J. E. D. (1988). Potential growth and stocking of *Santalum album* in Central Java. Report to ACIAR.

Fox, J.E.D. and Barrett, D.R. (1988). Sandalwood in the Kimberleys. Report to ACIAR.

Hamzah, Z. (1976). Silvical characteristics and silviculture of sandalwood (*Santalum album* L.) in the island of Timor. Forest Research Institute, Bogor. ***Report No. 227***, 62 + vi.

Hutchins, D.E. (1884). Letter regarding sandalwood flowering. ***Indian Forester*** **10**(5), 199-210.

Hutchins, D.E. (1884). Sandal. ***Indian Forester*** **10**(6), 247-261.

Jones (1982). Extract from Mission Report CIDA. (viewed at Secretariat, Kupang).

Jones (1983). Extract from Mission Report CIDA. (viewed at Secretariat, Kupang).

Kagy, V. (1988). "Memoire de fin d'etudes" Vers une exploitation raisonnee du bois de santal in Nouvelle Caldonie et dependances. Institute Superieur Technique d'Outre-Mer, C.H.C.I. Quai-George-V, 76600 Le Havre, France

Kramer, F. (1922). The habits of sandalwood (*Santalum album*) in Java. ***Tectona 15***, 731-762.

Mahmood, H. (1983). Report to the Government on Sandalwood prospects in Timor. (viewed at Secretariat, Kupang).

Nagaveni, H.C. and Srimathi, R.A. (1980). Studies on germination of the sandal seeds (*Santalum album* Linn). II Chemical stimulant for germination. ***Indian Forester*** **106**(11), 792-799.

Nagaveni, H.C. and Srimathi, R.A. (1981). Studies on germination of sandal (*Santalum album* Linn.). Pretreatment of sandal seeds. ***Indian Forester*** **107**(6), 348-354.

Nagaveni, H.C. and Srimathi, R.A. (1985). A note on haustoria-less sandal plants. ***Indian Forester*** **111**(3), 161-163.

Rai, S.N., (1986). Tree improvement work in sandal (*Santalum album* L.). ***Proceedings of the National Seminar on forest tree seed.*** Ed by S N Rai, Sandalwood Research Centre, Bangalore.

Rai, S.N. and Kulkarni, H.D. (1986). Sandalwood Plantations. pp 295-330. In Srivasta, H.D., Vatsya, B. and Menon, K.G. (Eds.) ***Plantation Crops. II.***

Rahm, T. (1925). Sandalwood on Timor. ***Tectona 18,*** 499-545.

Sinha, R.L. (1961). Sandal (*Santalum album*) in Bundelkhand forest division, Uttah Pradesh. **Indian Forester 87**(10), 590-597.

Srimathi, R.A. and Kulkarni, H.K.D. (1979). Preliminary findings on the heartwood formation in sandal *(Santalum album L.).* ***Report of the Sandal Research Centre, Bangalore, India.***

Surata, I.K., Fox, J.E.D, and Suriamidhardja, S. (1989). Soil texture for early seedling growth in *Santalum album* . ***Santalum 4,*** 1-13.

Silitonga, T. (1988). ***Jurnal Penelitian Hasil Hutan*** *5*(2), 80-84.

Venkatesan, K.R. (1979). Provisional research findings and notes - no 2. Sandal Research Centre, Bangaore India.

Tiyastoto, U. (1989). ***Laporan teknis litbang Kehutanan. 2***, 41 - 42.

APPENDIX 2

REPORT ON
CRAWFORD FELLOWSHIP PROGRAM

Report on Crawford Fellowship Program.

Fellows - Suriamihardja Sutarjo
Sarono Setyo
Biodata summarized in Attachment 1

Purpose of Visit of Indonesian Fellows

The Fellows requested the program be structured to study forest research management with an emphasis on the following aspects -

1. The principles of planning, organization, staffing, direction and control.
2. Identification of consumers' or governments' needs for knowledge and technology
3. The roles of Universities and Government R and D institutions
4. Introduction of research results/findings to the consumer or government
5. The role of international networks or corporations.

These aims generally matched those anticipated in our planning for the visit.

Program

Arrival 12 May 1990 - .
generally at Department of Forestry ANU with the following visits

ACT Forests 16 May	1 day
Tree Genes International (Pinebank) 17 May	1/2 day
CSIRO - DFFP-ACIAR-Seed Centre 23,24-May, 13 June	2 days
Qld. Forest Service (Gympie) 28 May - 1 June	3 days (exclusive of travel)
APM Forests (Amcor)-Traralgon 3 June	1 day (exclusive of travel)

Discussion was also arranged with:

Mr Yam Malla - Nepal-Australia Forestry Project
Ms Teresa Alves - Research Programs in Mozambique

Departure 15 June

Progress

Following a series of lectures, tutorials and discussions outlines were developed for three major reports -

(i) The principles of research planning

(ii) The identification of research needs and the application of results

(iii) The role of Government R&D institutions, Universities, International networks and Corporations

The outlines are attached as Attachment 2

The fellows worked diligently and made full use of the libraries at ANU and at CSIRO.

Originally it had been hoped (at the request of the Fellows) the three reports would be produced in English with copies in Indonesian. This proved too difficult in the time available. Production of reports in a foreign language is necessarily very slow although the first was produced in English it really needed substantial editing to be sensibly presented. The reports will, therefore, be finalized in Indonesia.

This was a better arrangement anyway as it must be doubtful if it is really necessary to spend much of the time here actually producing the report.

The program would not have been possible without the enthusiastic support of the organizations involved and the administrative work of ANUTECH. Sincere thanks are due to all concerned.

M.U.Slee

17 June 1990

Attachment 1

Biodata

Sutarjo Suriamihardja

Education - Faculty of Forestry, Bogor Agricultural University 1977

Position (since 1985) project leader Nusa Teuggara Forestry Research Project. In 1990 this will become the Forestry Research and Development Centre working for the "Forestry in small islands ecosystem with long drought conditions" (provinces of West Nusa Teuggara, East and East Timor and the district of South East Malaku)

Current research programmes in the project include

Sandalwood silviculture

Agroforestry of long drought uplands

Behaviour and population dynamics of deer, komedo and various birds.

The project is also the field executor of the collaborative research program established in 1987 by ACIAR and AFRO (The agency for Forestry R& D, Ministry of Forestry) entitled "Sandal wood and Fuel wood Silviculture in East Indonesia.

The project currently employs 10 university graduate research workers, 10 admin staff and field technicians

Setyo Sarono

Education - Faculty of Forestry, Gadjah Mada University, Jogjakarta 1976

Positions

1985-89 Head of division "Utilization in Regional Forestry Service at Benkulu Province"

1990 - present Head of Division, Forest Products Research and Development, Forest Product Research and Development Centre Bogor

Responsibilities - Administration

Formulation of research plans/programs covering Forest utilization, biodeterioration, biomass, pulping, sawmill, pulpwood

Dissemination of research results to the user

Attachment 2 - Outlines of reports

PRINCIPLES OF RESEARCH PLANNING

1. NEEDS

1.1. IDENTIFICATION OF THE NEEDS
(For full discussion see next report)

1.2. IMPORTANCE OF EXPLORATORY STUDIES TO DEVELOP -
1.2.1. TIME FRAMES
1.2.2. VALUE AND RETURN
1.2.3. RESOURCES REQUIRED
1.2.4. EXAMPLE OF QLD EXOTIC PINE DEVELOPMENT

1.3. ESTABLISHMENT OF PRIORITIES WHERE SEVERAL NEEDS ARE IDENTIFIED/COMPETING

2. AVAILABILITY OF RESOURCES

2.1. STAFF
2.1.1. PROFESSIONAL
2.1.2. TECHNICAL
2.1.3. WORKMEN

2.2. OTHER SUPPORT
2.2.1. GOVERNMENT AGENCIIES (E.G. CSIRO)
2.2.2. UNIVERSITIES
INDUSTRY
2.2.3. INTERNATIONAL SUPPORT
2.2.4. RESEARCH GRANTS

2.3. ROLE OF TAXATION?

3. ORGANIZATION AND USE OF RESOURCES

3.1. PRIORITIES

3.2. ALLOCATION OF RESOURCES UNDER DIRECT CONTROL
3.2.1. OWN RESEARCH STAFF

3.2.2. CONSULTANTS

3.3. USE OF RESOURCES UNDER INDIRECT CONTROL

3.3.1. CSIRO

3.3.2. UNIVERSITY PROJECTS

4. METHODS OF CONTROL

4.1. DIRECT CONTROL

4.1.1. ALLOCATION OF RESPONSIBILITIES

4.1.1.1. RELATIONSHIP WITH DISTANCE CENTRES

4.2. INDIRECT CONTROL

4.2.1. RELATIONSHIP WITH OTHER ORGANIZATIONS

4.2.1.1. WORK PLANNED AND ITS PROGRESS

4.2.1.2. REPORTING RESPONSIBILITIES

4.2.1.3. RIGHTS TO THE RESULTS

5. DISSEMINATION OF RESULTS

(See next report)

THE IDENTIFICATION OF RESEARCH NEEDS AND THE APPLICATION OF RESULTS

1. IDENTIFICATION OF NEEDS

- 1.1. DIRECTIVES FROM SUPERIOR OFFICERS
  - 1.1.1. INSTRUCTIONS
- 1.2. IDEAS OF RESEARCH WORKERS
- 1.3. REQUESTS AND SUBMISSIONS FROM OTHER STAFF
  - 1.3.1. WITHIN ORGANIZATION
    - 1.3.1.1. TRAVEL AND FIELD DISCUSSION
    - 1.3.1.2. IMPORTANCE OF RESEARCH ROUTINE CONFERENCES AND OTHER COLLABORATION
  - 1.3.2. IN OTHER ORGANIZATIONS
    - 1.3.2.1. IMPORTANCE OF RESEARCH COLLABORATION (e.g. DORC)
      - 1.3.2.1.1. WORKING GROUPS
      - 1.3.2.1.2. INTERNATIONAL CONFERENCES
  - 1.3.3. EXTENSION OFFICERS
  - 1.3.4. EXTENSION PROGRAMS
  - 1.3.5. PUBLISHING AND COMMUNICATION
    - 1.3.5.1. TYPES OF JOURNAL
      - 1.3.5.1.1. ACADEMIC SCIENTIFIC
      - 1.3.5.1.2. POPULAR SCIENTIFIC
      - 1.3.5.1.3. POPULAR

2. APPLICATION OF RESULTS

- 2.1. CONTENT OF RECOMMENDATIONS PRODUCED BY RESEARCH
  - 2.1.1. DEFINITION OF VALUE OF RESULTS
    - 2.1.1.1. RETURNS
    - 2.1.1.2. COSTS
  - 2.1.2. DEFINITION OF RESOURCES NEEDED TO APPLY RESULTS
    - 2.1.2.1. STAFF NEEDED
      - 2.1.2.1.1. NUMBER
      - 2.1.2.1.2. SKILL LEVELS
  - 2.1.3. OULTINE OF METHODS OF APPLICATION IN LARGE SCALE OPERATIONS
  - 2.1.4. LIMITATIONS

2.1.4.1. e.g. PARTICULAR SITES

2.2. METHOD OF ADMINISTERING THE IMPLEMENTATION OF RESEARCH RESULTS

2.2.1. DIRECTIVES

2.2.1.1. PRESCRIPTIONS

2.2.1.1.1. CONDITIONS WHEN APPLICABLE

2.2.1.1.2. SCATTERED FOREST CENTRES

2.2.1.1.3. SIMILAR (UNIFORM) CONDITIONS

2.2.1.1.4. LIMITED LOCAL EXPERTISE

2.2.2. OTHER PROCEDURES

2.2.3. EXTENSION

2.3. DISSEMINATION OF INFORMATION

2.3.1. INTERNAL

2.3.1.1. RESEARCH-ROUTINE CONFERENCES

2.3.1.2. PUBLICATIONS

2.3.1.2.1. RESEARCH REPORTS

2.3.2. EXTERNAL

2.3.2.1. CONFERENCES

2.3.2.2. PUBLICATIONS

2.3.2.2.1. NEWS MEDIA

2.3.2.2.2. POPULAR JOURNALS

2.3.2.2.3. POPULAR SCIENTIFIC JOURNALS

2.3.2.2.4. ACADEMIC SCIENTIFIC JOURNALS

The roles of Government R&D Institutions, Universities and International networks and corporations

1. Demonstration of the need for research programs in development programs/schemes

(Examination of most major projects reveals extent of ignorance, need for knowledge and dangers of proceeding without supporting research)

2. Definition of problems and methods of approach

2.1. Types of problems

2.1.1. Practical field operations

2.1.1.1. Examples

2.1.1.2. Responsibility for attention

2.1.1.2.1. Local field staff

2.1.1.2.2. Local research staff

2.1.1.2.3. Supporting organizations (e.g. CSIRO) ???

2.1.2. Development of field operations

2.1.2.1. Examples

2.1.2.2. Responsibility for attention

2.1.2.2.1. Local research staff/Local field staff

2.1.2.2.3. Supporting organizations (e.g. CSIRO) ???

2.1.3. Assessment of alternatives to present operations

2.1.3.1. Examples

2.1.3.2. Responsibility for attention

2.1.3.2.2. Local research staff

2.1.3.2.1. Supporting organizations (e.g. CSIRO)

2.1.4. Improvement of efficiency of operations

2.1.4.1. Examples

2.1.4.2. Responsibility for attention

2.1.4.2.2. Local research staff

2.1.4.2.1. Supporting organizations (e.g. CSIRO)

2.1.5. Supporting operations (e.g tree breeding)

2.1.5.1. Examples

2.1.5.2. Responsibility for attention

2.1.5.2.2. Local research staff

2.1.5.2.1. Supporting organizations (e.g. CSIRO)

2.1.6. Explanation of scientific principles

2.1.6.1. Examples

2.1.6.2. Responsibility for attention

2.1.6.2.1. Supporting organizations (e.g. CSIRO)

2.1.6.2.2. Universities

2.1.5.2.2. Local research staff ?

2.1.6.2.3. Other

3. Role of international organizations in research

3.1. Organization of information exchange

3.1.1. Working groups

3.1.2. Publications

3.1.3. Other

3.2. Support for projects

3.2.1. General lack of this support at research level

3.2.1.1. Reasons

3.2.1.1.1. Cost and difficulty of quantification of returns

3.2.1.1.2. Need for intercountry agreement

3.2.2. Use of experts

3.2.3. Problems

3.3. Development of training

3.3.1. Short courses

3.3.2. University and other training courses

3.4. Organization of multi-party research

e.g. co-operative trials