AUSTRALIAN CENTRE FOR INTERNATIONAL AGRICULTURAL RESEARCH

Final Report - ACIAR Project 9043

MULTIPURPOSE TREE AND SANDALWOOD SILVICULTURE IN EASTERN INDONESIA

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT,
WESTERN AUSTRALIA

940238

Contents

Front Cover: Young S. album plantation at Kununurra being inspected by collaborating scientists from BPK, Kupang.

Executive Summary

INTRODUCTION

Project:	Multipurpose Tree 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:** Ir Sutarjo Suriamihardja, Balai Penelitian Kehutanan (BPK), Kupang, West Timor.
Date of Commencement:	1 July 1991
Date of Completion:	30 June 1995

While this project proceeded in the normal fashion in most respects, it suffered a severe handicap in that it did not have a formal Project Arrangement with the Government of Indonesia. Despite several trips to Jakarta by the Australian Project leader and ACIAR staff, it was not possible to reach final agreement on the final wording of a PA. This had the operational outcome that at no stage did the project have a budget from GOI, and ACIAR carried most project costs as a result. Lack of a counterpart budget, and delays caused by uncertainty over the formal project arrangement documents also meant that some of the operational objectives had to be reduced.

Project 9043 was intended to be a follow on to ACIAR Project 8613. Essentially, it was intended to continue the species screening work at a low level, refine the provenance selection and silviculture of candidate multipurpose tree species for small farmers and commence multipurpose species screening on the much harsher climate and soil conditions of Eastern Sumba Island. It was also intended to speed up the research on sandalwood plantation establishment and management by continuing the work initiated by Dr Fox at Curtin University and by the appointment of a full time sandalwood research officer at Kununurra, the cost of whom was shared equally between this ACIAR project and CALM.

DESCRIPTION OF WORK

The objectives of the Project, as defined in the project Document, were:

1. Assist BPK to define a group of multipurpose trees (MPTS) for fodder, fuel and small poles adapted to the soil types and climate of West Timor and Sumba Island.
2. Commence a research program into cultural methods for selected MPTS to produce the outputs required by small farmers in NTT.
3. Develop a reliable establishment technique for sandalwood plantations in NTT and the Kimberley region of WA.
4. Continue sandalwood silvicultural research, including the selection of plus trees in West Timor.
5. Support the conservation of germplasm of other commercial sandalwood species outside Australia in secure reserves or seed production areas.

RESULTS

Acacia/Rhizobia species/inoculation trial West Timor

This trial, undertaken in cooperation with CSIRO Tree Seed Centre and Dr P. Dart of the University of Queensland, demonstrated that marked improvements in tree growth could be obtained for several species of *Acacia* introduced to West Timor when the seedlings were inoculated with Rhizobia specially selected from Australia. Some other species in the trial did not respond to inoculation, indicating that suitable varieties of *Rhizobium* adapted to those species already exist in Timor.

The growth responses were confined to the *A. colei-holosericea-neurocarpa* species complex. Other species that did not benefit from the inoculation in this trial were *A. auriculiformis*, *A. crassicarpa*, *A. salicina*, *A. ampliceps*, *A. leptocarpa*, *A. difficilis* and *A. longispicata*. The growth responses were also observed only on the 1993 field trial established on a pellusturt soil type in the lowlands of West Timor. A replicate was established in 1994 on a rhodostalf soil type in the cooler, wetter highlands did not demonstrate any growth responses to inoculation, but it is not known whether this was a real effect or reflected a failure in nursery hygiene.

MPTS silvicultural trials West Timor

(i) Direct seeding trial

Previous work in ACIAR Project 8613 had resulted in the selection of a group of tree species that would be useful for small farmers in NTT for a number of purposes: fuelwood, fodder, small timber and land rehabilitation. This trial was intended to demonstrate a cheap method of gaining adoption in practice as most small farmers in NTT cannot afford the relatively expensive nursery-raised seedlings. We investigated the influence of time of sowing, level of soil cultivation and degree of weed control in two tree species, the commonly used *Sesbania grandiflora* and in *Acacia oraria*.

The trial demonstrated that direct sowing is a viable and practical method of establishing *Sesbania* and *Acacia* in West Timor. Although the data were deficient in some respects, they indicate that later sowing tends to give better survival, but early sowing provides better growth at least up to the age of 9 months. Survival was definitely improved by site preparation with a hoe or crowbar, with the latter giving consistently better survival, but growth was not improved. Post emergent weeding was not shown to provide a consistent benefit to survival or growth.

(ii) Fertiliser trial

This field trial was established in 1994, partly to give BPK staff experience in working with fertiliser trials and partly to determine which major nutrient (if any) was limiting growth of two *Acacia* species on lowland soils derived from Bobonaro clay. This soil type is very extensive in Timor but is the least productive and is often severely eroded. Rehabilitation of these degraded lands essentially depends on effective reforestation and a useful growth response from this trial would indicate whether fertilisation was likely to be worthwhile for ongoing regreening efforts by Dinas Kehutanan.

The trial did indicate that worthwhile initial growth responses could be obtained from added nitrogen, but not from phosphorus or potassium. Since the project terminated in 1995, it was not possible to draw firm conclusions about the longevity and practical significance of the growth response.

MPTS species screening trials East Sumba/West Timor

The MPTS screening trials carried out in the previous ACIAR Project 8613 were extended to eastern Sumba Island, which is the drier and most degraded part of the island. Although handicapped by difficulties with the nursery facilities, species screening trials were established in 1992, 93 and 94. The 1993 trial in Sumba was largely replicated at Oetium in West Timor, some differences being due to seedling failures in Sumba.

The three years of trials have enabled the Project to define a group of species that would be effective in addressing two critical resource shortages for villagers and small farmers in eastern Sumba; fuelwood and fodder. It was particularly satisfying to see that the results of these field trials were being taken up by NGO groups working to improve farmer practices in Sumba. Details of the recommendations developed from this work are found in the body of this report.

Sandalwood plantation research Kununurra

This phase of the Project was particularly effective. We now have a reliable sandal plantation technique that is being used operationally in an operational scale plantation establishment program on the Ord River Irrigation Area (ORIA). We also have a sound set of medium and long term field trials established aimed at defining mid rotation sandal plantation management procedures. Firm links have been established with other sandal research workers through the publication, under the auspices of this Project, of a Sandalwood Research Newsletter.

Curtin University/BPK joint research

The work undertaken in this component of the Project is detailed in the attached report from Curtin University. In brief, this part of the Project has provided valuable support for the conservation of high quality sandal germplasm from West Timor (a matter of increasing concern to MOF officials) and has also greatly improved our understanding of genetic variation in sandalwood from Timor.

Other activities

In addition to the objectives set out above, the Project continued to carry out activities aimed at improving the research capacity of the BPK, such as purchasing some equipment. In one activity, the Crawford Fund supported bringing a specialist CALM officer to Kupang to carry out intensive training in the use of the statistical package Minitab. In others, staff of the BPK were brought to Kununurra to inspect CALM sandalwood research trials, and other BPK staff were supported by project funds to attend an international workshop on sandalwood silviculture arranged by FAO/CIRAD-FORÊT in New Caledonia.

The Project Leader also visited Flores Island to investigate the possibility of extending the MPTS screening trials to that island. While there was strong interest and support from local Dinas staff, this line of work was not continued for two reasons:

- the earthquake in Flores caused heavy damage in Dinas facilities and the requirements for reconstruction work removed any local resources from availability for this work;
- the BPK was unable to provide any significant research staff or budget support.

Discussion of results in relation to the Project objectives

The first objective of the Project was to assist BPK to define a group of multipurpose trees (MPTS) for fodder, fuel and small poles adapted to the soil types and climate of West Timor and Sumba Island. This was certainly achieved for East Sumba. For West Timor limited additional work in this area was undertaken which supplemented previous species screening research from ACIAR 8613. The lack of resources at BPK and the failure of GOI to provide Project funding were constraints on this avenue of research.

The second objective was to commence a research program into cultural methods for selected MPTS to produce the outputs required by small farmers in NTT. A start was made on this by the establishment of the direct sowing trial at Oetium. The Rhizobial inoculation research trials were also seen as contributing useful knowledge to this objective. In fact, if the planting of any of the*Acacia colei-holosericea-neurocarpa* complex were to take place operationally in, for example, rehabilitation of degraded land or landslip sites, inoculation with the special Rhizobia would be important. It had been intended to carry out thinning of some areas of*Acacia colei* established in 1990 at Oetium to provide data on yields of corn under alley cropping, but lack of staff resources at the BPK prevented this from being done (refer to Final Report ACIAR Project 8613). On the whole this objective could be classed as achieved, but more could have been done but for the funding and staff constraints.

The third objective of developing a reliable establishment technique for sandalwood plantations in NTT and the Kimberley region of WA was achieved during the course of this Project. Survival percentages in NTT were often adversely affected by post planting damage from cattle or fire, but at Kununurra survival figures of 90 per cent were being achieved in the last two years of the project. This is a most satisfactory outcome.

The fourth objective was to continue sandalwood silvicultural research, including the selection of plus trees in West Timor. The silvicultural research was continued at Kununurra where several valuable field trials were established. The work in Timor by Curtin University supported the continuation of sandal plus tree selection and also extended our knowledge of sandal genetic diversity. This objective was achieved satisfactorily.

The last objective of the project was to support the conservation of germplasm of other commercial sandalwood species outside Australia in secure reserves or seed production areas. Some of the work supported by Dr Fox in West Timor certainly went some distance toward this objective. Over 100 plus trees were identified by BPK in the Soe-Kapan-Niki-Niki area of central West Timor. In the last two years of the project, two series of sandal progeny trials were planted in NTT by BPK, with the dual aims of examining heritability of sandalwood heartwood development and vigour, and of providing a future source of high quality seed.

The support provided by the Project for the New Caledonia sandalwood workshop also contributed in a real way to this objective. However, it had been hoped that it would have been possible to play a more direct role in assisting the conservation of sandal germplasm in other countries, especially PNG, where there is concern about the long term survival of *S. macgregorii*. In the event, lack of funds prevented any activities in this area. This objective was therefore only partly achieved.

S. album plus tree near Siso, West Timor

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NOTE: This list of publications does not include the notes presented by people associated with the Project at the 1995 New Caledonia sandalwood workshop, nor all the material contributed by others to the Sandalwood Research Newsletter.

FOLLOW-UP

During the course of the Project the CALM team made conscious efforts to ensure the results of the research would be used in NTT after its termination. On Sumba we made good contacts with the World Food Project-funded agroforestry program being run by Australian volunteer Mick Jeffrey, and with an American-operated NGO group working on the south coast of Sumba. Both were keen to use the results of our screening trials in Sumba in their work.

In West Timor we similarly cultivated contacts with a church-sponsored NGO group, Yayasan Alpha Omega, and with Tony Djogo at the Polyteknik Pertanian, a group who operate within Nusa Cendana University in Kupang. We did, in fact, plan to do some work in cooperation with Djogo in Flores, but this was prevented by the earthquake, as explained elsewhere.

We do have concerns that the BPK will be unable to maintain many of the field trials established by the project. Some of them have served their purpose and can be abandoned, but some are valuable in the longer term (eg, the Acacia provenance trials) and should be protected. In view of the financial difficulties faced by BPK in the last year of the Project it seems likely that some useful plots will be lost.

It has been most heartening to see the increasing confidence and quality of the work being performed at the BPK over the years we have been associated with them. While we certainly do not claim this is all due to the ACIAR Project, we have given them some valuable runs on the board in the form of a large number of successful field trials that have improved the standing of the BPK with the Dinas and with Perum Perhutani. The sandalwood propagation work in Timor, in particular, has been considerably improved by our research cooperation.

A concerted effort was made during this second ACIAR project in NTT to publish material arising from the research, or associated with it in some way, in local journals. Dr Fox and his associates at Curtin University were particularly active in this way.

At Kununurra, considerable effort was directed to informing farmers, agricultural advisers and regional planners about the progress of the sandal research on the ORIA. There is increasing interest in commercial tree plantations on the Ord as one possible approach to the control of rising groundwater tables.

ACIAR Project 9043 Final Report

INTRODUCTION

As mentioned above, this Project suffered from the lack of a formal Project Arrangement which would have given it assured funding from Jakarta for the work ascribed in the project design to the counterpart staff at the BPK in Kupang. The continuing uncertainty over the PA in 1990-92 meant that one whole planting season was virtually lost and the silvicultural research program was severely curtailed. As no funds were provided from GOI for maintenance of the field trials established during ACIAR 8613, this Project was obliged to make funds available for routine fire protection and weed control.

There were also staffing difficulties in Kupang. During the previous Project 8613, we were fortunate to have a very capable local research officer, Harisetijono, assigned to the Project. Hari was awarded an ACIAR Fellowship and left Kupang early in 1992 for postgraduate study at the University of Western Australia. The process of implementing the ACIAR Fellowship was a very time-consuming one for the Project Leader.

Hari was not directly replaced in Kupang, and it fell to Hari's assistant Dedi Setiadi to carry the brunt of the work associated with the Project. His situation was made worse by rapidly increasing demands on the resources of the BPK made by Dinas and Kanwil staff. To his great credit, Dedi grew into the task and gave invaluable support to the Project. Additional valuable support was provided by Ir. Sutarjo Suriamihardja, Director of the BPK, who was always most forthcoming with assistance during the visits of CALM staff to Indonesia.

From 1990 onward the work program at the BPK increased considerably, with staff being given responsibility for urgent field research in East Timor, Sumba, Flores and Malaku. As a result, research officer and technician time was at a premium and it was difficult for the BPK to fulfil some obligations for plot maintenance and treatment following on from the previous Project 8613. While the work planned for this Project undoubtedly suffered from this pressure, it was at least an indication of the value placed on the work of the BPK by the Kanwil and Dinas Kehutanan.

On the CALM staffing side, Mr Richard Moore withdrew from involvement in the Project due to family commitments and he was placed by Mr Ray Fremlin, a very experienced research and plantation establishment officer. Mr Joe Havel continued to provide valued input to the Project for the first two years.

In 1992 a proposal was received from the CSIRO Tree Seed Centre to provide assistance for the establishment of a combined *Acacia* species and *Rhizobium* inoculation trial on alkaline soils in West Timor. This was intended to be a replicate of similar trials established elsewhere in SE Asia. This opportunity was taken up to incorporate into the ACIAR Project as it seemed that the lack of the correct *Rhizobium* might explain the unexpectedly poor performance of some species tested in Project 8613. Information on this aspect, and exposure to working with *Rhizobium* was thought to be particularly useful to staff at the BPK in their work elsewhere on rehabilitation of degraded sites in NTT. TSC provided funds for the field trial establishment.

In the event, this trial assumed a large role in the silvicultural research program as it was a larger commitment of time and effort than had been anticipated and it had to be established over two seasons. Three years of species screening trials were established on a very difficult site at Hambala, near Waingapu, Eastern Sumba. The remaining silvicultural research was confined to a direct seeding trial, a fertiliser trial and one years MPTS screening trial intended to replicate the trial established that year in Sumba, all located at the Oetium field trial site.

Following our experience with Project 8613, all field work in Timor for this Project was confined to two sites: Oetium, about 25 km from Kupang, just south of the town of Oesau, and at Buat, near Soe. This resulted in much more easily controlled plot maintenance and a considerable saving on costs. However, the expected plot protection benefits were not always realised and the 1994 Buat plot was destroyed by cattle in 1995.

OTHER ACTIVITIES

During the course of this project, it became clear that staff at the BPK were suffering from an inability to properly analyse data from their field trials. The previous ACIAR Project here had provided specialist training in Perth for Udi Tiyastoto in the statistical analysis package Minitab, and had also provided a copy of Minitab for the BPK. Udi was subsequently transferred to Java, so this skill was lost to the research station. After discussion with the OIC, Ir Sutarjo Suriamihardja, it was decided that the most efficient way to address this problem, and to avoid future dislocation due to staff transfers, was to bring a suitable trainer from Australia to conduct an intensive short course in Kupang for a number of the BPK staff.

An application was made to the Crawford Fund for support David Ward, a CALM specialist in the use of Minitab, to Kupang for a week. This application was successful and Ward spent a week in Kupang in March 1994. This innovation was highly successful, being well supported by between 8 and 12 BPK staff at a time. Much of the tuition was conducted in their own time, which attested to its popularity. The training was very practically oriented and used their own data in a workshop format. Ward was also able to spend some time with individual staff members coaching the over difficulties or providing biometrical advice on analysis of particular datasets. Following this visit to Kupang the Project provided the BPK with an upgraded version of Minitab.

The Project also provided assistance during a team visit to Kupang to a postgraduate student from Melbourne University, Miss Diane Haffner, who came to Kupang to obtain samples of Timor sandalwood for her Masters project. After considerable difficulty she was eventually able to obtain samples from 30 trees near Soe. These yielded interesting data on the apparent age of initiation of heartwood development. The average age of heartwood commencement in the sample trees was 23 years, considerably greater than expected from published Indian data.

We continued work on thinning the species screening trials established at Sikumana in the previous ACIAR Project. Our intention was to remove most trees on each plot (originally planted 5 trees by 5 trees at one metre spacing) to the best 2 or 3 trees and let these grow on to maturity as a demonstration of the potential of these species. We started the thinning in cooperation with BPK staff and left the completion of the task to them after our departure. Felled trees were measured at several points up the stem, then cut into standard fuelwood lengths and bundled ready for market. The fuelwood bundles and tree crowns were weighed on field scales as it was intended to carry out dry weight calculations using the oven supplied to the BPK in Project 8613. In the event this was not done as accommodation changes in the research office required that the lab be closed down to make way for more office space. Nevertheless, useful data on fuelwood yield from several species was obtained.

CALM biometrician David Ward carrying out Minitab training at BPK, Kupang

The Project Leader made two trips to Jakarta, in 1992 and 1993, in an effort to conclude negotiations over the MOU and Project Arrangement, there having been a change in Director-General of AFRD after the first year. While these discussions were conducted in an amiable atmosphere, there was no useful result. Nevertheless, a copy of each trip report to ACIAR was also sent to the Director-General AFRD to ensure that he was kept abreast of progress in the Project.

The Project supported the attendance of two BPK staff members Komang Surata and Edy Sutrisno, Dr Fox and Andrew Rado at a workshop on sandalwood plantation technology held in Noumea, New Caledonia, in August 1994. Dr Fox presented several notes on the work carried out at Curtin University and Rado gave a paper on research trends in sandalwood with an emphasis on germplasm conservation.

The Project also provided funds for the purchase of a motorcycle for the BPK in Kupang to assist in the inspection of the field trials to try to prevent further damage by farmers, or cattle or by fire. On Sumba, the project purchased a water pump to alleviate water supply problems at the Hambala nursery.

RESULTS

ACACIA SPECIES AND RHIZOBIUM INOCULATION TRIALS - WEST TIMOR

Introduction

This trial was intended to be established at two sites: on a lowland Bobonaro clay at Oetium (pellusturt soil) and at a highland Raised Coral Terrace site at Buat (rhodostalf soil), near the town of Soe, about 110 km from Kupang. The Oetium site was already well cleared, having been previously used for ladang several years before, and only carried poor quality grasses and a few lontar palms of various sizes and a few individuals of 'pohon kon' (*Ziziphus* sp). The Buat site carried a few large *E. alba* stems and very dense *E. alba* coppice regeneration up to two metres in height. The latter were the result of intensive fuelwood cutting in the vicinity of Soe township.

Site preparation at Oetium was quite simple, requiring the felling of a few old lontar palms and the poisoning (with dieseline) of some lontar regeneration. This was followed by a pre-planting broadcast application of glyphosate herbicide to control grass competition. At Buat the few old*E. alba* trees were left undisturbed and the plots located to avoid their influence. However, it was necessary to carry out a broadscale glyphosate spray application to control the eucalypt coppice.

The Acacia species used in the trial were:

A. neurocarpa
A. colei
A. ampliceps (3 seedlots)
A. leptocarpa
A. salicina
A. crassicarpa
A. holosericea
A. auriculiformis (2 seedlots)
A. longispicata (2 seedlots)
A. difficilis

One provenance of *A. longispicata* and one of *A. ampliceps* failed to produce sufficient plants in the nursery.

Seedlings were raised in the BPK nursery at Sikumana. Seed was sown at the usual time in late August, following conventional pretreatment with boiling water. The first inoculation with Rhizobia was carried out in November 1992. Inoculated and uninoculated seedlings were kept in separate parts of the nursery, clearly marked by plastic tape, with the inoculated group on the down hill side of the uninoculated controls. In this way it was hoped to avoid any accidental transfer of*Rhizobium* to the controls by overland flow during heavy rainfall.

The seedling stock produced by the Sikumana nursery were very good this year, although seedling numbers were down in some species, making it doubtful at the start that we would be able to plant both trials in the manner planned. Moreover, the plants had not been hardened off by removing the shadehouse cover, as instructed, so they were very soft and vulnerable to excessive planting shock. It was immediately apparent that there had been a positive response to the inoculation in some species, even at the nursery stage.

Planting commenced at Oetium at the wet had commenced and rain was received at the time the CALM team arrived. However, the rainfall stopped suddenly and severe losses of newly planted seedlings forced us to review our plans. In the event we decided to use all available planting stock to replant at Oetium. This decision was taken because the rainfall situation was the same at Buat and the herbicide spraying there had also not been as successful as hoped. By directing all planting stock to Oetium we were able to ensure that one replicate of the field trial was successfully established.

The same procedures were used in the nursery for the following season, and the inoculated and control seedlings were raised in the same place as the previous season.

We returned to Buat the following year (January 1994), resprayed the field trial area and planted the second replicate. Again, the quality of the nursery stock from Sikumana was good, although we could see no obvious signs of a response to inoculation. This time planting conditions at Buat were excellent and the weed control was also very well carried out.

Results

At Oetium we observed a marked positive response to the Rhizobial inoculation in some species. This is illustrated in the accompanying photograph. There was also a considerable difference in the performance between the various species tested in this trial, as shown in the table below.

Oetium trial 22 months after planting (Dgl = diameter at ground level)

Seedlot	*Species*	*Ht +R*	*Ht -R*	*Dgl+R*	*Dgl-R*	*S+R*	*S-R*
14631	*A. ampliceps*	257	260	2.02	2.03	92	92
17409	*A. ampliceps*	269	250	2.36	2.16	82	94
17966	*A. auriculiformis*	177	201	1.50	1.60	83	95
18213	*A. auriculiformis*	205	202	1.61	1.66	94	88
14660	*A. colei*	305	202	2.04	1.52	99	76
13681	*A. crassicarpa*	145	169	1.12	1.22	53	72
16177	*A. difficilis*	149	131	0.91	0.85	33	40
16389	*A. holosericea*	405	284	2.74	1.85	94	61
15478	*A. leptocarpa*	207	166	1.09	0.95	81	78
17262	*A. longispicata*	196	236	1.18	1.25	51	30
18170	*A. neurocarpa*	340	197	2.34	1.37	91	59
18165	*A. salicina*	197	194	1.27	1.25	82	72
Standard Error of treatment means		*39*		*0.26*		*6*	

Generally, statistically significant differences between +R and -R treatments are found in the same species for height, Dgl and survival. The significant differences were confined to *A. colei, A. holosericea* and *A. neurocarpa*, all closely related species. In these species inoculation provided very worthwhile increases in height and diameter growth as well as survival. In all other species there was no consistent response.

Growth response to inoculation in A. neurocarpa, control plot in foreground

By contrast, there were no statistically significant differences between the +R and -R treatments at Buat, when the plots were measured 18 months after planting. The pooled measurement data are presented to illustrate the differences in growth between the two sites.

Seedlot	*Species*	*Height (cm)*	*Dgl (cm)*	*Survival %*
15734	*A. ampliceps*	62	0.88	1
17049	*A. ampliceps*	92	0.73	1
17966	*A. auriculiformis*	92	1.41	69
18213	*A. auriculiformis*	114	1.90	77
14660	*A. colei*	192	1.46	43
13681	*A. crassicarpa*	182	2.03	79
16177	*A. difficilis*	140	1.46	36
16389	*A. holosericea*	313	2.35	60
15478	*A. leptocarpa*	79	1.23	49
14587	*A. longispicata*	137	1.52	39
18170	*A. neurocarpa*	149	1.30	18
18165	*A. salicina*	56	0.59	22
Standard error of difference of means		*37*	*0.30*	*14*

The Buat trial was destroyed by livestock soon after this measurement had been completed. These two trials again demonstrated the paradox encountered before in the species screening trials part of the previous project: the growth of many species is considerably better in the lowlands, in spite of a shorter growing season and lower rainfall, than on the more fertile soils around Soe.

A paper has been drafted for submission to a journal on the results of this field trial.

A. colei with inoculation (background) and uninoculated (foreground) to the left of Dedi.

MPTS SILVICULTURAL TRIALS WEST TIMOR

Direct seeding trial

Introduction

Thinking ahead to the possible implementation of the results of the species screening trials by small farmers in NTT, we were concerned to find a way to cheapen the process of establishing trees. Raising seedlings in a nursery would put the cost of the plants beyond their reach, so we established a trial in 1991-92 to explore the potential of direct seeding. In doing this we were also influenced by the approach of the BPK which at that time was not in favour of direct seeding. The trial was located at Oetium, which is a site typical of many used by farmers for cyclic ladang.

Field Trial Design

Two species were used, *Sesbania grandiflora* (widely used by small farmers and known to be an easy species to establish from seed) and *A. oraria* (a local species in Timor, but not one generally planted by small farmers). Sowings were carried out in the first week of December 1991, and January, February and March 1992. We used line plots of 25 seeds sown 5 cm apart, with two replicates. Three site preparation treatments were applied ; cultivate planting site to a depth of 10 cm with a cangkul (hoe), cultivate to a depth of 20 cm with a linggis (a short crowbar), and control with no cultivation. We evaluated the effect of post sowing weed control by adding three pot sowing treatments; weeding to 20 cm around seedlings, weeding to 75 cm around seedlings and control, no weeding.

Results

We encountered difficulties with the analysis of the data as some plot measurement sheets were mislaid by BPK, consequently, the data presented here have not been subjected to proper statistical analysis. The data are derived from the total number of seedlings surviving at the time of measurement in September 1992, from the 50 seeds sown.

Survival - Sesbania grandiflora, survivors from 50 seeds sown

Month Sown	*Weed Control*	*Cangkul*	*Linggis*	*Control*
December	20 cm	14	16	1
	75 cm	4	5	0
	No weeding	12	6	0
January	20 cm	10	1	0
	75 cm	0	6	0
	No weeding	0	24	0
February	20 cm	15	21	6
	75 cm	27	33	4
	No weeding	19	7	1
March	20 cm	7	7	6
	75 cm	1	38	6
	No weeding	1	12	7

A field trial of this nature is obviously influenced by the rainfall pattern in any individual season. The tables indicate that the best survival for both species was obtained by sowing in February. However, January was a month of notably poor rainfall, as noted by the CALM team when they took part in the January sowing and the establishment of a species screening trial on Sumba in that month.

In terms of the site preparation treatments, it is quite clear that for both species, the control treatments gave very poor results in December, January and February, compared with both cultivation treatments. On the whole, cultivation with the linggis gave consistently better survival than with the cangkul. With respect to the post emergent weeding, inspection of the tables indicates a trend for no benefit for December and January, but a small benefit from weeding if the sowing takes place in February and March. There did not appear to be any consistent benefit from weeding 75 cm around the seedlings compared with only 20 cm.

Survival - Acacia oraria, survivors from 50 seeds sown

Month Sown	*Weed Control*	*Cangkul*	*Linggis*	*Control*
December	20 cm	8	4	1
	75 cm	7	17	0
	No weeding	23	7	0
January	20 cm	2	0	2
	75 cm	2	3	5
	No weeding	4	10	1
February	20 cm	10	17	8
	75 cm	29	42	24
	No weeding	7	13	3
March	20 cm	8	5	0
	75 cm	12	17	29
	No weeding	1	2	8

Turning now to the height growth achieved by each treatment, some more definite conclusions can be reached. If one aberrant value (based on a single plant) in the *Sesbania* control treatment is ignored, there is a clear trend for height growth to be best for the earlier sown seedlings in both species, as would be expected.

Height - Sesbania grandiflora (cm)

Month Sown	*Weed Control*	*Cangkul*	*Linggis*	*Control*
December	20 cm	34.3	66.3	14.5
	75 cm	58.6	27.1	-
	No weeding	24.6	49.6	-
January	20 cm	19.7	9.0	-
	75 cm	-	19.2	-
	No weeding	-	38.9	-
February	20 cm	29.6	32.0	30.6
	75 cm	17.4	17.5	37.0
	No weeding	20.0	6.8	89.0
March	20 cm	3.9	9.7	6.4
	75 cm	6.0	7.5	17.6
	No weeding	6.0	9.6	5.0

Height growth in *A. oraria* was always inferior to that shown be *S. grandiflora*, which perhaps explains the lack of interest by farmers in that species. There was again no consistent difference between the cangkul and linggis treatments, and in the February and March treatments, there was no improvement offered by either treatment over the controls. We could also not detect any influence of post emergent weeding on height growth.

Height - Acacia oraria (cm)

Month Sown	*Weed Control*	*Cangkul*	*Linggis*	*Control*
December	20 cm	7.2	11.4	7.0
	75 cm	9.7	12.3	-
	No weeding	6.9	11.0	-
January	20 cm	6.0	-	6.8
	75 cm	18.5	5.7	5.5
	No weeding	4.1	4.9	7.5
February	20 cm	5.8	3.5	5.5
	75 cm	4.7	5.2	4.5
	No weeding	4.7	3.6	5.5
March	20 cm	3.2	5.0	-
	75 cm	4.2	3.1	3.7
	No weeding	3.5	4.2	2.6

Conclusions

The small numbers of seedlings surviving, in addition to the missing data, mean that we cannot draw any firm conclusions from this trial as to optimum sowing technique. However, the trial still had value in demonstrating that direct sowing was a quite successful establishment technique, provided seed supply is not limiting.

Fertiliser Trial - Oetium

Introduction

From a perusal of published information about soils in NTT, it was apparent that many soils in the province are deficient in P and N, and there is some evidence that minor element deficiencies may also occur. This trial was intended to show whether there is a response to any of the major nutrients on soils derived from Bobonaro clay. This soil type is very widespread in Timor and is often severely eroded. Its rehabilitation to a productive land use is one of the challenges faced by MOF in this province.

A good response to applied fertiliser may well explain some of the poorer than expected growth of some tree species in NTT and thus provide useful information for later follow up by staff of the BPK to improve plantation productivity. The species selected for the trial were two Acacias which have potential for fuelwood and timber production in NTT on soils of this type (pellusturt).

As the 1993 *Rhizobium* inoculation field trial had conclusively demonstrated that improved early growth can be obtained with inoculation of seedlings in the nursery with special*Rhizobium* brought from the University of Queensland, it was necessary to remove that source of variation in tree response by inoculating all plants used in the trial.

The objective of the field trial was to explore the nutrition requirements of two exotic species in NTT, as a guide to further research to improve yields in intensively managed plantations. A secondary objective is to give BPK staff experience in a nutrition field trial, so that they could continue this line of research when the ACIAR project terminated.

Field Trial Design

The experimental design was a simple omission trial: control, no fertiliser, NP, NK, PK, and NPK. The seedlings were planted and the fertiliser was applied in January 1994 at the following rate per plant for each of the macronutrients used:

N applied as urea, 32g/tree, i.e. 15g/tree elemental N
P as triple superphosphate 50g/tree 10g/tree elemental P
K as potassium chloride 24g/tree 10g/tree elemental K

It is realised these rates do not ensure equal levels of each applied nutrient, nor do they conform to any nominated balance between the elements. As there is an almost total absence of information about fertiliser responses on the alkaline clayey soils found in NTT, there is no guidance to assist in designing a trial. These rates are based on Western Australian experience, in the absence of better local knowledge.

Furthermore, these three fertilisers are all that were currently available in Kupang. At this stage it was not considered justifiable to go to a lot of trouble to specially import more exotic fertiliser formulations, especially minor element mixtures. That would be a later phase of this type of research if it appeared desirable for the BPK to explore that aspect. Although the N rate, in particular, may appear high, the heavy clay soil was expected to provide sufficient buffering to prevent plant damage. The fertilisers were applied in January 1994, in a hole 15 cm from each seedling on the downhill side.

The individual plots were of 25 trees, planted 5 trees by 5 trees at 1 m by 1 m spacing. As this was intended to be a short term trial, lasting three years at the most, there seemed little need for extensive buffers between treatments. All trees in each plot were therefore measured. There were four replicates of each treatment in a randomised block design. All plots received the standard preplanting overall spray with glyphosate which gave effective control of competing grass for 2-3 months. Weeds were controlled again by hand cutting in March 1994.

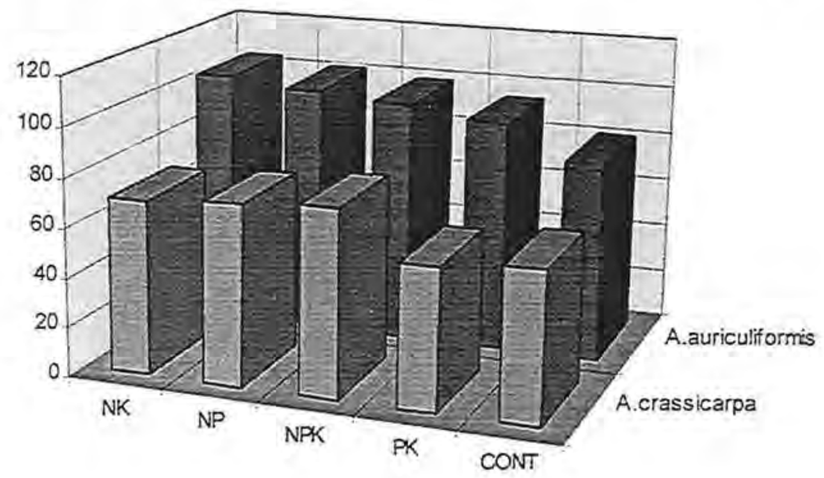
Two species were used, *A. crassicarpa* and *A. auriculiformis*. The latter was known from previous experience to tolerate these cracking clay soils and to produce reasonable growth on them, while *A. crassicarpa* had been unthrifty in previous field trials on this soil type. If fertiliser could raise the productivity of this species on these sites this would be useful information for the BPK.

Results

Measurements were carried out in June and October 1994. Only the October data have been analysed and presented here.

As expected, early growth of*A. auriculiformis* was markedly better than that of*A. crassicarpa*. At the time of measurement, mean height of the former species was about 20 cm greater than for *A. crassicarpa*. None of the fertiliser combinations tried here raised the productivity of the latter species to that of *A. auriculiformis*. However, both species did respond positively to the added fertiliser. There was a clear indication from the growth responses in both species that the main factor improving growth was the addition of nitrogen. In *A. auriculiformis*, there was some evidence of a response to P as well as N.

Figure 1: Mean Height (cm) 1994 Fertiliser Trial Oetium, NTT



In *A. crassicarpa*, the N fertiliser combinations produced about a 10 cm improvement in height, while in *A. auriculiformis* the growth response to added N was 20 cm. This would imply that the *Rhizobium* varieties used here are still not providing adequate N to the plants.

Conclusions

Although the Project terminated at this point and it was not possible to follow the progress of the trial until about age 3, when it might produce more clear cut results, the exercise is considered worthwhile as it did give BPK staff experience in establishing a fertiliser trial, something they had not done before, and the trial did demonstrate that useful growth responses could be gained on these soils at Oetium.

MPTS SPECIES SCREENING TRIALS EAST SUMBA AND WEST TIMOR

Oetium, West Timor

Introduction

The 1993 species screening trial Oetium was intended to be a replicate of that established in the same year at Hambala, but was not actually identical due to nursery problems in Sumba. All species tested were Acacias and two provenances were used for most species. The species list for Oetium was:

A. colei 13775 Tanami Bore NT
A. mangium 16584 Bensbach PNG
A. holosericea 16143 Coen Qld
A. auriculiformis 16160 Alligator River NT
A. auriculiformis 16162 Reynolds River NT
A. ampliceps 15755 Broome WA
A. trachycarpa 17963 Port Hedland WA
A. cowleana 14613 Helen Springs NT
A. crassicarpa 15482 Archer River Qld
A. colei 16754 Portland River WA
A. bidwillii 14599 Richmond Qld
A. holosericea 15732 Edith River NT
A. auriculiformis 16106 Mibini PNG
A. auriculiformis 18017 Bensbach PNG
A. trachycarpa 16759 Carolina Creek WA
A. cowleana 17202 Huttons Bore WA
A. polystachya 17789 Bolt Head Qld
A. crassicarpa 13681 Mata PNG

In selecting these species, we gave some attention to the introduction of potentially useful new species for fodder or food (*A. cowleana*, *E. bidwillii*) and extending our information on the performance of different provenances of species already in NTT, such as *A. auriculiformis*, or which had been identified by previous work as having potential on some soils (*A. crassicarpa*, *A. trachycarpa*, *A. ampliceps*, *A. holosericea* and *A. colei*)

The field trial design was a randomised block with four replicates, and as it was a screening trial, the plots were of 25 trees, at 1m x 1m spacing. As this was a comparatively uniform site, there were consistent results across the four replicates.

Results

The survival and height growth data as at August 1993, were as shown below.

As can be seen from these data, on pellusturt soils in this area, the best species by far, in respect of height growth, were *A. bidwillii*, *A. auriculiformis*, *A. polystachya*, *A. ampliceps* and *A. trachycarpa*. The last two of these species are good fodder plants in Australia and could be used by small farmers in Timor on this soil type. During the fallow period after being used for gardens, it would be possible to establish very useful fodder crops on these soils while rapidly improving their fertility status during this time. *A. auriculiformis* and *A. polystachya* could produce a very useful crop of fuelwood or small poles and *A. bidwillii* has potential for use as human food as it produces very large seed.

The variation in plant survival generally reflected the height growth. If growth was vigorous then survival was usually also higher than 75 per cent. In most species where more than one seed provenance was tested there was little variation in survival or height growth between provenances, except for the two seedlots of *A. crassicarpa*. The difference in survival between the Queensland and PNG provenances of this species is in line with previous results with these species in NTT.

Species	*Serial No*	*Survival %*	*Mean Height cm*
A. colei	13775	62	13.0
A. colei	16754	55	13.0
A. mangium	16584	33	10.6
A. bidwillii	14599	79	24.4
A holosericea	16143	75	13.2
A. holosericea	15732	85	16.6
A. auriculiformis	16160	97	26.3
A. auriculiformis	16106	93	29.2
A. auriculiformis	16102	98	30.9
A. auriculiformis	18017	98	38.2
A. ampliceps	15755	61	40.5
A. trachycarpa	16759	69	30.0
A. trachycarpa	17963	61	27.6
A. cowleana	17202	20	11.9
A. cowleana	14613	20	9.2
A. polystachya	17789	75	32.4
A. crassicarpa	15482	16	5.2
A. crassicarpa	13681	32	7.0

Conclusions

The 1993 species screening trial at Oetium provided a useful extension to our knowledge of the performance of several species of *Acacia* on dry phase pellusturt soils. The poor performance of *A. crassicarpa* here, compared with its good performance on a similar soil near Soe in Project 8613, confirms that although it tolerates this soil, it requires much higher rainfall, or at least a water-gaining situation, for good growth. The poor performance of *A. cowleana* was disappointing as it was believed to have potential in NTT for fodder, small fuelwood and edible seed production. *A. ampliceps* again demonstrated its value on the drier soil types in NTT. It has real potential for wide use for cattle fodder. *A. polystachya* is a species that has not performed well before in NTT but did grow well here, and deserves wider trial for land rehabilitation and timber production uses.

Hambala, Sumba

Introduction

A fenced field trial area was set up on the main Waingapu-Lewa Road about 10 km from Waingapu, the main town of East Sumba. It was located within 200 metres of the BPK outstation and nursery at Hambala so that it could be easily protected from wildfires and from damage by villagers seeking fuelwood. This area around Waingapu has been rendered almost bare of any trees by continual fuelwood harvesting, and local people now have to walk several km to find suitable fuelwood. It is part of an extensive area in this province marked by depauperate vegetation and shallow soils, and having an annual rainfall of 500-600 mm. The soils are similar to those formed on Viqueque sites in West Timor, being moderately alkaline. Soil depth was very variable but often less than 30cm over fractured marl. In the past, the area probably carried an open savannah, but now is virtually barren, carrying only poor grasses and the occasional introduced *Acacia auriculiformis, Leucaena leucocephala* or natural cemara (*Casuarina junghuhniana*).

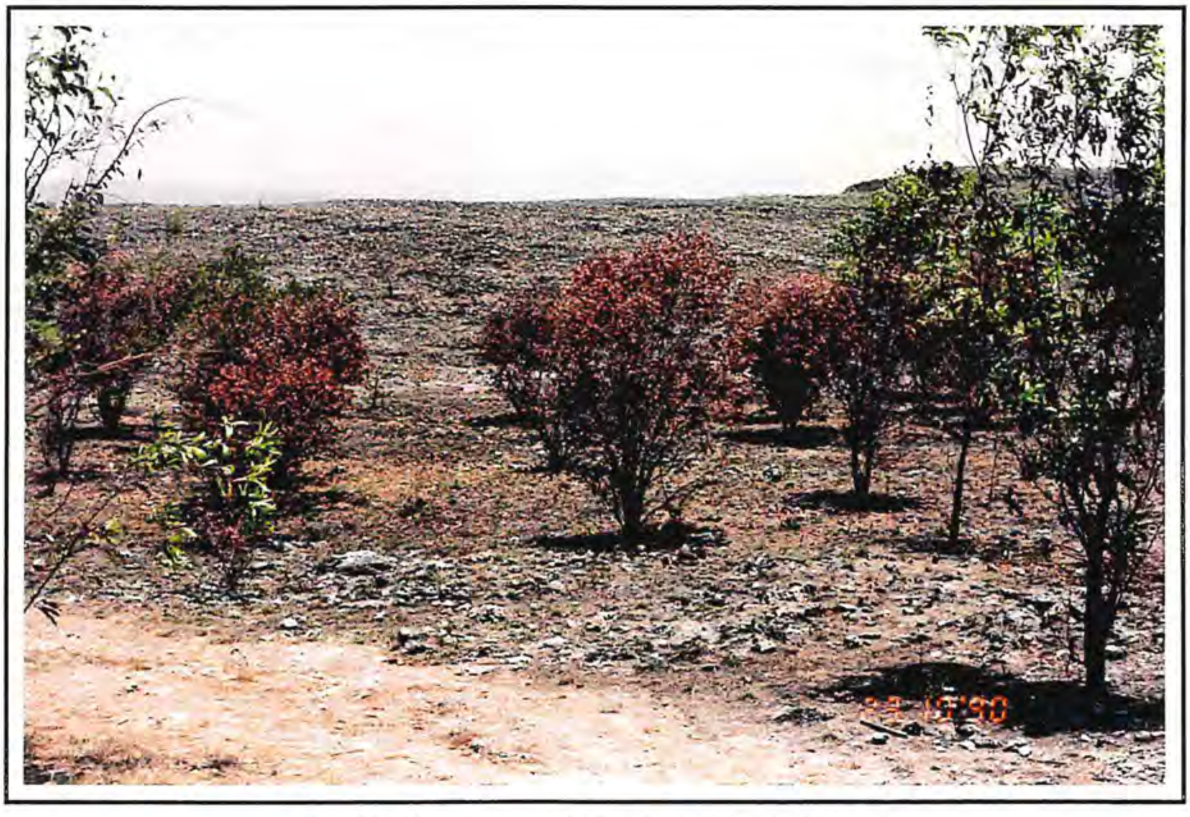
Typical landscape on the hills behind Waingapu, East Sumba

The objective in this work was to determine which species of tree might be useful for rehabilitation of these severely degraded sites, preferably species that would have value either for fuelwood or for fodder, although it was also clear that if small sized timber could be produced it would be of value to small farmers for house construction. We were therefore at the species screening trial stage.

In selecting species for trial here we were conscious of the severe fire damage situation in the region, the grass-covered hills being burnt on an annual basis to promote a little green pick for the ever-present cattle. It was also felt important to concentrate on species that could demonstrate fast initial growth as a small farmer cannot wait more than 2/3 years for some sort of benefit from any tree that he might plant. The limited moisture holding capacity of the thin soils combined with the low rainfall meant that site productivity would inevitably be low.

The nursery at Hambala was located on a difficult site to take advantage of a permanent water supply, but although the water was available, getting it to the plants was a continual problem. The project purchased a petrol-powered pump that improved the situation for one season, but in the last year of the Project the pipeline from Waingapu reached Hambala and the water supply problem was finally cured.

Despite this improvement, plant quality was always a difficulty at Hambala. The soil mix was not suitable, having too high a clay content and there seemed to be a number of nutrient deficiencies associated with it. As a consequence, the planting stock were always less than the desired size and the number of plants in particular species was often less than planned. For this reason the number of replicates in the species trial varied, with consequent difficulties in later analysis.



A problem facing research in East Sumba-a local trial burnt

Field trials were established in three seasons, 1992, 1993 and 1994. All were planted in January, and all were planted under conditions of considerable concern over erratic rainfall. It is largely a matter of chance if our January visit, which for administrative reasons had to be scheduled some weeks ahead, happened to coincide with sufficient rainfall to begin the planting. This was specially difficult in the Sumba situation where local staff did not have the capability to carry out the planting. There was a research officer stationed at Hambala, Tjetjep, but he suffers severely from malaria and was often unwell. For this reason the nursery program often lacked direction at critical times.

In spite of these problems, we did manage to establish three useful species screening trials at Hambala. We know that they were of practical use both to the local forestry staff in Waingapu and to expatriate NGO staff who called in to the trials during one of our visits to talk about the results. We therefore feel that the work was very worth while. On the subject of NGO staff we must acknowledge the valuable assistance of an Australian working with the World Food Program in Waingapu, Mick Jeffrey. He gave us most useful assistance during the last year of the project, and especially during the last planting visit in January 1994.

Field Trial Design

For the 1992 field trials the species selected from past work in Timor were:

Sesbania formosa (fodder and fuelwood value)
Acacia colei (fuelwood, possible edible seeds)
A. holosericea (fuelwood value)
A. ampliceps (fodder and fuelwood)
Eucalyptus camaldulensis (fuelwood and small poles)
E. tereticornis (fuelwood and small poles)

New species tested in Sumba were:

A. cowleana (fuelwood)
A. bidwillii (fuelwood, possible edible seeds)
A. trachycarpa (fuelwood, fodder)
A. polystachya (fuelwood)

As in the previous research program in Timor, we used local species as markers against which to test the performance of the introduced species. The marker species used in Sumba were:

A. auriculiformis (not native but naturalised, fuelwood)
Sesbania grandiflora (fodder, fuelwood)
Casuarina junghuhniana (fuelwood)
Leucaena leucocephala (naturalised, fodder, fuelwood)

For the 1993 trials the eucalypts and *A. holosericea* failed in the nursery. However, we added *Acacia crassicarpa* (fuelwood, timber), four provenances of *A. auriculiformis* as we suspected some variation in drought tolerance between provenances of this species, *A. mangium* (timber) and *Pterocarpus indicus* (timber), another local species. We had hoped to include local *Casuarina junghuhniana, A. auriculiformis* and *S. grandiflora* as markers, but local seed was not available.

For 1994 the species raised at the nursery were:

A. colei 13775 and 16764	*A. ampliceps* 17759 and 15755
A. auriculiformis 16160 and 16162	*A. trachycarpa* 17963 and 16759
A. holosericea 15732 and 16143	*A. rostellifera* no number
A. neurocarpa 18170	*Sesbania formosa*
S. grandiflora	*Casuarina junghuhniana*
Leucaena leucocephala K636 (a Brewbaker giant lamtoro selection)	

In choosing these species we concentrated on those that we thought would have value for fodder as well as fuelwood production, as these are the main requirements of people living in this area. *A. rostellifera,* for example, is a species from the northern wheatbelt/sub-tropical part of Western Australia that is a prized sheep fodder

Seedlings were raised in polybags at a small nursery at Hambala, near the field trial site. Unfortunately, the quality of the plants in the first year's trials was adversely affected by water supply problems at the nursery and were usually only about 20 cm in height when planted. There were also insufficient plants that year to be able to lay out the desired four replicate plots of each species. Two replicates only were possible in 1992, but in 1993, most species had four replicates, as nursery performance had improved.

The field trial plots were planted 5 trees by 5 trees at 1-metre spacing, in order to economise on site space requirements and to minimise maintenance, as the research outstation at Hambala had very limited staff resources. The trial design was a randomised complete block. All plots were sprayed pre-planting with glyphosate, applied from a Stihl SG17 power sprayer, which gave very effective weed control. On most of the trial area the weed control effect persisted through until the second year.

For the second year trials the nursery water supply problems were overcome, but the plants were not moved during growth in the nursery, so that the roots of some species grew through the drainage holes in the polybags into the soil. Consequently, when lifted to move to the field, these plants suffered severely from dehydration. We attempted to compensate for this, and to counter the effects of dry weather at the time of planting (in both years), by immersing the seedlings in a bucket of water just before planting, to thoroughly soak the soil in the polybag.

For the final year field trials we had hoped to establish a site preparation trial using*A. colei* as well as the species trial, but the nursery performance was again very disappointing and sufficient seedlings were available only for the species screening trials. This trial was planted but no subsequent measurement data were sent from Hambala, in spite of several requests, so no results can be presented.

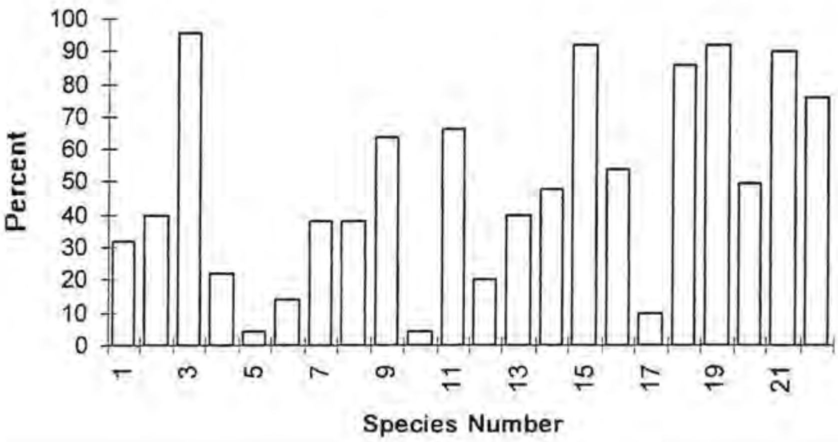
Tree heights were measured in December 1992 and 1993. Data presented here for the 1992 trial are the mean heights of the two replicate plots. No statistical analysis was carried out due to the lack of adequate replication, so the results of the 1992 trial must be viewed with some caution. For the 1993 trial, it was possible to plant more replicates, so the data are more reliable. However, even here, lack of sufficient plants meant that we had four replicates for only ten of the sixteen species available for trial.

Results

1. 1992 Trial

The major issue with the field trial was to see what species could survive this extremely harsh site. As might be expected, there was widely variable survival in the trial. Some species had better than 90 percent survival at the end of the first dry season, while others were virtual failures (see Figure 2 below).

Figure 2: First year Survival P92 Plots



Species List 1992 Trial

1. *Acacia colei* 13775 Tanami Bore NT
2. *Acacia colei* 16764 Portland R WA
3. *A. holosericea* 15732 Edith R NT
4. *A. holosericea* 16143 Coen Qld
5. *A. cowleana* 14613 Helen Springs NT
6. *A. cowleana* 17202 Huttons Bore WA
7. *A. bidwillii* 14599 Cloncurry Qld
8. *A. ampliceps* 15755 Broome WA
9. *A. ampliceps* 17789 Dampier WA
10. *A. polystachya* 17721 Bolt Head Qld
11. *A. trachycarpa* 17963 Port Hedland WA
12. *A. trachycarpa* 16759 Carolina Ck WA
13. *Sesbania formosa* 15752 Beagle Bay WA
14. *S. formosa* 15439 Maitland R Hwy WA
15. *Euc. tereticornis* 15825
16. *E. camaldulensis* 17635 Katherine R NT
17. *E. tereticornis* 16479 Mt Garnet Qld
18. *E. camaldulensis* 16730 Katherine NT
19. *A. auriculiformis* local
20. *S. grandiflora* local
21. *Casuarina junghuhniana* local
22. *Leucaena leucocephala* local

The species with high survival rates, i.e. greater than 75 percent were:

A. holosericea 15732
E. camaldulensis 16730
L. leucocephala local
E. tereticornis 15825
S. grandiflora local
C. junghuhniana local

No species failed completely, but those which were virtual failures, ie, less than 20 percent survival, were:

A. cowleana 14613
A. polystachya 17721
E. tereticornis 16479
A. cowleana 17216
A. trachycarpa 16759

The remaining species had intermediate survival greater than 20 percent but less than 75 percent.

The performance of some species was not up to expectations. For example, *A. trachycarpa* is a species which handles similar conditions in northern Western Australia very well. It can be relied upon for good survival and good early growth when it is used as host for *Santalum album* there. Its poor performance, in terms of survival, may be a consequence of the seedlings being small and in bad condition for outplanting. Similarly *A. ampliceps* did not perform as well as hoped. Although average in respect of height growth, survival was less than 40 per cent for one provenance and only 60 per cent for the other.

This species was also notable for the morphological variation among individual trees in the plots. There was some evidence that the seedlot was not pure and that some hybridisation, probably with *A. bivenosa*, had taken place. The putative hybrids with this species were invariably the best plants on each plot, indicating that further trials using that species may be justified.

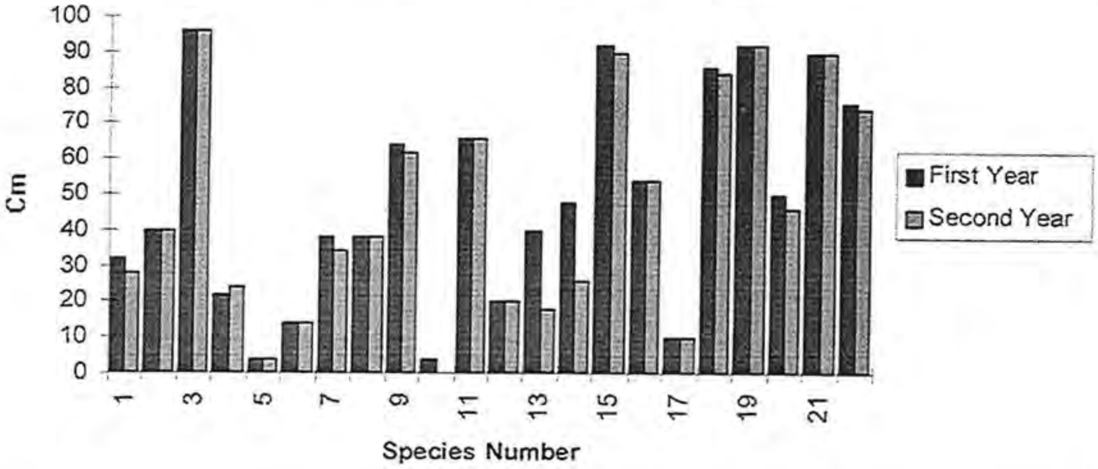
There were some notable differences in survival between different provenances of some species, such as the two provenances of *A. holosericea*, between provenances of *A. trachycarpa*, and *E. tereticornis*. One would hesitate to suggest these differences are real, in view of the extreme variability of the site. Such differences could well merely reflect chance plot effects. Further trials would be required to clarify this point.

There was not much to choose between the two species of *Sesbania* in terms of survival or height growth, although it had been expected that *S. formosa* might do better than *S. grandiflora* on this site.

Most species managed to maintain their survival into the second year, except for both provenances of *S. formosa*, which suffered severe attack from leaf-eating beetles, and *A. polystachya*, where the few remaining plants died (see Figure 3).

A. ampliceps plot, P92, showing suspected hybrid plant

Figure 3: Plant Survival over Two Years, P92 Trial

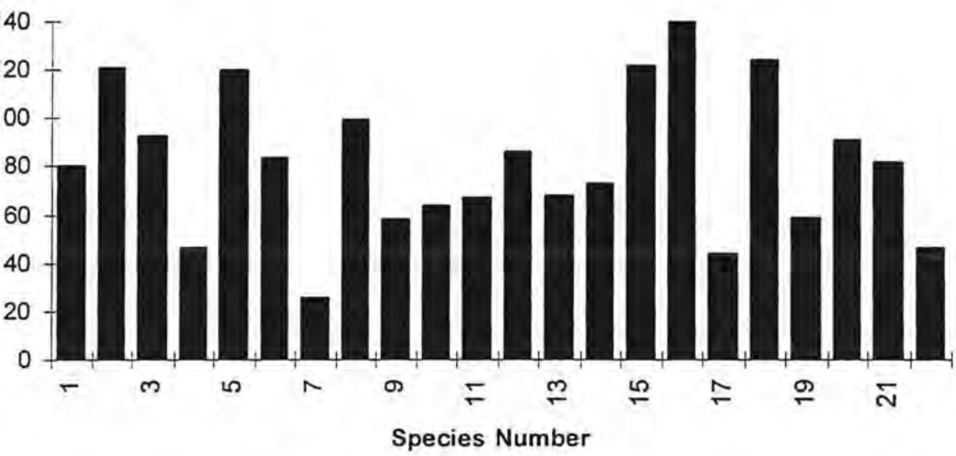


Height growth in the first year was also quite variable between species (see Figure 4). Those able to achieve a height greater than 100 cm were:

A. colei 16674	*A. cowleana* 17202
E. tereticornis 15825	*E. camaldulensis* 17365

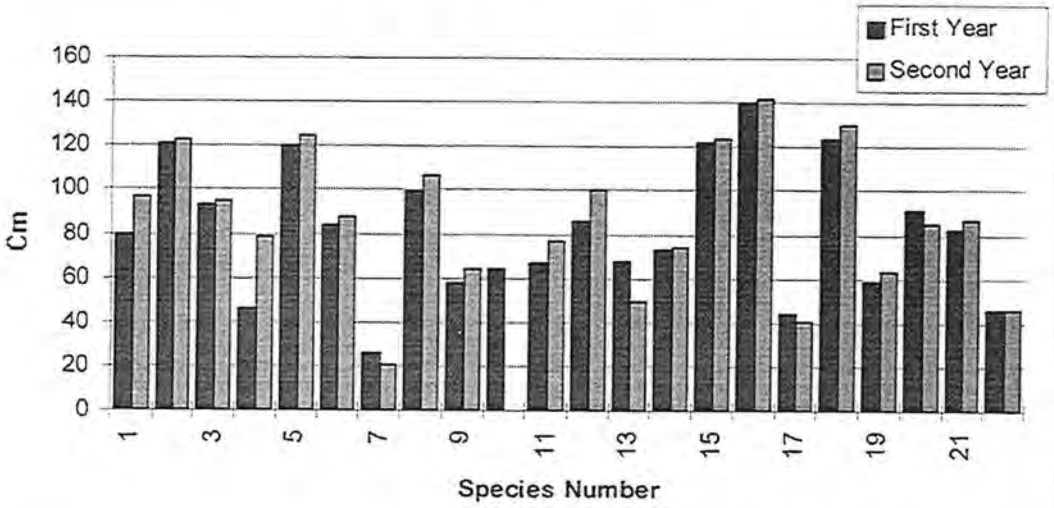
Poorest growth, less than 50 cm average height, was found in *A. bidwillii, E. tereticornis* 16479 and *L. leucocephala.*

Figure 4: First Year Height Growth (cm) P92 Trial



The second re measurement at age 2 from planting, revealed that very little growth had taken place in the second year (Figure 5)

Figure 5: Height Growth P92 Trial

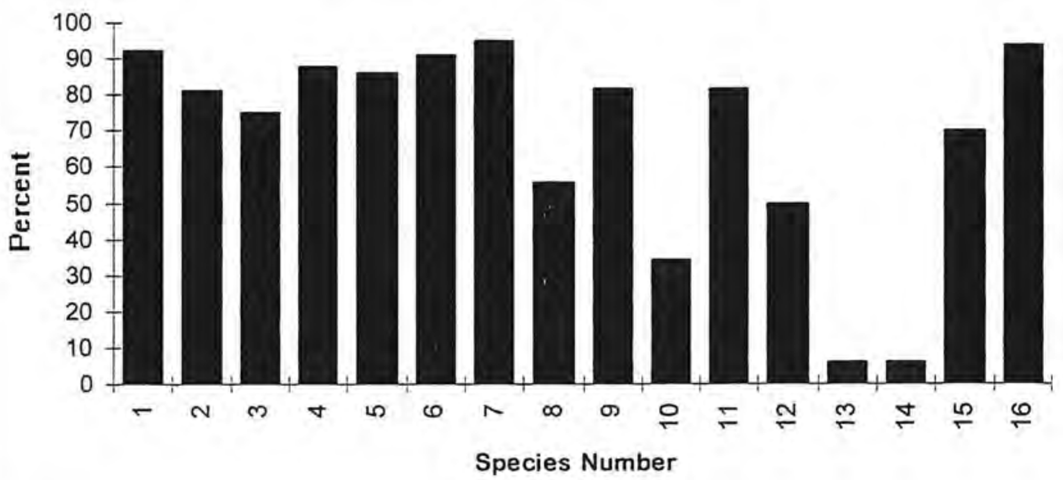


These data indicate that the limitations of the site, most likely in terms of water availability, are severely restricting potential tree growth. Although the seedlings may survive reasonably well, a tree will grow very slowly unless it is located in a pocket of deeper soil.

2. 1993 Trial

Survival of the seedlings was notably better for most species in the 1993 field trial, reflecting slightly better soil conditions at the trial site and possibly a less severe drought that year (see Figure 6, below).

Figure 6: P93 Trial Survival



Species List 1993 Trial

1. *A. auriculiformis* 16160 S. Alligator R NT
2. A. *auriculiformis* 18017 Bensbach PNG
3. *A. auriculiformis* 16162 Reynolds R NT
4. *S. formosa* 16567 Buckleys Plain WA
5. *S. formosa* 15439 Maitland R Hwy WA
6. *A. ampliceps* 17789 Dampier WA
7. *A. bidwillii* 14599 Cloncurry Qld
8. *A. auriculiformis* 16106 Mibini PNG
9. *A. ampliceps* 15755 Broome WA
10. *A. crassicarpa* 13681 Mata PNG
11. *A. colei* 16764 Portland R WA
12. *A. trachycarpa* 17963 Pt Hedland WA
13. *A. crassicarpa* 15482 Archer R Qld
14. *A. mangium* 16584 Bensbach PNG
15. *A. colei* 13775 Tanami Bore NT
16. *Pterocarpus indicus* local

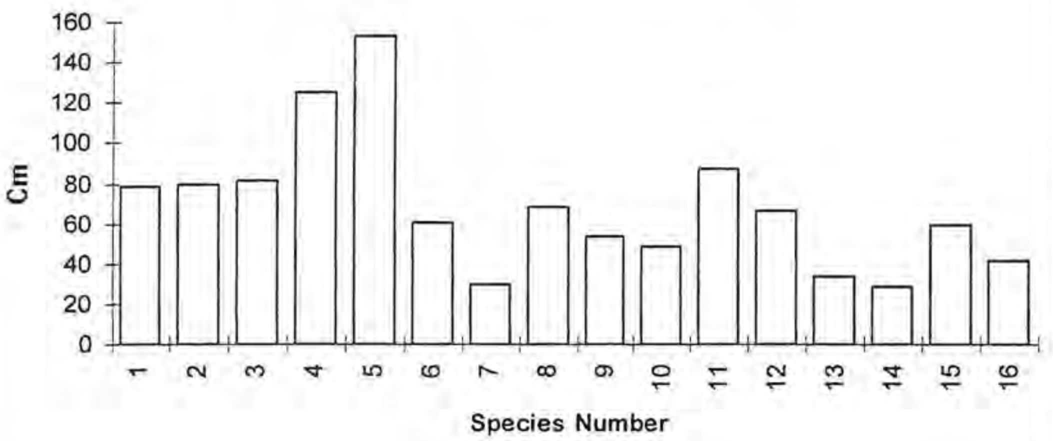
Species with high survival rates, above 75 per cent were:

A. auriculiformis 16160, 18017, 16162
A. ampliceps 17789, 15755
A. colei 16764
S. formosa 16567, 15439
A. bidwillii 14599
P. indicus local

Species which were virtual failures were *A. mangium* and *A. crassicarpa*. Considering the preference of these species for much more moist climatic conditions, this result was to be expected.

We again observed that each plot of *A. ampliceps* contained at least one plant much more vigorous than the rest, and which exhibited morphological characteristics similar to *A. bivenosa*. These plants appeared to be hybrids, as noted earlier.

Figure 7: P93 Trial Mean Height at One Year



The most notable features of the 1993 trial was the very good performance of *S. formosa* and the much better height growth of *A. colei*, compared with the previous year. Unfortunately there were no seedlings of the local *S. grandiflora* available to plant for comparison with the *S. formosa* in this trial, but it would appear that the first year height growth of the latter is at least as good as the local species on this site. As at January 1994, there was still no severe beetle attack on the *S. formosa*, and this factor may also have contributed its better growth in the second trial.

All the provenances of *A. auriculiformis* did well in the second year and there was little to choose between their performance in terms of height growth, indicating all are equally well adapted to this site.

Although some species with a more bushy growth habit, such as *A. ampliceps* and *A. bidwillii*, do not show up well on height growth, they were both very healthy and are likely to succeed on this site. *A. bidwillii* has a prostrate habit of growth for the first few years, as does *A. leucophloia*, a species which occurs naturally in NTT.

3. 1994 Trial

In 1994, *A. colei* and *A. neurocarpa* failed in the nursery and there were uneven numbers of several other species. Many seedlings were also in poor condition. Nevertheless a trial was designed to make the most of the situation, testing the following species:

A. ampliceps 17759 four replicates
A. auriculiformis 16162 four replicates
Sesbania grandiflora local four replicates
S. formosa 16567 one replicate
Leucaena leucocephala K636 four replicates
A. trachycarpa 16759 two replicates
A. ampliceps 15755 four replicates
A. auriculiformis 16160 two replicates
S. formosa 15439 one replicate
Casuarina junghuhniana local four replicates
A. trachycarpa 17963 two replicates
A. rostellifera one replicate

These were planted in January 1994, but no measurement data are available.

Discussion and Conclusions

These two field trials for which we have data have yielded useful information on the suitability of several tree species to the very harsh sites which occur over a considerable area of east Sumba. Several species have been shown to grow faster than native species on the island, or to have the potential to produce material which native species cannot do in this environment. In particular, several species have potential for use to alleviate the severe fuelwood shortage in this area. Further research is required to determine growth rates under realistic field conditions, as these fields trials were only screening experiments.

Provided wildfire and grazing are controlled, they could be readily used to create a new fuelwood resource in a short period of time. The success of these screening trials indicates that it is possible to undertake reforestation on these sites, which cover a considerable area in eastern Sumba. To do so, however, would require more research and site capability mapping.

The good performance of the two *Sesbania* species indicates they could be used more widely than they are now, as a fodder source for cattle and goats. The excellent early growth of *S. formosa*, in particular, suggests that it might have promise for use as an annual. It is also likely that some of the *Sesbania* species that have an annual growth habit, such as *S. sesbans*, might be useful in this environment and should be tested.

Acacia ampliceps is another species introduced in these field trials which shows promise for use as a fodder in east Sumba, as does *A. bidwillii*, although its biomass production is less than that of the first species. However, *A. bidwillii* has very large seeds, which may have potential for human consumption. *A. trachycarpa* also performed well and would have potential for use as a fodder plant here. *A. holosericea* and its close relative *A. colei* also showed good early growth, but more trials are necessary to explore possible variation in performance with seed provenance.

A possible hybrid between *A. ampliceps* and *A. bivenosa* which occurred in all trial plots of the former species was very vigorous and indicated that *A. bivenosa* might be worthy of testing on these sites. It also suggests that there could be large gains in productivity from a program of hybridisation of suitable *Acacia* species. This possibility deserves further investigation.

For fuelwood production in this area, *E. camaldulensis*, *E. tereticornis*, *A. holosericea*, *A. auriculiformis* and *A. colei* will clearly produce more than the local marker species and could be planted for that purpose with considerable benefit to local people,

Where land rehabilitation is the objective, and grazing has to be contended with, both *A. holosericea* and *A. colei* would have value as they are both unpalatable to livestock. They tolerate very harsh, shallow soil conditions and produce useful fuelwood as well as improving soil by nitrogen fixation.
For the production of small logs for on farm construction purposes, the two eucalypts used in our trials are worth planting on favourable sites. Other eucalypts may be worthy of trial where only fuelwood production is the objective.

Of course, the results reported here are based on only one or two years of measurements, and therefore should be regarded as preliminary. However, our previous experience in West Timor would indicate no gross changes in the rankings of these species over the next four-five years, unless some unforeseen insect damage occurs.

Acacia ampliceps plot Sumba P93 showing possible A. bivenosa hybrid

Acacia holosericea plot Sumba P93

SANDALWOOD SILVICULTURAL RESEARCH KUNUNURRA

The research described here was carried out at an area at the Kimberley Research Station leased from the WA Department of Agriculture. The KRS lies within the main Ord River Irrigation Area (ORIA) and most of the soils on the Station are Cununurra Clay, an alkaline black cracking clay very similar to the pellusturt soils encountered in West Timor. The KRS has access to flood irrigation from the main Ord River Dam so water supply is never a problem. It is basically just a matter of opening a valve. However, flood irrigation does impose certain management requirements in respect of channel design and maintenance, which have to be accommodated in tree plantation design. Flood irrigation also carries with it very heavy grass growth, so control of competition becomes a critical factor in plantation establishment.

Nursery facilities were a continuing problem during the Project. In the beginning CALM attempted to contract out the nursery work to the local Voyager Nursery company. They did quite a good job technically but ran into financial difficulties and folded. Subsequently, its head nursery hand tried to carry on the business on his own, and although he possessed the necessary technical skills he found it impossible to make a living from just raising seedlings for CALM. In the end, it was found necessary for CALM to lease the former Voyager facilities and carry out all the work itself. This require the input of additional funds by CALM, without which Rado would have been diverted from much active research into routine nursery management.

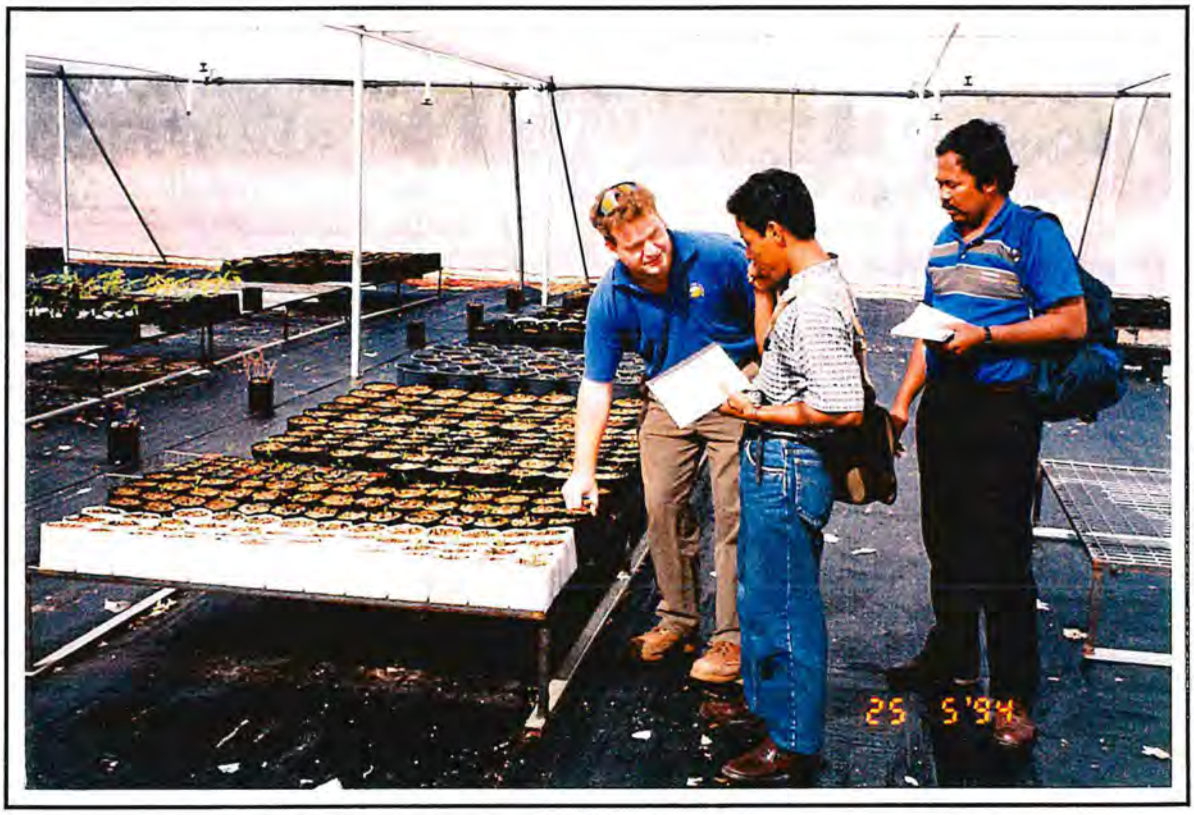
New research officer Andrew Radomiljac was appointed in October 1992 and made a good start to his work at Kununurra and quickly developed a work program following consultations with staff of CALM research division and with colleagues at the Forest Research Station in Kupang. To ensure that good links were maintained with other CALM research staff input to his research program was obtained from Dr Per Christensen of CALM's research division.

He also developed links with Dr Fox at Curtin University and with Dr Jen McComb at Murdoch University, who was working on propagation of sandalwood using tissue culture. She raised clonal material from three parent sandalwood trees which were planted out at Kununurra by Rado in May 1993.

The Project Leader visited Timor with Rado in April 1993 to assist him to get to know the research officers engaged on sandalwood research there, Markum and Komang. He was able to see much of their work and reach a useful degree of understanding about mutual problems. Subsequently, Markum and Komang visited Kununurra to see Rado's research and Rado visited West Timor again, primarily to see the results of an extensive sandal progeny trial established at several sites near Kupang.

The Project Leader went to Jakarta in April 1993 to meet Ir Soedjadi, the new Director General of AFRD and Ir Nana Supriana, the new Director of AFRD Bogor, to discuss the project and try to advance the several matters, such as the conclusion of the MOU between ACIAR and MOF, the Project Agreement and the supply of sandalwood seed from Timor to Australia for research purposes. Both were most cordial in our meetings, but little progress was made on any of the matters discussed.

During our July 1992 trip to Timor and Sumba, in which we plan the coming year's program, the CALM team assisted Ms Deanne Haffner of Melbourne University, who was studying heartwood formation in sandalwood, under a grant from the WA Sandalwood Research Institute and with direction by Dr Ted Hillis. After encountering many obstacles she was eventually able to obtain wood samples from 30 mature sandalwood trees near Soe.



Markum and Komang inspecting nursery facilities at Kununurra with Andrew Radomiljac

Dr Fox also continued his cooperative work with Markum and Komang and advised on the commencement of progeny trials and experimental design at the Oesonbai field trial site, as set out in his separate report. Selection of the plus trees in West Timor by Markum and Komang continued.

Another activity undertaken by Rado was the editing and preparation of a Sandalwood Research Newsletter, to encourage communication among people in various countries interested in growing sandalwood. During the course of the Project, four issues of the Newsletter were published. These are shown in Appendix 2. It now has a circulation list covering Australia, Indonesia, Fiji, Vanuatu, India, PNG, Hawaii and New Caledonia. This publication has served a very real need in promoting interest in research on sandalwood, especially in South Pacific countries. CALM's existing links and common interest in sandal wood with CIRAD FORÊT in New Caledonia have been strengthened by the Project.

Results

First Year Research Program

In his first year at Kununurra, Rado concentrated on plantation establishment techniques specific to the situation on the Ord River Irrigation Area (ORIA). Field experiments laid out included:

(1) Herbicide use at planting

Control of grass competition is an important factor in obtaining good sandal seedling survival in the ORIA. Past experience had shown that complete grass control with herbicides is possible but risky, as the level of application required also kills the sandal. In any case complete removal of grass is not desirable as the grass does seem to act as a host and also gives some protection against desiccating winds.

A range of herbicides was tested against control, 'weedmats' and application of a mulch. The results were written up by Rado for publication in Australian Forestry. The most effective weed control technique is to use a pre-emergent herbicide with no knock-down ability, such as simazine or Surflan, applied by a tractor-mounted boom spray after planting the sandal and pot host, but prior to the initial flood irrigation.

Sandal plantation showing weed control using herbicides

(2) Tree establishment technique

This was a factorial experiment investigating the effect of season of planting, the need for pre-existing long term hosts and microclimate amelioration on sandal survival and early growth. The study showed conclusively that the best season to plant is June-July, that pre-established long term hosts were not necessary and that microclimate amelioration with mulch, weedmats or plastic tree guards were not beneficial.

The data below are from the planting season trial, 6 months after establishment. Treatments means followed by the same letter are not significantly different from each other (p=0.05 by pairwise t-test) .

Season of Planting	*Sandal Survival %*	*Sandal Height cm*	*Sandal Diam. cm*	*Sandal Vigour*	*Pot Host Survival %*
June	95.4 a	56.02 a	1.16 a	3.18 a	58.0 a
October	13.4 c	57.85 a	1.15 a	2.59 b	11.8 b
February	70.9 b	37.26 b	0.87 b	2.02 c	54.8 a

For the pre-established host trial, the data also for six months after establishment are as follows.

Pre-estab. Host Species	*Sandal Survival %*	*Sandal Height cm*	*Sandal Diam. cm*	*Sandal Vigour*	*Pot Host Survival %*
Lysiphyllum cunninghamii	49.2 b	46.9 b	0.90 b	2.28 b	49.8 a
Cathormium umbellatum	57.6 b	51.0 a	1.00 a	2.45 b	28.6 b
Nil	78.8 a	51.4 a	1.05 a	3.06 a	41.7 a

(3) Pot host trials

Two pot host studies were established in 1993.

(A) Influence of pot host, seedling age and supplementary nursery nutrition on sandal field establishment. These studies proved the importance of a pot host and indicated that *A lternanthera nana* was a very good pot host, in terms of sandal growth, with easy and cheap propagation as well as easy control. This pot host normally dies off after the first season in the field.

Data measured 287 days after field establishment. Means followed by the same letter are not significantly different from each other (p = 0.05 by pairwise t - test).

Pot Host	*Pot Host Survival %*	*Sandal Survival %*	*Sandal Height cm*	*Sandal Diam. cm*	*Sandal SGA*
A. nana	86.7 a	97.1 a	96.2 a	2.04 a	3.94 a
S. formosa	71.7 b	84.7 b	93.7 a	1.99 a	3.87 a
C. retusa	0	67.1 c	69.8 b	1.12 b	2.34 b
A. hemignosta	30.0	50.4 cd	61.0 c	0.89 bc	1.78 c
A. hemiglauca	86.3 a	57.4 c	52.4 d	0.69 c	1.64 c
Control no host	-	36.7 d	50.1 d	0.74 c	1.47 c

A paper on this work has been compiled and submitted to Forest Ecology and Management.

Seedling of S. album outplanted with Alternanthera nana pot host

(B) A cooperative trial was undertaken with Curtin University testing several plant species as pot hosts for sandal. Species tested were:

Acacia ampliceps
A. bivenosa
Cajanus cajan
Capsicum sativa
Sesbania formosa
Desmanthus virgata
Alternanthera nana
Duranta repens

This field trial awaits formal evaluation.

(4) Intermediate host trial

A field trial was established to compare sandal growth with the following intermediate hosts:

A. mangium
A. trachycarpa
A. coriacea
Sesbania formosa
Melaleuca alternifolia

Control, no intermediate host.

This is a medium term field trial that will not yield firm results for 5/7 years.

Second Year Research Program

(1) Sandal clonal trial

This was a small trial examining the effect of different host type on long term sandal growth and heartwood formation with clones from three different parents. The clones were raised by Dr Jen McComb at Murdoch University following an extensive period of research on tissue culture of *S. album* funded by the WA Sandalwood Research Institute.

The theory here is that any observed differences in the rate of heartwood formation or heartwood oil content should be due entirely to some influence of the host plant, since the soil and environmental conditions will be the same for all trees, and within each clone there will be no genetic variation. By using three clones we hope to gain some information on the heritability of age of heartwood formation or heartwood oil content.

S. album at Kununurra 4 months after outplanting, using A. trachycarpa as intermediate host.

(2) Germplasm of S. austro-caledonicum

This trial uses seed obtained by the Project Leader from New Caledonia as part of a cooperative sandal species trial with CIRAD-FORÊT. CALM provided seed from 10 different parents of *S. spicatum* and obtained in return seed from 10 different parents of sandal from New Caledonia. The seedlings from New Caledonia were planted out at Kununurra as a progeny trial and will provide useful information on the variation in growth and heartwood formation under Kununurra conditions for this species.

(3) Evaluation of potential for artificial improvement in sandal heartwood formation

Since heartwood formation is the whole objective of sandalwood silviculture, other methods of accelerating heartwood formation are of interest. While there is every indication from test borings in young trees that we are getting satisfactory heartwood formation, anything that might improve this is worth exploration. Sandal trees were treated with chemicals that appear to have some potential for the stimulation of heartwood formation. No results are available as the treated trees are being left for 3/4 years before sampling.

In this same context, we have attempted to obtain seed of improved genetic quality from India to raise the standard of germplasm used for operational scale sandal plantings at Kununurra.

S. album 9 months after outplanting using S. formosa pot host

(4) A. tumida provenance trial

This trial was established in January 1994 in cooperation with Chris Harwood of the CSIRO Tree Seed Centre to test the variation in performance of several sources of seed of this widespread species and also to provide a future seed source. Funding for the establishment of this trial came from TSC. A second similar experiment was established in January 1995.

Third Year Research Program

(1) Field nutrition experiment

The broad aim of this experiment was to quantify the effect of improved plant nutrition resulting from application of a range of nutrients on sandal and host survival and growth. It was hoped that by 'supercharging' sandal and intermediate host seedlings they will be better able to get ahead of competing grasses and other weeds and possibly save on weed control costs.

(2) High value tree species experiment

The intent of this trial was to identify a range of high value tropical tree species suitable for use on the soils of the ORIA, either as sandal hosts or even as single species plantations. There is evidence from past small scale plantings of teak and other species such as West African mahogany, that there is real potential for commercial timber production within the ORIA.

This potential gains greater significance in view of the increasing concern in the region over rising groundwater tables and the need to find effective means of controlling this rise. Commercial tree plantations with or without sandalwood have considerable potential for this purpose and there is active interest in tree planting by farmers. In a very real way, the research supported by this Project has contributed to raising the awareness of ORIA farmers to the value of tree crops.

Species currently planted out for field testing are:

Dalbergia cochinchinensis
D. latifolia
P. indicus
Intsia bijuga
Khaya senegalensis
Flindersia brayleyana
Cedrela odorata
D. oliverii
Pterocarpus macrocarpus
P. marsupium
Agathis robusta
Sweitenia mahogani
Toona australis

(3) Nursery nutrition experiment

This experiment aimed to develop improved techniques for handling sandal in the nursery in association with the preferred pot host, *Alternanthera nana*. The trial used three different levels of application of Osmocote commercial fertiliser. It provided important information on sandal and *A. nana* nursery nutrition requirements which have assisted in refining nursery program to produce a consistent supply of high quality seedlings for field establishment.

(4) Pot type selection for sandal

Due to the need to add a pot host species during sandal propagation, a relatively large pot has been used. Prior to 1995 the standard pot type was a 3-litre polybag. This presents a number of practical problems; the volume and weight are excessive, causing handling difficulties, the sand-based mix loses soil moisture more quickly than the surrounding Cununurra Clay after planting, causing seedling moisture stress, and the pot cannot be efficiently recycled. This trial was designed to test the practicality of using a variety of rigid plastic pots for raising sandal.

S. album 9 months after outplanting using Alternanthera pot host, with intermediate S. formosa host in background

(5) Fast growing leguminous species selection

This trial was intended to identify fast growing legumes suitable for the black soils in the ORIA that would be both good sandal intermediate or long term hosts and would also have commercial potential, for example, for pulpwood. Species being tested are:

Acacia auriculiformis (two provenances)
A. mangium (two provenances)
A. crassicarpa (two provenances)
Paraserianthes falcataria

Again, this is a long term trial.

(6) Sandalwood espacement and host/parasite ratio

A critical question for commercial sandal plantations relates to the carrying capacity of hosts and the long term stocking rate of sandal plantations. The requirements of flood irrigation infrastructure and the logistics of weed control after initial sandal establishment are such that it is necessary to avoid infilling or later long term host planting. Therefore it is necessary to ensure that the plantation system is suitably designed to provide the right growing conditions for sandal at different stages of growth.

This is a long term field experiment that uses three stocking levels of sandal, 925, 462 and 308 stems per hectare, with sandal/long term host ratios of 2:1, 1:2 and 1:3.5.

Discussion and Summary of Outcomes of Kununurra Sandal Research

As a result of the research carried out by Rado, we now have a routine nursery and field establishment system for sandal that can be relied upon to provide 90 per cent survival. In brief the system is as follows:

Sow seed in December -January
Add pot host in March
Prepare field sites May-June
Irrigate prior to planting
Plant out seedlings, together with intermediate host*S. formosa* and long term host July. At the moment a variety of long term hosts is being used.
Apply simazine herbicide immediately after planting
Commence irrigation program

Further refinements are being made continuously, for example, through developing a technique for reducing seedling container size to facilitate subsequent handling and to enable cost reduction by recycling the containers.

The research program has also established a set of field trials that will in the near future provide useful information on the following important issues for sandal plantation silviculture:

- whether heartwood formation is influenced by the long term host plant used;
- growth and yield of sandal under ORIA conditions;
- the effect of different host/parasite ratios on sandal growth and heartwood production;
- the potential for combining the production of sandal as well as high value tropical hardwoods on the ORIA;
- the potential for other species of *Santalum* on the ORIA.

The major areas of deficiency in knowledge faced in the development of commercially successful sandal plantations in the ORIA are:

(1) lack of long term (20-30 year) tree growth and heartwood yield data;
(2) information on optimum middle rotation plantation management, for example, the optimum stocking of sandal and host;
(3) the opportunities for integration of sandal plantations with high value tropical hardwoods as a viable and practical plantation system.

CALM is continuing research on these matters.

Acknowledgments

Several people contributed major efforts to the success of this Project. Firstly, in Indonesia, Dedi Setiadi provided very capable on-ground support both in West Timor and in Sumba during planting seasons, in spite of his lack of enthusiasm for flying to Sumba in the 'Merpati kecil'. The Project also received unfailing support from the OIC BPK, firstly Ir Sutarjo Suriamihardja and later Ir Maralop Sinaga. We also benefited from discussions with CUSO volunteer working on agroforestry in NTT, Ted Burke.

In Sumba, World Food Program afforestation officer Mick Jeffrey gave sterling support during two planting seasons and also helped with the final year nursery program.

On the CALM side, Ray Fremlin provided much drive and establishment expertise and Joe Havel made a strong contribution on experimental design and establishment. Both put in very long hours while in NTT and made major contributions to the work. Ray's ability to produce high quality field trial maps at a moment's notice on Harvard Graphics was especially useful.

For both this and the previous Project 8613, we must also mention the unfailing support of the staff of the Tree Seed Centre in Canberra, who provided all the seed that was used in this research except a small amount that was collected locally. Dr Peter Dart and the late Alan Gibson provided the *Rhizobium* inoculum used in the Oetium and Buat trials.

APPENDIX 1

REPORT ON SANDALWOOD RESEARCH
BY
J.E.D. FOX AND D.R. BARRETT,
CURTIN UNIVERSITY

curtin
University of Technology
Perth Western Australia

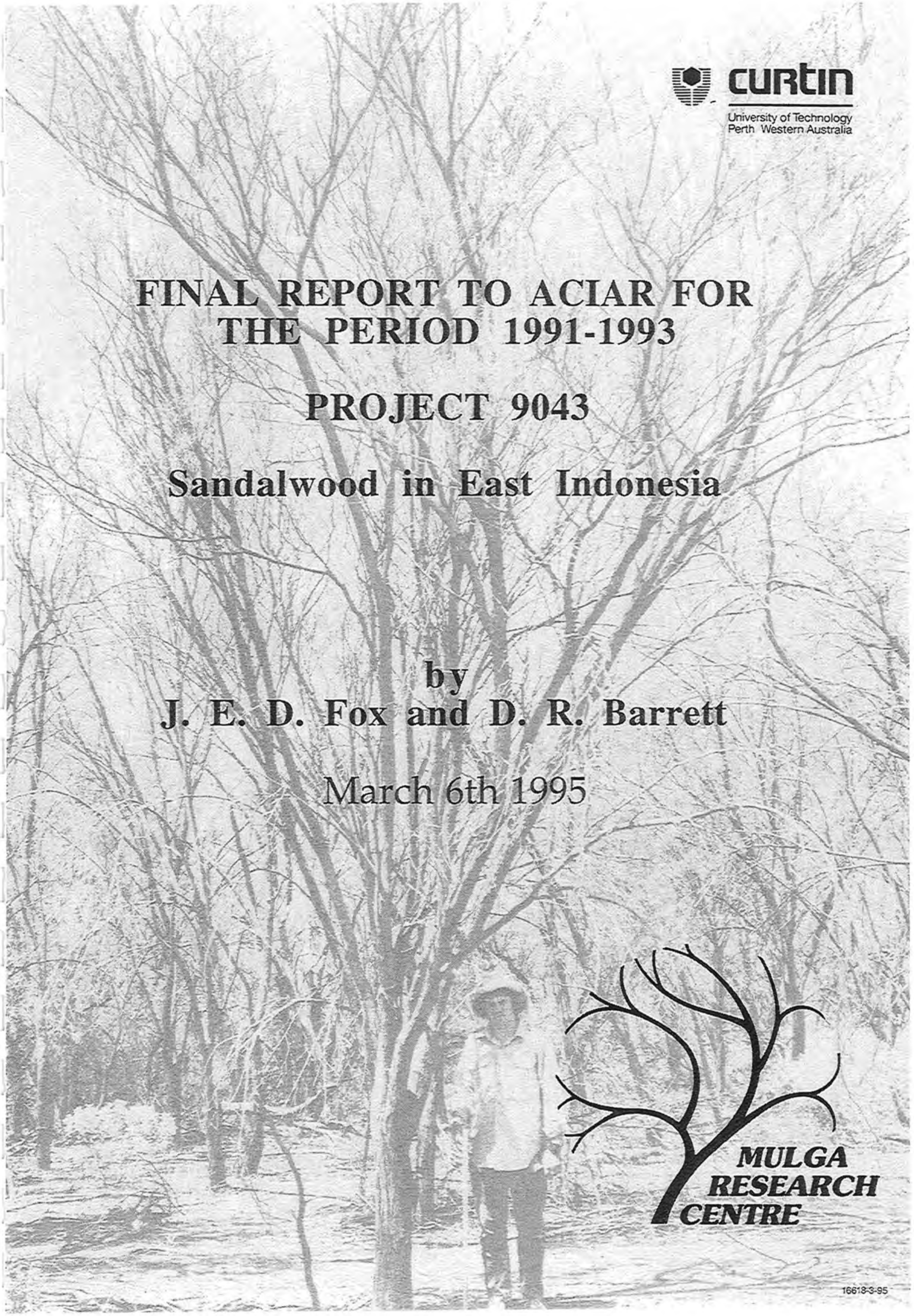
FINAL REPORT TO ACIAR FOR THE PERIOD 1991-1993

PROJECT 9043

Sandalwood in East Indonesia

by
J. E. D. Fox and D. R. Barrett

March 6th 1995



MULGA RESEARCH CENTRE

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FINAL REPORT TO ACIAR FOR THE PERIOD 1991-1993

PROJECT 9043

J. E. D. Fox and D. R. Barrett

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FINAL REPORT TO ACIAR FOR THE PERIOD 1991-1993
PROJECT 9043

INTRODUCTION.

Research into cultivation of sandalwood, *Santalum album*, under programs sponsored by the Australian Centre for International Agricultural Research (ACIAR) has now run for two consecutive three year periods and included a number of important aspects. Some work, adequately covered in the first three years, was not continued in the second period; other work extended over six years and a few projects were initiated in the second triennium.

The objectives of ACIAR project 9043 which ran from 1991 to 1993 inclusive, were to:

1. develop a reliable technique for sandalwood plantation establishment in Timor using cooperative studies between Curtin University and the Balai Penelitian Kehutanan in Kupang;
2. continue research into methods of management of sandalwood plantations to maximise tree growth and heartwood development;
3. identify, protect and test 100 candidate parent trees of superior quality in West Timor. A considerable number of plus trees is required to sustain a serious program of cendana regeneration in Nusa Tengara Timor province.

SUMMARY OF ACIAR PROJECT 8613 (1988-1990).

Work was carried out in Timor and in Western Australia (Perth).

Candidate plus tree selection criteria were standardised for Timor. Field graphs, taking into account relative heartwood and sapwood widths, girth, bole height and volume were drawn up to assist in the selection of potential plus trees. A large number of mature trees was screened and about 50 potential plus trees were identified, located on maps, tagged and photographed. The Netpalen area was identified as a particularly valuable source of candidate trees, and the Siso area as poor in potential plus trees. Seed from some of the candidate trees was used to produce a limited number of seedlings. These were planted out, mainly at Oilsonbai.

The optimum temperature for germination (25^{o}C) was determined. It was demonstrated that certain seed pre-treatments (soaking in gibberellic acid and knicking the seed coat), assist the rate of germination. Pre-treatment is not considered necessary in Timor when seed supplies are adequate.

The first three years saw the screening of at least forty potential pot hosts among the four nurseries in Timor, the selection of the best soil mixture for use at the nurseries and the demonstration that height was a good indicator of overall plant growth. *Desmanthus virgatus*, *Crotalaria juncea* or *Alternanthera* cv., as pot hosts enabled sandalwood seedlings to grow more rapidly in the nursery than other species tested and are superior to the traditionally used *Capsicum frutescens*. Subsequent field performance (over 4 years) is best with those sandalwoods initially hosted to *D. virgatus*. In Timor conditions this species was found to be the best pot host species. It is additionally valuable in that it also has the capacity to function as an intermediate field-host for sandalwood.

'No-host' treatments always performed poorly and should be discontinued. Plastic potting bags should be large enough (200 mm diameter) to accommodate both sandalwood and host without overcrowding. Overwatering, (seedlings should be moist but not sodden), slugs and caterpillars were identified as potential nursery and establishment problems.

Inspections of natural areas showed *S album* to be associated with *Albizia chinensis, A lebbek, Acacia leucophloia* and *Casuarina younghouniana* as long term hosts. Planted *Cassia siamea* was also noted as a good host. Nursery grown sandalwood seedlings were planted out into field sites with a range of short and longer term hosts with a view to assessing comparative performances. Some sites had no long term hosts at planting out and these were to be added later.

Shade, humus and leaf litter were shown to be clearly beneficial for young seedlings in the field. Signs of leaf galling (*Cyanopsis*), fungus, mealy bug and soil mineral deficiencies were evident on foliage in some areas.

Allelopathy was not a problem but it was noted that sandalwood did not grow with *Eucalyptus alba*.

Growth rate (mean girth increased 6 mm per year) and heartwood oil yield (1.2-3.7%) were determined for a number of existing older trees. Tree height and volume were shown to be highly correlated with oil content.

Other studies involving fertiliser trials and planting out methods had not been successful or results were indefinite. In other cases, conclusions were limited by poor quality nursery stock, plastic tubes and potting mixes. Larger and more complicated experiments, with several variables had most problems and should be avoided in future. Environmental factors such as over-abundant grass and other weed growth, fire, cattle intrusion or human encroachment (particularly gardening activities) caused problems and suggestions were made to overcome these problems. Protected areas, for example, Government reserve land, may be most suitable for trials and plantation sites.

Some of the work of the first 3 years was written up during the period of that project (see Fox and Barrett 1991). The remainder was written up as part of the work of the second triennium.

REPORT ON RECENT ACIAR PROGRAM NO 9043 (1991-1993).

A. GENETIC STUDIES

Santalum album is one of Indonesia's most valuable trees. From a scientific viewpoint, conservation of the germ plasm of the species is vital. From an economic perspective it is important to ensure that material of superior genetic stock is preserved from harvesting so that plantations can be made using genotypes which meet the criteria established in the first 3 year project (1988-1991).

A1. Genetic variation - Anthony, Fox and Barrett (1993); Brand (1993); Brand, Fox and Markum Effendi (1993a); Brand, Fox and Markum Effendi (1993b) and Fox and Barrett (1992); Anon (1992).

Natural populations differ in having big leaf and small leaf forms. Heartwood was poor in some areas. Some populations may have a low genetic base. In a comprehensive survey of candidate plus trees in Timor, Markum Effendi located additional candidates at Netpalen and collected seed of a number of selected trees. Jon Brand assisted with field work in Timor and performed morphological and isozyme studies in Perth. Natural variation within and between populations was assessed by comparison of stands of trees in different localities. These studies provided good initial information as outlined below.

Big and small leaf trees in Timor do not appear to be separate varieties in a genetic sense, although there are significant differences in leaf length, width, length/width ratio, area, dry weight, petiole length and diameter, and stomatal number within and between populations. Oenlasi, Niki Niki and Buat populations had the largest leaves, Siso and Netpalen the smallest. Big and small leaf populations have similar heartwood content ranges. Leaf size differences do not appear to be related to altitude. Progeny from seed of parents with the two leaf types were genetically similar. Their chlorophyll contents were also similar to the parent and not related to altitude.

Netpalen populations had greater heartwood percentage and tree size than other populations. Indications are that altitude may have an effect on heartwood production, but this may be related to the residual nature of the presently superior populations at higher altitudes. Heartwood content is dependent on tree size: as the stem diameter increases so does heartwood area. About 80% heartwood at 1.3 m appears to be the maximum.

Mean seed weight and diameter are significantly different within and between *S album* populations. Greatest values come from Netpalen but these parameters are not related to altitude. Germination values are highly variable with medium to large seeds germinating faster and in greater percentages. Seedling height, leaf number, internode length and hypocotyl diameter at 12 weeks, are not significantly affected by seed size.

There are only small genetic differences *between S album* populations in West Timor, although four groupings are apparent:- Netpalen, Ajaubaki & Siso; Buat, Niki Niki; Oenutnanen; Oenlasi. The proportion of genetic diversity *within S album* populations was much higher than between the populations in West Timor. This suggests that a single large population such as Netpalen would contain much of the gene pool. However, several population groups must be conserved. Genetic differences between seedlings from parents with different levels of heartwood or leaf sizes were not detectable using isozyme analysis applied to a set of discrete *Santalum album* populations. A large genetic distance was detected between West Timor and Indian *Santalum album* populations indicating that there is a case for the two populations to be considered as separate varieties or races.

Other trials have shown that prior to sowing, or storage, it is necessary to clean off the outer fleshy mesocarp. Testa colour (endocarp) is linked to efficiency of seed cleaning and darker seeds are more prone to contamination by bacteria or fungi. In the laboratory a constant temperature of 25^{o}C provides favourable conditions for growth. Germination tends to be staggered in time and various treatments such as nicking the seed testa or soaking in gibberellic acid enhance germination. Such treatments are only necessary when seed is in short supply or very uniform plants are required for experimental purposes. Viability differs with provenance and storage time. If stored under dry, refrigerated conditions fresh seed remains viable for at least a year.

Presentations of work done were made at the recent Sandalwood Seed, Nursery and Planting Technology Conference in New Caledonia which included discussion of practical aspects of performing electrophoresis and germination trials (Fox 1994b,d; Fox, Brand Barrett and Markum Effendi 1994a,b).

A2. Plus tree program - Markum Effendi (1992).

The aim was to conserve a sufficient number (about 200 eventually) of candidate plus trees representing all areas where the species ocurs although isozyme studies (section A1 above) suggest a single large population, such as Netpalen, will contain a good proportion of the gene pool so far investigated. A further 58 candidate plus trees have been identified, mainly at Netpalen. Further candidate trees should be sought in East Timor. Nothing is currently known of the genetic variability between populations in East and West Timor. So far just over 100 trees have been selected. All these have been marked and had their positions plotted on a map. Records were made for the Forestry Research Institute and the trees secured by notifying Government authorities and local peoples. The total seed collected from each candidate plus tree year by year is being noted.

A3. Progeny trials - Markum Effendi and Komang Surata (1993a,b).

In the short term the aim was to establish sets of progeny from superior trees and test their characteristics. In the long term it was hoped to establish seed collection stands or orchards of valuable stock. So far 5,888 seedlings have been planted on 5.2 ha. Of these nearly 2,000 survive (33%). Assessment needs to be longer term before definitive conclusions can be drawn as to site suitability and particularly progeny performance. Unless longer term hosts exist or are provided, sandalwood will not persist until of harvestable age. Establishment sites chosen were at different altitudes with different soil types.

A4. Progeny trial sites, plantings and survival (as of March 1994)

- **Oilsonbai** (0.2 ha, fenced, Bobonaro clay, low altitude, established 1990/91). The site tends to be wet but has *Acacia auriculiformis* long term hosts. Three hundred and thirty seedlings (with *Desmanthus virgatus*. pot hosts and *Acacia villosa* field hosts) from 11 different parents were planted. Progeny from each parent were planted in separate lines. Twenty percent survive.
- **Sikumana** (1 ha, unfenced, coastal, raised coral terrace, red soil, established 1993). Eleven hundred seedlings (with *Alternanthera* sp. pot host) from 47 parent trees were planted. *Acacia villlosa* was used as the site host. The site was burned subsequent to planting and although large numbers of *A villosa* survived over 1,000 sandal progeny died. This site will have to be replanted. There are no long term hosts on site.
- **Burean** (0.5 ha, unfenced, in hills near Kupang, intermediate altitude (*c.* 600 m), Bubonaro clay, established 1993). This site was in a dip and overgrown with *Imperata* grass. Nearly all seedlings died, probably because the site was too wet and there was too much competition. Of 500 sandal (with *Alternanthera sp.*pot hosts and *Acacia villosa* field hosts) planted from 47 parents, 40 remain alive. There are no long term hosts on site. It was suggested that legumes, *A villosa*, *A mangium* or *Cassia siamea* could be planted into the grass preparing the site for *S album* in a few years time or alternatively that the site should be abandoned. An adjoining site which has existing *Cassia siamea* may be much more suitable for sandalwood.
- **Camplong** (1.5 ha, fenced, forest reserve with squatters, intermediate altitude, Bubonaro clay, established 1994). Twenty four parent trees were represented in the 1,750 seedlings planted (with *Alternanthera sp* pot hosts and *Acacia villosa* field

hosts). Seedlings were planted at 2x3 m spacing in this trial, in random blocks of 25 seedlings each from the same parent. Fourteen hundred seedlings (80%) survive. There are no long term hosts on site and there is much weed and grass growth.

- **Oelbubuk** (2.0 ha, fenced, in the Soe region, highest altitude (*c.* 900 m) Bobonaro clay, established 1993). This trial has been hindered by gardening activities. The clay soil and high rainfall are potential problems. However, it is a useful area and has the advantage of having existing Teak and *Casuarina younghouniana* as long term hosts. Two thousand two hundred sandalwood have been planted with *Acacia villosa* field hosts. To date there is 20% survival.

A summary table of candidate plus tree progeny plantings is given in the Appendix 1.

B. SILVICULTURE

The aim of this work was to develop methods which allow a high proportion of individuals to persist to maturity in artificial stands. This should allow for maximum growth in the most effective, speedy and efficient way. It was considered a good idea for Mr Komang to extend his co-operation with Perhutani (Government Department of Forestry) since he could pass on successful techniques to assist in improving their poor record at growing sandalwood. A number of pilot plantings and trials have been established over the last 6 years. The aspects being investigated are:

B1. Secondary hosts - Fox, Doronila, Barrett and Komang Surata (1995a) and Komang Surata (1992b)

This is necessarily a long term project but the aim is to confirm the suitability of possible hosts in sustaining sandalwood in a range of sites suitable for plantations. Fast growing tree hosts with economic importance of their own (such as timber trees) are to be preferred.

B2. Early tending - Fox, Barrett, Komang Surata and Markum Effendi (1995b); Fox 1994e; Fox, Doronila, Barrett and Komang Surata (1995b); Barrett and Fox (1993); Komang Surata (1993a and b); Komang Surata (1992a and b); Sutarjo Suriamidhardja, Komang Surata and Fox (1991); Sutarjo Suriamidhardja, I Komang Surata and Kharisma (1991); I. Komang Surata (1991)

A guide to common nutrient deficiency symptoms in seedlings ofS *album* was produced in Perth. Procedures which have been found to be most successful for enhancing survival and growth over the first three years were catalogued. Studies on the efficiency of weeding, mulching and other methods of competition reduction and the frequency with which this needs to be done, were initiated. These findings are incorporated into the protocol given below.

B3. Shade control - Barrett and Fox (1994); Anthony, Fox and Barrett (1993); Fox and Barrett (1992); Komang Surata (1992a); Kharisma and Sutarjo Suriamidhardja (1991)

Experiments were sought to quantify shade regimes most beneficial to early growth and survival of sandalwood for both the nursery and plantation. From this it is hoped to develop criteria for thinning host plantations to best favour *S album* growth. Shade is definitely beneficial in terms of growth and survival at the seedling stage and until adequate host connections have been made in the field. Thereafter the sandalwood becomes more heliophilous and sunny conditions promote best growth.

B4. Stocking levels - Komang Surata (1993a,b)
The aim was to investigate the stocking levels attainable on different soils with a range of hosts so as to provide guidelines for spacing and host arrangement when sandalwood is planted. Some sandalwood plantings were made at 3x3 m spacings (Oilsonbai), others at 2x3 m (Camplong). Spacing should be 3x3 until a better distance level is found.

So far 40,810 seedlings have been planted on some 38.5 ha. Of these 14,200 survive (34%). In many cases assessment needs to be longer term before definitive conclusions can be drawn as to suitability of site and techniques. Unless longer term hosts exist or are provided, sandalwood will not persist until of harvestable age. This work involved Ir Sutarjo Suriamihardja, Ir Komang Surata, Ir Markum Effendi and Professor John Fox.

B5. Pilot plantings and survival (as of March 1994)

- **Fatukoa** (2 X 5.0 ha, fenced, in the Soe region, greatest altitude (*c.* 900 m) raised coral terrace, established 1992/3 and 1993/4). Eleven thousand seedlings have been planted (*Alternanthera sp* pot hosts and *Acacia villosa* field hosts). Sixty five percent survive (7,150 individuals). Problems include the coral rock soil, fire and the absence of any long term hosts. Intercropping (corn and subsistence crops) occurs.
- **Oilsonbai** (>1.0 ha, fenced, Bobonaro clay with low fertility, low altitude, established 1989/90/91). Two thousand and sixty seedlings were planted. Longer term field hosts (*Acacia auriculiformis.*) were present on the site. Different pot hosts were used in the 89/90 plantings (as reported in the first 3 year report) and 30% have survived to date. Hosts may also need tending (*e.g. Duranta repens* has grown very vigorously and is overshadowing the sandalwood). This planting was also used to compare growth of sandalwood in 4 different shade regimes caused by lopping off increasing numbers of branches from the long term hosts. In March 1994. Ir Komang indicated from visual inspection that the most sunny regimes were best but height and diameter measurements, and susceptibility to infection were being noted for longer term assessment. Competition reduction by regular grass pulling or cutting (with and without mulching) was compared with an untended (control) plot. Regular inspection for signs of pests and disease showed that some sandalwood trees in this trial were infected with *Cyanopsis* (tight leaf curl/galls especially on upper leaves and stems) and some leaves had yellow/red leaf spot fungus. Ir Komang liaises with entomologists in Bogor. He has taken no action at Oilsonbai as he has observed that the infections disappear naturally after a year or so.
- **Kefamenanu** (0.5 ha, unfenced, old, red soil with N deficiency, established 1993). Five hundred and fifty seedlings were planted (*Alternanthera sp* pot hosts and *Acacia villosa* field hosts) but there were no long term hsts on site. So far there is 75%

survival. Intercropping by villagers with *Cajanus cajan*, mung beans and peanuts is seen as advantageous by Ir Komang as grass and weeds are kept in check.

- **Fatukanutu** (Perhutani) (25.0 ha, unfenced, raised coral terrace, established 1994). This trial is a pilot plantation in co-operation with the government. Of 27,500 seedlings (*Alternanthera sp* pot hosts and *Acacia villosa* field hosts) put in with existing long term *Cassia siamea* field hosts 20 5% survive (5,500 individuals).
- **Netpalen** (1.0 ha, unfenced, Bobonaro clay, established 1991). Eight hundred seedlings were planted (*Alternanthera sp* pot hosts and *Leucaena leucocephala* field hosts) into a site with *Acacia leucaenea* and *Casuarina younghouniana* long term hosts. One hundred remain (12% survival). The wetness of the site is seen as a problem.
- **Buat** (Nursery only, local soils are clay). A recently established trial here essentially repeats an earlier experiment conducted at Kefamenanu in the first ACIAR project. That was a failure. Outside the glass house at Buat, under shade cloth, root cutting trials with root sections of 10-20 mm diameter, were taken from local trees and put into sand beds either horizontally or vertically and watered twice daily. Different root lengths (50, 75, 100, 125 and 150 mm) were used. Only 6 cuttings grew and they had all been vertically placed. Lengths of 100-150 mm developed most successfully. A similar trial was conducted within the glass house but using a mixture of 1:3 sand:local soil, only vertical cuttings and additional lengths of 175 and 200 mm. Only a few cuttings grew and they were from the 100-150 mm length cuttings. The soil tended to cake, although watered twice daily.
Sikumana nursery is far better for nursey work because the local soil is not clay and rainfall is not as high, even if transport distances to planting sites are greater.
- **Nevonaek** (nursery trial only, established 1992/3). This was a trial by Ir Komang to contrast growth with and without the addition of cow dung to the potting mix. He concluded that cow dung is beneficial.

PROTOCOL FOR *S ALBUM* ESTABLISHMENT IN TIMOR.

A formalised set of procedures was developed as a result of the ACIAR project findings for growing *S album* in Timor. These may be modified as ongoing trials provide more information. For clarity these are given in point form:

1. Plant seed in June using either 3 seeds to a pot (as is the usual practice in Timor), or in trays. The Timor practice is acceptable where sufficient viable seed is available.
2. Use local soil mixed with coarse river sand in proportion 5 to 3 for pots at Oilsonbai and Sikumana. Soil for other areas has not been tested but some sand in admixture is probably advisable.
3. Use large pots - 200 mm top diameter X 200 mm high.

4. Use *Desmanthus virgatus* or failing that *Alternanthera* or *Crotalaria juncea* as pot hosts. *Acacia villosa* is also acceptable.
6. *S album* seedlings should be >250 mm high and have some brown bark at field planting time. Seedlings are usually about 6-7 months old at this time.
7. Plant out seedlings in late December (dry sites - Oilsonbai & Sikumana), at the beginning of the rains when soil N at its highest. In wetter sites (higher altitude, inland *e.g.* Kapan) planting can be done at other times but the best times are not known.
8. Intermediate and secondary (field) hosts are obligatory. *Acacia villosa* is a good intermediate host and *Cassia siamea* a good secondary host. The relative value of other potential secondary hosts is not known but possibilities include: *Acacia oraria, A auriculiformis, A leucophloia, A catechu, A crassicarpa, A mangium, Paraceríanthes spp, Pterocarpus ndicus, Casuarina younghouniana* for dry areas and *Sesbania grandiflora, Adenanthera pavonina* for wetter or watered places.
9. Plant *S album* about 500 mm away from secondary hosts if the hosts are planted at the same time or about. 2 m away if the host is already there.
10. Put *Acacia* hosts in 1 - 2 years before *S album.* Other hosts should be planted 2 - 3 years prior to *S album.*
11. *S album* seedlings should be shaded for the first year or so (about 50%) for best survival
12. Heavy ground cover should be removed.
13. Land for planting should be wooded, not grassy. If grassy, it should be planted with potential host trees first. It should be representative of other areas where larger plantings can be done later if suitable. Land about which the soil and vegetation status is already known is preferred. If land of unknown status its status should be described. Protected land (forest reserve land) where sandalwood has grown in the past may be suitable but the suitability must be balanced against the detrimental effects of interference in scarce remaining natural forest.
14. Land should be fenced for a minimum of 3 - 5 years.
15. Fire control is essential (weed control, control burning, 5 m fire breaks).
16. Early tending during the wet season is necessary so that the sandalwood is not shaded and smothered.
17. Mulching in dry sites advantageous.
18. Artificial watering should only be considered in rare cases - *e.g.* commercial enterprises or in very special small trials or possibly in extreme, unusual, short term weather conditions.
19. Spacing should be 3x3 m until better found or unless overplanting (*e.g.* 1 m spacings)
20. Fill in deaths from first planting in next year or overplant in the first planting.

21. Seedling height is highly correlated to dry mass (ie growth) so height can be used as an estimate of seedling vigour.
22. Tree height and volume are highly correlated to oil content so oil can be can estimated in the field.
23. Some gardening is allowable in some soils and in some rainfall areas for up to 2 years only. But, gardening is to be kept out of all experimental plots.
24. Pests and diseases should be investigated and identified at Bogor.
25. Prior planning in detail and ongoing record keeping is to be standardised at a high level.
26. Good team work must be encouraged.
26. Leadership must be strong with continuing thorough supervision ensuring that instructions are carefully followed.

A more generalised protocol for the early stages was presented at the ACIAR sponsored Sandalwood Seed, Nursery and Planting Technology Conference (Fox 1994e) and occurs in the conference proceedings (Fox, Barrett, Komang Surata and Markum Effendi 1995b). Another version is published elsewhere (Fox, Barrett, Brand and Markum Effendi 1994).

Other important experimental procedures used, results obtained and ensuing issues relating to the sandalwood projects were also presented at the Sandalwood Seed, Nursery and Planting Technology Conference. Presentations and papers resulting largely from the first 3 year project considered the relationship between heartwood content and tree size (Fox 1994d; Fox, Brand, Barrett and Markum Effendi 1994b); growth and yield in relation to silvicultural characteristics (including a review of spike disease) (Fox 1994f; Fox and Barrett 1995); dormancy and germination of *S album* seed (Fox 1994c; Fox, Barrett, and I Komang Surata and Markum Effendi 1995a); the selection of superior pot hosts for maximum growth (Fox 1994g; Fox, Doronila, Barrett and I Komang Surata, 1995b). Germination trials were published elsewhere (Fox, Barrett, Brand, and Markum Effendi 1994). Each of these presentations and papers included discussions of practical aspects of performing the trials and tests described.

A further paper outlining the general distribution of the family Santalaceae and in particular the species *Santalum* was presented (Fox 1994a) and appears in the proceedings of the conference (Barrett and Fox 1995).

ASESSMENT OF THE PAST PROGRAMS.

The stated objectives were largely achieved. There has been good cooperation resulting in institution building, in-service training, research skill development, writing and reporting. This benefits both Australia and Indonesia. The findings have been very useful for the long term aim of establishing plantations and providing safe reserves.

The following aspects have been investigated: nutrition and deficiencies, the suitability of different shade levels, trialling of plantation hosts, estimates of suitable stocking density, benefits of large *versus* small seed, comparison of Indian seed with Indonesian seed. Oil testing of candidate plus trees has not yet been started but should be undertaken as soon as the remaining 50 candidate trees have been designated. Important aspects of the collaborative program included training of Indonesian researchers in methods and procedures. An example of excellent technique developed comes from the plus tree seed collection and labelling by Markum Effendi. The work was carefully and reliably performed without supervision.

An MSc thesis and other publications are already available (see publication list). Considerable cooperation was obtained between the Indonesian and Australian researchers in relation to joint publication work. Our initial understanding of inter-relationships between genetically and environmentally acquired characteristics and differences between and within *S album* populations has been considerably improved.

Administrarion has been satisfactory. We would have benefitted from more discussions and feedback from ACIAR, in particular in relation to the finalising of the project, where considerable confusion resulted from mistaken signals. In retrospect, the Sandalwood project would have been more effectively run as a stand alone effort. No cross-referencing was noted from the fuelwood component.

SUGGESTED FUTURE WORK.

1. Finish locating and safe-guarding more candidate plus trees - 100 was the original target for this project.
2. Undertake candidate plus tree selection in other areas (*e.g.* East Timor and possibly Sumba).
3. Maintain tree markings, records (including fruit collection) *etc.* and update regularly.
4. Investigate the level of germination of *S album* at different ages of parent tree. This has importance for seed collection and determination of sowing rates.
5. Oil testing of candidate plus trees (as a contributing factor for determining eventual plus tree status) should be done in conjunction with progeny evaluation.

6. Investigation of the genetics of heartwood production (longer term study is needed).

7. Possible genetic indicators of future heartwood content, possibly present at an early stage (even in seedlings), should be investigated by isozyme work.

8. Nursery culling and higher density planting should be considered.

9. The most suitable pot soil mixture for Soe and Kefamenanu nurseries to be determined.

10. The best times for planting out seedlings in wetter sites should be determined.

11. Trials with planting in different levels of intermediate host (eg *A villosa*) spacing/shade for early shade requirements in field.

12.The Forest Department must secure Netpalen as a safe perpetual reserve.

13. Ownership, disposal, tax and royalty matters should be resolved to allow scope for private development of plantations.

14. Curtin has substantial resource material and research expertise which should be used in similar cooperative projects.

15. Differences and similarities between Indian and Timor *S album* populations could be further investigated.

16. Continue assessing (and possibly extending) trials already underway and keep good records. Six monthly for the first few years and then yearly and later 3-5 yearly assessments would be reasonable.

17. Ensure that all work done so far is written up and available for future use. This is very important in order to maximise information obtainable from work done.

PUBLICATIONS RESULTING FROM ACIAR PROGRAMS.

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Anon (1992). Tree improvement and provenance trials of sandalwood in Nusa Tenggara Islands. Research News ***Savana*** **7**, 37-40.

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Barrett, DR and Fox, JED (1993). *Santalum album*: Photographic record of nutrient deficiency symptoms in seedlings. ***Aisuli*** **6,** 1-26.

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Brand, JE, Fox, JED and Markum Effendi (1993a). Variation in seed size and germination of *Santalum album* (L.) population in NTT'S Timor. ***Santalum*** **12**, 37-49.

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Fox, JED (1994d). Heartwood and tree size in *Santalum album* in Timor, Indonesia. **Presentation at Sandalwood Seed, Nursery and Planting Technology Conference. Noumea, New Caledonia.** 31 Jul - 12 Aug 1994.

Fox, JED (1994e). Protocol for establishment of *Santalum album* in Timor, Indonesia. **Presentation at Sandalwood Seed, Nursery and Planting Technology Conference.** 31 Jul - 12 Aug 1994.

Fox, JED (1994f). Silviculture of sandalwood. **Presentation at Sandalwood Seed, Nursery and Planting Technology Conference.** Noumea, New Caledonia. 31 Jul - 12 Aug 1994.

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APPENDIX 1.

Santalum album planting sites, Timor NTT, Indonesia. (1990 - 1994)

PLUS TREE PROGENY

Site (F=fenced)	Size (ha)	Soil type	Date estab-lished	Parent trees represented (no.)	*S album* planted (no.)	*S album* surviving (no.)	Survival (approx-imate)	Original pot host	Site host(s) at planting	Long term field host(s)	Problems with site	Advant-ages of site	Comments
1 Sikumana low altitude	1.0	Raised coral terrace (red soil?)	1993	47	1100	10	1%	*Altern-anthera sp.*	*Acacia villosa*	none	fire burnt entire site		Site atop rounded, rocky coraliferous hillock. Red soil. Pot hosts mainly alive. May be less than 10 alive. Komang intends planting C siamea as S album long term hosts in 1997
2 Camplong F medium altitude	1.5	Bobonaro clay	1994	24	1750	1400	80%	*Altern-anthera sp.*	*Acacia villosa*	none except few large Eucalyps	weeds/grass incl.Cynodon? & yellow pea flowered - scrambling twiner		Pots had 3 Sikumana red soil:1 sand. Intercropp-ing (Tampang sari) & corn. Site too open. Markum to make individual shade houses for dry, hot season No dry season yet. No long term host plans. 2X3 m spacing. Random blocks, each 25 trees same parent. 3 replicates of each block. Is forest reserve/squatters
3 Oelbubuk F highest altitude (c.900 m)	2.0	Bobonaro clay	1993	47	2200	440	20%	*Altern-anthera sp.*	*Acacia villosa*	*Teak & Casuarina young-houniana*	clay soil with high rain	existing hosts	See region.
4 Oilsonbai F	0.2	Bobonaro	1990/91	11	330	66	20%	*Desmanthu virgatus*	*Acacia villosa*	*Acacia auric-uliformis*	clay soil/ wet		Two trials here - plus tree and other pilot planting. Progeny from each parent in one row - ie lines of progeny from single parent
5 Burean medium altitude (c.600 m)	0.5	Bobonaro clay?	1993	47	500	20	4%	*Altern-anthera sp.*	*Acacia villosa*	none	Imperata grass too wet, located in a dip		
Total plus trees	**5.2**				**5888**	**1936**	**33%**						

APPENDIX 1. (continued)

Santalum album plantings, Timor NTT, Indonesia. (1990 - 1994)

PILOT PLANTINGS AND TRIALS (NOT PLUS TREES)

	Site (F=fenced)	Size (ha)	Soil type	Date estab-lished	*S album* planted (no.)	*S album* surviving (no.)	Survival (approx-imate)	Original pot host	Site host(s) at planting	Long term field host(s)	Problems with site	Advant-ages of site	Comments
6	Fatukoa F (BPK/Dinas)	5.0 5.0	Coral raised terrace	1992/3} 1993/4}	11000	7150	65%	*Altern-anthera sp.*	*Acacia villosa*	None	coral rock fire		Alternanthera persisting to date. Intercropping, corn etc here.
7	Oilsonbai(1)	1.0	Bobonaro clay not as rocky as Fatukoa,	89(few lived) 90(replant)	960	307	32%	10 different pot hosts		*Acacia auric-uliformis*	Low soil fertility	existing long term hosts	Trial used to compare shade regimes created by lopping branches (Jan 94) off long term host. Some trees, in rows near-est fence to right of gate had Cyanopsis (tight leaf gall form-ing/curl, especially on upper leaves and stem), others had and /or leaf spot-yellow/red fungus. Komang says diseases go natur-ally after about 1 year.
	Oilsonbai(2)	1.0?	more soil.	1991	1100	750	68%	*Desmanthus* virgatus					
8	Kefamenanu	0.5	Old, red soil, w N deficiency	1993	550	412	75%	*Altern-anthera sp.*	*Acacia villosa*	None			Intercropping by villagers with C cajan, mung bean & peanuts seen as advantageous by Koman; - keeps down grass & weeds
9	Fatukanutu (Perhutani)	25.0	Coral raised terrace	1994	27500	5500	20%	*Altern-anthera sp.*	*Acacia villosa*	*Cassia siamea*			Pilot plantation
10	Netpalen	1.0	Bobonaro clay	1991	800	100	12%	*Altern-anthera sp.*	*Leucaena leuco-cephala*	*Acacia leucaenea Casuarina younghou-niana*	wet		
11	Buat	Nursery only operative - root cuttings and layering trials. Under outside shade cloth: Root sections (1 - 2 cm diameter) taken from local trees and put into sand beds either horisontally or vertically. Different root lengths tested - 50, 75, 100, 125, & 150 mm. Watered twice daily. 100 - 150 mm lengths best. Only 6 (all vertical) out of 50 in all grew Inside nursery: similar trial but using bags of 1;3 sand:local soil and only vertical cuttings. Used same lengths but also 175 & 200 mm. Used 100 of each length (7X100 pots). Only few from 100 - 150 mm lengths grew. Soil caked, watered twice/day. Sand better than soil mix such trials. Markum and Komang say Sikumana is much better for nursery work than Buat (or other clay areas), even if seedlings have to be transported further. No field plantings here in second 3 years of program.											
12	Nevonaek	This is a nursery trial by Komang (1992/93)to contrast growth with addition of cow dung with no additioı He found cow dung gave better results. He used Alternanthera sp. pot hosts.											
Total non plus trees		**38.5**			**41910**	**14219**	**34%**						

APPENDIX. 2

Abstracts of papers presented at the New Caledonia Workshop 1994.

1. **Germination of Seed of *Santalum album*.**
2. **Establishment Procedures for *Santalum album* in Timor**
3. **Heartwood and Tree Size in *Santalum album*.**
4. **Genetic Variation in *Santalum album***
5. **Superior Pot Hosts for Maximum Nursery Growth in *Santalum album*.**
6. **Botanical Characteristics of Santalaceae**
7. **Silviculture of Sandalwood**

Germination of Seed of *Santalum album*.

to be presented by
Associate Professor John E. D. Fox
School of Environmental Biology
Curtin University of Technology, Perth, WA 6001, Australia
and Australian Centre for International Agricultural Research

ABSTRACT

Ripe seed of *Santalum album* is contained within a large fleshy fruit. The flesh is attractive to birds and, if not removed, imposes an inhibition to germination of a physical nature. Prior to sowing, or storage, it is necessary to clean off the outer fleshy mesocarp. Testa colour (endocarp) is linked to efficiency of seed cleaning and darker seeds are more prone to contamination by bacteria or fungi. In the laboratory a constant temperature of 25°C provides favourable conditions for growth. Germination tends to be staggered in time and various treatments have been used to speed up germination.

Treatments of nicking the seed testa or soaking in gibberellic acid enhance germination. These are only necessary when seed is in short supply or very uniform plants are required for experimental purposes. Viability differs with provenance and storage time. If stored under dry, refrigerated conditions fresh seed remains viable for at least a year. Seed weight and size differ between trees of different areas. Seeds from individual trees also differ in germination and smaller seeds germinate less well than larger seeds.

Cirad Forêt, Nouméa

Establishment Procedures for *Santalum album* in Timor

to be presented by
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and Australian Centre for International Agricultural Research

ABSTRACT

Raising of seedling plants of *Santalum album* for satisfactory plantation establishment involves consideration of seed supply and handling, potting mixtures and nursery practice. Procurement and handling of good quality sandalwood (*Santalum album*) seed is crucial to the development of satisfactory plantations. Seeds are relatively large (100 - 200 mg) and are prone to fungal attack under moist seed bed conditions or when sown in organic mixtures. Selection of suitable potting materials is constrained by local availability of sources. Free draining mixtures which allow satisfactory root development are to be preferred. In the absence of marked soil deficiencies little advantage is derived from fertiliser addition. Limited quantities of organic matter may be usefully added to the soil mixture.

Young plants appear to benefit from shade but full sun is not necessarily disadvantageous and routine planting is best planned on a grid system for ease of tending. The timing of nursery operations is geared to producing plantable seedlings of > 25 cm height at the commencement of the wet season in December. Planting holes should be prepared early. Planting into established stands of field hosts, where root competition has not developed to the full extent, will allow sandalwood plants to parasitise host roots while growing conditions are favourable.

Heartwood and Tree Size in *Santalum album.*

to be presented by
Associate Professor John E. D. Fox
School of Environmental Biology
Curtin University of Technology, Perth, WA 6001, Australia
and Australian Centre for International Agricultural Research

ABSTRACT

Heartwood present in individual *Santalum album* trees differs between trees of the same age and size. Light brown heartwood contains most oil. Distinct colour differences between sapwood and heartwood are utilised in allocation of trees for harvesting and in surveys of standing trees to contrast anticipated value of individuals for seed collection. Designation of plus tree status implies high quality based on characters such as fast growth, high heartwood content at an early stage of growth, straight boles as well as flowering and fruiting ability. Such trees will form the nucleus of a tree improvement program for West Timor, Indonesia.

A survey of 76 felled trees of *Santalum album* indicated that % heartwood of the cross sectional area at 1.3 m in excess of 60% is at the upper end of the current range. A recent survey of 174 trees in the main growing region confirmed most provisionally selected candidate plus trees as among the best available. The extreme upper limit of heartwood is *c.* 70% at 1.3 m for natural stands in West Timor. This study adds evidence to the contention that heartwood % at 1.3 m is a better criterion for selecting candidate plus trees than total heartwood, heartwood area or tree size.

Taller *Santalum album* trees with more heartwood at higher elevations is probably due to these being older than at lower elevations. Trees in the more remote mountainous areas are less accessible and thus less subjected to harvesting attention in the past. These are the areas that now need to be especially reserved to guarantee a genetic base for re-establishment of sandalwood in other localities.

Cirad Forêt, Nouméa

Genetic Variation in *Santalum album*

to be presented by
Associate Professor John E. D. Fox
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and Australian Centre for International Agricultural Research

ABSTRACT

Santalum album occurs in India and Indonesia. As current programs require attention to selection of material for plantation development, it is of interest to document genetic variability. Good heartwood development is considered an important selection factor. Foliar material from seedlings of ten Timor populations and two Indian sources were examined using gel electrophoresis.

Mean expected heterozygosity of *Santalum album* populations in West Timor is relatively low, probably due to its localized distribution. The proportion of genetic diversity within *Santalum album* populations is much higher than between populations. This suggests that intra-population differences are important in selection. A large genetic distance was detected between West Timor and Indian *Santalum album* populations indicating that there is a case for them to be considered as separate varieties or races. Possible genetic differences between seedlings from parents with different levels of heartwood or leaf sizes were not detectable using isozyme analysis applied to a set of discrete populations of *Santalum album* in West Timor, Indonesia.

Cirad Forêt, Nouméa

Superior Pot Hosts for Maximum Nursery Growth in *Santalum album.*

to be presented by
Associate Professor John E. D. Fox
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and Australian Centre for International Agricultural Research

ABSTRACT

Cultivation of *Santalum album* is characterised by high rates of attrition in the nursery and in the field. The hemi-parasitic nature of the species necessitates formation of good haustorial connections between the sandalwood plant and host(s). The traditional nursery host in Timor has been *Capsicum frutescens*, but experimental justification for this species was not available to confirm its' value. When grown with an efficient pot-host, early haustorial connection should enhance both nursery growth and subsequent field survival. We considered that it should be possible to demonstrate differences between potential host species, that some would be better than others and that, if possible, superior hosts could be discovered. Several experiments have been undertaken to contrast nursery performance of *Santalum album* with a range of species as initial- or nursery-stage hosts for plantation establishment in Timor.

Pot-hosts of *Desmanthus virgatus*, *Crotalaria juncea* or *Alternanthera* cv., enable sandalwood seedlings to grow more rapidly in the nursery than other species tested. These species are demonstrated as being superior pot-hosts to the traditional *Capsicum frutescens*. Subsequent field performance, over 4 years, is best with those sandalwoods initially hosted to *D. virgatus.* This species has the capacity to function as an intermediate-host for sandalwood and for Timor conditions it should be the preferred first-stage, or in-pot, host plant species.

Botanical Characteristics of Santalaceae

to be presented by
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and Australian Centre for International Agricultural Research

ABSTRACT

The family Santalaceae is characterised by the parasitic habit and other distinguishing features which are described. There are 37 genera represented in tropical, sub-tropical and temperate regions of both the New and Old World. The nine genera which occur in Australia are briefly described and of these *Santalum* is the most well known. It includes the sandalwood species which are a valuable source of fragrant timber and oils. The Australian species of *Santalum* are described, with greater detail given for those studied at Curtin University: *S album* (effects of shade vegetative growth) and *S spicatum* (flowering and fruiting). Other species of *Santalum* are covered in less detail.

Cirad Forêt, Nouméa

Silviculture of Sandalwood

to be presented by
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and Australian Centre for International Agricultural Research

ABSTRACT

Early survival of the semi-parasitic *Santalum* species in cultivation is poor and dependent on early host connections. N, K, Na, P, Ca, water and amino acids are transferred to sandalwood. Survival and growth is related to the success of haustorial connections. Host plants provide shade and nutrition. Young plants of *Santalum album* thrive in shade. Full sun is not an impediment to satisfactory growth of large plants.

Knowledge is lacking concerning growth and yield of *Santalum album*. Central Java measurements of both planted and natural regeneration areas are presented. Three height classes are proposed to predict productivity by measuring younger stands. Taller trees in young stands are likely to provide the larger trees which will reach harvestable size. Comparison of stem diameters at particular ages indicate that larger trees should grow at least 1 cm per annum, and *S. album* trees in Central Java should reach a mean diameter of 40 cm in under 40 years. Crown /stem diameter ratios fall from c. 50 at 5 cm stem diameter to 40 at 15 cm. As the stands age, stocking levels of large trees of the order of 26 ha^{-1} at 40 cm to 50 ha^{-1} at 30 cm are possible.

The literature on spike disease is reviewed. Sandalwood species appear attractive to a range of fungi and strict attention to hygiene is required in the nursery. When grown as an exotic *Santalum album* seems relatively free of pests and disease although all species are grazed by stock and wild herbivores. Some 150 species of insects have been recorded as using the sandalwood tree in India in various ways. They include Coleoptera 34 species; Hemiptera 74 species; Lepidoptera 29 species; and Thysanoptera 15 species.

APPENDIX 2

COPIES OF SANDALWOOD RESEARCH NEWSLETTER

Sandalwood Research Newsletter

November 1993 | Issue 1 | ISSN 1321-022X

Introduction to the Sandalwood Research Newsletter

Editor: Andrew Radomiljac

As a result of an increasing global demand on *Santalum* species wood and oil products there is increasing exploitation pressure on existing *Santalum* species populations. However, through-out the Asian and Pacific Island countries there is a concerted effort to increase *Santalum* species conservation and plantation establishment (Daruhi 1993, Cherrier 1993, Jiko 1993, Applegate and McKinnell 1993 and Harisetijono and Suramihardja 1993).

Santalum species have high cultural and economical value to a large number of Asian and Pacific Island nations, such as *Santalum album* in Nusa Tengarra Timur, Indonesia. Within Indonesia efforts are being currently undertaken to increase the population size of this valued resource through plantation establishment. Other island nations such as New Caledonia and Fiji also acknowledge the importance of plantations of their native *Santalum* species.

The Sandalwood Research Newsletter (SRN) aims to distribute *Santalum* species literature from nations and their respective research and management organisations. Within many 'isolated' nations their *Santalum* species research and management programs will be enhanced through increasing access to international *Santalum* species literature.

The SRN is an initiative conceived by the Australian Centre for International Agricultural Research (ACIAR).

Increasing *Santalum* species awareness through the distribution of international *Santalum* species literature will:

i) promote *Santalum* species conservation.

ii) stimulate *Santalum* species plantation establishment.

iii) increase *Santalum* species research and management liaison between interested organisations.

iv) increase *Santalum* species literature exposure.

The SRN will become a bimonthly newsletter with distribution ranging through-out all nations currently involved in *Santalum* species research and management.

It is hoped that articles will be received for a range of *Santalum* species research and management issues. If you wish to contribute an article to the SRN or wish to be included on the SRN mailing list, please write to the Editor giving your name, organisation and postal address. All articles on relevant *Santalum* species topics are welcomed.

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inside...

Self and cross pollination in *Santalum Spicatum* and *S. album*

Acharee Rugkhla and Dr Jenny McComb

Acharee Rugkhla, a Thai national, is currently undertaking her Phd studies at the division of Biological and Environmental Sciences, Murdoch University, Perth, Western Australia.
Supervisor: Associate Professor Dr. Jenny McComb.
Phd Thesis: Interspecific hybridization between Santalum spicatum and S. album.
Dr. Jenny McComb is an Associate Professor at the division of Biological and Environmental Sciences, Murdoch University, Perth, Western Australia.

Interspecific hybrids of *Santalum spicatum* and *S. album* may combine the cold and drought tolerance of *S. spicatum* with the high oil content and fast growth of *S. album*. We are attempting to produce a sexual hybrid between the species by hand pollination and investigated pollen tube growth and fertilisation.

Trees at Curtin University, Perth W.A., were selected using the criteria of higher growth rate, disease resistance and early flowering. Unopened inflorescenses were enclosed in 2 layers of perforated thin polyethylene bags containing a wire spiral to avoid contact between flowers and the bags. Enclosed unpollinated flowers and enclosed emasculated flowers were used as controls. Five to 15 samples in each treatment were harvested 3 days after pollination. The pistil was dissected from the flower and squash preparations were stained for fluorescence microscopy using aniline blue fluorochrome (Martin 1959). The initial fruit set was recorded at 14 days after pollination for *S. album* and 21 days for *S. spicatum*. Mature fruit set was recorded 1 month before harvesting.

In intraspecific crosses of *S. album*, initial fruit set was 20% (Table 1), which supported the results of Jyothi *et. al.* (1991). In *S. spicatum*, initial fruit set was 5%, final set 1.3%, which was higher than natural fruit set 0.14 - 0.45% (Barrett 1987). Although the chance of fertilisation was increased by hand pollination, the fruit set obtained remained low which is a common characteristic of most woody perennial species producing hermaphrodite flowers (Sutherland 1986). In *S. spicatum*, only a small percentage of pollen tubes were found to have penetrated the embryo sac. Fertilisation was also reported to be poor in *S. acuminatum*, but in this species possible reasons included the fact that some ovaries had no developed embryo sacs and the plants had an inadequate supply of nutrients and water (Sedgley 1982). Some authors have suggested that fruit abscission of *S. spicatum* was associated with overcast conditions, inadequate nutrition (Fox and Reeve 1991) and inherent characteristics (Barrett 1987).

The low fertility following self pollination (Table 1), assessed by both initial fruit set and pollen tube growth, confirmed the self incompatibility previously reported in *S. album* (Bhaskar 1980, 1992; Jyothi *et al.* 1991). *S. acuminatum* has also been reported to be cross pollinated (Keighery and Dixon 1986). Sindhuveerendra and Sujatha (1989) indicated that some trees of *S. album* partly self pollinated but up to 75% of the selfed fruit abscised before maturity. Sites of pollen tube inhibition at the upper style, lower style and around the embryo sac suggested a complex mechanism for genetic control of self incompatibility which was also found in *Banksia* (Fuss and Sedgley 1991).

Interspecific hybrids were extremely difficult to obtain (Table 1) as most pollen tubes were inhibited in the style (Table 2). *Santalum* flowers are initially green and change through pink to dark red. Pollen tubes only penetrated the embryo sac in red flowers which were the only flower

Table 1 Production of inter and intra-specific hybrids following hand pollination of *Santalum album* and *S. spicatum*

Cross	No. of Flowers Pollinated	Initial Fruit Set		Mature Fruit Set	
		No.	%	No.	%
S. album x *album*	533	113	20.1	39	7.3
S. spicatum x *spicatum*	1165	60	5.2	15	1.3
S. album selfed					
among flowers	220	4	1.8	2	0.9
same flower	180	0	0	0	0
S. spicatum selfed					
among flowers	250	1	0.4	1	*0.4
same flower	210	0	0	0	0
S. album x *spicatum*	680	3	0.4	0	0
S. spicatum x *album*	940	4	0.4	0	0
Bagged, unpollinated flower	1200	0	0	0	0
As above but also emasculated	150	0	0	0	0

*The fruit size was small and abnormal in shape.

Table 2 Pollen tube numbers in the style, ovary or embryo sac of pistils fixed 3 days after pollination

Cross	*S. Album*			*S. spicatum*		
	Style	Ovary	Embryo sac	Style	Ovary	Embryo Sac
Intraspecific	22.4±6.1	5.2±1.5	0.3±0.1	16.6±5.2	0.8±0.5	0.2±0.2
Self	6.8±0.6	1.2±0.8	0.2±0.2	2.7±4.0	0.7±0.3	0
Interspecific	3.6±1.2	0.2±0.2	0.1±0.1	3.0±2.0	0.3±0.3	0

types from which hybrid fruits developed in *S. album* trees. All the hybrid fruit abscised within 1 to 3 months. It is likely that there is more than one mechanism involved in interspecific incompatibility. In addition to the inhibition of pollen tube growth in the stigma and style, a post fertilisation mechanism may be involved.

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THE WESTERN AUSTRALIAN SANDALWOOD RESEARCH INSTITUTE

The Sandalwood Research Institute was formed in 1980 by the Australian Sandalwood Company. The intention of the Company was to put some of the returns from the Western Australian sandalwood export industry back into research which would benefit the industry. The role of the Institute was to channel funds from the industry back into research on sandalwood in tertiary institutions.

At the time the SRI was formed, there was some concern about the long term future of the sandalwood harvesting industry. There was justifiable concern about the lack of regeneration of the Western Australian sandalwood (*Santalum spicatum*), which is found over a large area of the semi-arid part of the State. For that reason, early research projects concentrated on various aspects of the regeneration of *S. spicatum*.

Following reports in the literature of success with tissue culture of *S. album* in India, research on the potential for use of this technique with *S. spicatum* was funded at Murdoch University in Perth. It became apparent that *S. spicatum* was a most recalcitrant species in this regard and this line of research was dropped in favour of tissue culture of *S. album*.

Currently, the Sandalwood Research Institute is supporting research on heartwood formation in *S. spicatum* and *S. album* at Melbourne University and further research on tissue culture in *S. album*. It is also contributing some funding to the sandalwood research program at Kununurra reported elsewhere in this Newsletter.

F H McKinnell

Determining Heartwood Formation within *Santalum album* and *S. spicatum*

Deanne Haffner

Deanne Haffner has completed her M(ForSc) thesis at the University of Melbourne, Victoria.
M(ForSc) Thesis: The Quantity and Quality of Heartwood in two species of sandalwood.
Supervisor: Dr W E Hillis

Deanne Haffner's M(ForSc) thesis is divided into two sections for the SRN. Part 2 (Determining heartwood oil content within Santalum album and S. spicatum) will be published in the second issue of the SRN.

Commercially, the value of any sandalwood tree depends upon the quantity and quality of heartwood it contains. To date, there has been much dissension about the age at which heartwood formation is initiated in sandalwood and there is little information about the rate of which heartwood is subsequently developed. Many theories exist as to which factors may affect these processes but very few have been concluded from experimental evidence.

It is know that there is large variation in the age at which *S. album* initiates heartwood formation (Srimathi and Kulkarni, 1979) and that some individuals never form any heartwood (Rai, 1990). Growth rate appears to be the best indicator of the proportion of heartwood, however, very little information is available about how the rate of heartwood formation is affected by tree age and growth rate.

In this study, 39 *S. spicatum* and 30 *S. album* trees were sampled from different sites in Western Australia and West Timor, Indonesia to examine the factors that affect the amount and quality of heartwood. From this work a method was established to estimate the heartwood content of a standing tree and to predict the error associated with such an estimate.

Methodology

Tree height and diameter at 150 mm above ground level were measured in all trees. In *S. album*, the crown size was also measured.

At 150 mm above ground level in each tree, a cross-section was cut, sanded and then painted with potassium iodide-iodine solution (equal volumes of 2% w/v potassium iodide/water and 2% w/v iodine/ ethanol) (Kutscha and Sacha, 1962) to test for starch found only in the sapwood. The sapwood and heartwood area and the sapwood width were measured and the number of growth increments was counted.

Results and Discussion

Tree height and diameter

The mean tree height (10.2±1.9 m) and diameter over bark at 150 mm above ground level (309.8±74.1 mm) of *S album* were significantly greater than the mean height (3.2±0.7 m) and diameter (172.5±36.7 mm) of *S. spicatum*. The large variation in tree heights and diameters within each species reflects the differences in ages of the trees as well as the differences between sites or genotypes.

Amounts of heartwood and sapwood

At 150 mm above ground level, the mean total cross-sectional area of the *S. album* cross-sections was three times that of *S. spicatum* but the mean heartwood proportion was only 41.2% of the cross-sectional area in *S. album* compared with 81% in *S. spicatum* (Table 1). Although the heartwood area was only 1.5 times greater in *S. album* compared with *S. spicatum* (Table 1), the heartwood was formed in one third of the time (Table 2).

Two of the 30 *S. album* trees sampled appeared to contain no heartwood.

Factors related to sapwood and heartwood content

In both species, the amount of sapwood was positively correlated with the growth rate of the tree. In *S. spicatum* this also correlated with the heartwood content, however, no relationship could be found between the heartwood content of *S. album* and any of the parameters measured.

Predicting the heartwood content in stand trees

The heartwood area at 150 mm above ground level in *S. spicatum* may be best predicted by either the total cross-sectional area or the diameter over bark, which gave the regression equations.

HW area = 0.891 total area - 10.6
HW area = 1.43 diameter over bark - 132

The proportion of the cross-sectional area that was heartwood was considerably lower in *S. album* (Table 1) and hence the sapwood component had a significant effect on the regression analyses. For those *S. album* trees found to contain heartwood, the heartwood area could be calculated from the total cross-sectional area and the sapwood width (SWW) by the formula:

HW area = 92.9 - 4.47 SWW + 0.632 total area

It is essential that these regression equations are checked against a different sample of trees. More work is required to convert these values to volume estimates, particularly by measuring the height to which the

Table 1 **Comparisons of the mean area of the heartwood (HW), sapwood (SW) and the total cross-section, the sapwood proportion of the total area and the sapwood width (SWW) at 150 mm above ground level in cross-sections of *S. spicatum* and *S. album***

Variable	*S. spicatum*		*S. album*	
SW area (cm^2)	26.0	(11.4)	257.5	(126.2)
HW area (cm^2)	115.9	(66.8)	174.1	(102.1)
Total area (cm^2)	142.0	(74.4)	436.9	(157.0)
SW area (%)	19.0	(8.9)	58.8	(17.9)
SWW (mm)	6.5	(0.4)	45.7	(24.6)

The standard deviation is in parentheses.

Table 2 **Comparison of the mean number growth increments (GI) in the sapwood (SW), heartwood (HW) and total cross-section and the proportion of the total GI that are in the SW at 150 mm above ground level in cross-sections of *S. spicatum* and *S. album***

Variable	*S. spicatum*		*S. album*	
SW GI	11.7	(3.7)	23.6	(7.0)
HW GI	79.4	(24.9)	26.1	(12.7)
Total GI	91.8	(24.6)	48.6	(10.6)
SW GI (%)	13.5	(5.4)	48.2	(14.9)

The standard deviation is in parentheses.

heartwood extends and the heartwood taper.

Growth increments

The mean total number of growth increments was much higher in *S. spicatum* than in *S. album*, and both the number of growth increments and the proportion of the growth rings in the sapwood were much higher in the *S. album* than *S. spicatum* cross-sections (Table 2).

Tree age at heartwood initiation

Assuming that the number of growth increments in the sapwood at 150 mm above ground level is equivalent to the age of heartwood initiation, in *S. spicatum*, the age at which heartwood was initiated ranged from 4 to 22 years with a mean of 11.7 years (Table 2). In the *S. album* trees that contained heartwood, the number of growth increments in the sapwood varied from 14 to 46 with a mean of 23.6.

Rate of heartwood formation

No relationship was found between the number of growth increments in the sapwood and either the rate of growth or tree age. Therefore, it was assumed that once heartwood was initiated, it increased at the rate of one growth ring per year.

Conclusions

It is unlikely that the estimates of the age at which heartwood was initiated were accurate since the number of growth rings in sandalwood are known to either under or over-estimate tree age by 53% (Chowdhury and Ghosh, 1949). It was concluded that the data collected in this study were not appropriate to estimate either the age at which heartwood was initiated or the rate of heartwood formation.

To answer many of the questions that relate to age, especially the age at which heartwood is initiated and the rate of heartwood formation, trees of equal and known age (and genotype) should be compared on a range of sites over time.

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Acknowledgements

This study was part of a postgraduate program at The University of Melbourne funded by the Sandalwood Research Institute of Western Australia. The assistance of the Department of Conservation and Land Management in Western Australia and of the Balai Penelitian Kehutanan in Kupang, West Timor, are gratefully acknowledged.

Introduction and Overview of *Santalum* Research in Kununurra, Western Australia

Andrew M Radomiljac

Andrew Radomiljac is a Research Officer with the Department of Conservation and Land Management involved with silvicultural and tree breeding research of Santalum album. Kununurra, Western Australia. This position is jointly funded by the Australian Centre for International Agricultural Research (ACIAR), the Sandalwood Research Institute (SRI) and the Sandalwood Conservation and Regeneration Program (SCARP).

Introduction

This paper outlines the background and present status of *Santalum album* and other *Santalum* species research within the Ord River Irrigation Area (ORIA), Kununurra, Western Australia (Figure 1.). *Santalum* species research occurs within a flood irrigation scheme, consequently allowing for the irrigation of *S. album* plantations.

Santalum species research is categorised into two components:

i. development of *S. album* nursery propagation and silvicultural techniques.

ii. germ plasm conservation of threatened and endangered *Santalum* species.

Background

Exploitation of Asian, Australian and Pacific island *Santalum* species has resulted in a severe decline of the *Santalum* species population. A strong demand exists for sandalwood, either for joss stick manufacturing or for the perfumery industry. Without the advent of an artificial sandalwood oil substitute (McKinnell 1990) and continual exploitation the differential between the supply and demand for sandalwood products will increase.

Australia contains 6 of the 29 *Santalum* species (Applegate and McKinnell 1993). One of the 6 species, *S album*, occurs along the northern extremities of the Australian coastline (Figure 1). This species is an exotic. Introduced by Indonesian fisherman or traders.

Of the native *Santalum* species only *S. spicatum*, occurring predominantly in Western Australia (Figure 1.), is considered to be of significant commercial value. Average heartwood oil content of *S. spicatum* is 2 percent (McKinnell 1990) and it is harvested for the production of joss sticks only.

Exploitation of *S. spicatum* has placed pressure on this species population. A proportion of remaining *S. spicatum* occurs in nature reserves and is removed from the harvestable population. Natural regeneration is low due to fire and grazing. Long rotation lengths, 50 - 100 years, dispels the possibility of establishing commercially viable *S. spicatum* plantations.

S. album plantations within the ORIA is perceived to release exploitation pressures from *S. spicatum*.

Climate

The ORIA climate (Table 1.) is tropical with monsoonal rains occurring during a four month period, December to March.

Table 1 Climatic data of the Ord River Irrigation Area

Rainfall (mm)	Mean Max Temp (C)	Mean Temp (C)	Mean Min Temp (C)	9am RH (%)	Evaporation (mm)
745	35.1	27.7	20.5	43	272

Soils

The most predominant soil type conducive to flood irrigation in the ORIA is a hard setting, self mulching clay soil, Cununurra clay.

Two other soil types exist, a sand and levee type soil. These two soil types have limited application to *S. album* plantations due to their inappropriateness for flood irrigation and the presence of *Mastotermes darwiniensis*.

Site preparation

Plantation establishment occurs on cleared agricultural land. Site preparation parallels intensive agriculture techniques. Intensive site preparation is required for two reasons:

i) flood irrigation requires the planting site to be levelled prior to planting bed and the irrigation furrow formation.

ii) planting beds, due to the Cununurra clay's hard setting nature, require a fine tilth. This is achieved by intensive cultivation.

Research developments

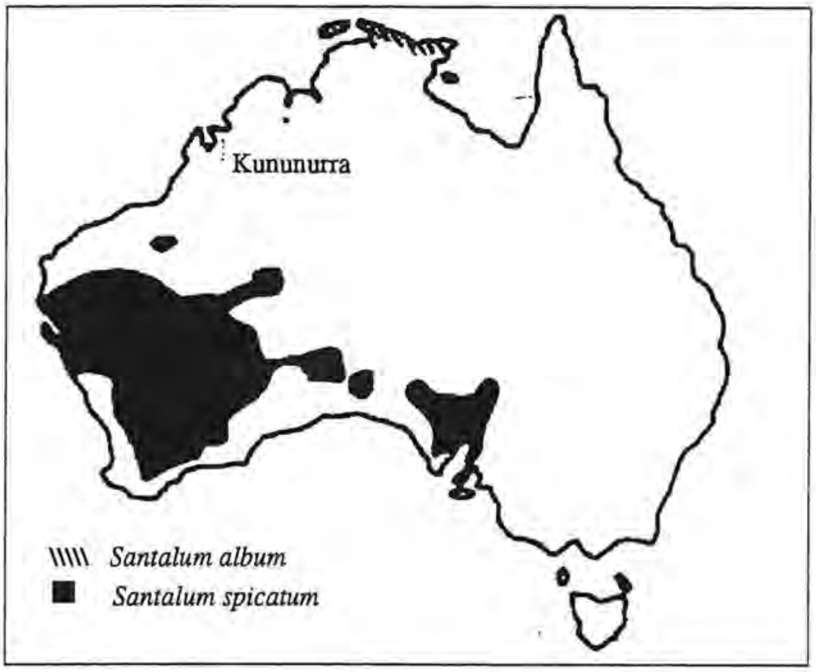
The first significant *S. album* planting at Kununurra occurred in 1986 where 180 seedlings were planted. Seed being of Indian origin. This planting is sexually mature and supplies seed for research purposes.

Two *S. album* research trials were established in 1987 (McComb unpublished). Firstly, a site selection trial, concluding the appropriateness of the Cununurra clay soil for *S. album* plantations. Secondly, a host selection trial, concluding *S. album's* host preference is positively correlated to the hosts' ability to fix nitrogen.

Favourable *S. album* host species include *Sesbania formosa, Acacia coriacea, Cassia siamea, Dalbergia sisso, Acacia trachycarpa* and *Acacia ampliceps*. Poor *S. album* host species are characteristic of their inability to fix nitrogen. Poor *S. album* hosts species include *Anacardium occidentale, Eucalypt spp, Gmelina arborea* and *Cordia sebstana*

A low level of quantitative research has been conducted on nursery propagation of *S. album*. Two areas of the nursery propagation that have been investigated include seedling potting mixture and preliminary pot host selection.

Figure 1 Distribution of *Santalum spicatum* and *S. album* in Australia



(Modified from Hewson and George 1984)

Present research status

Santalum species research in the ORIA is relatively new. Quantitative *S. album* research commenced in 1993 with the appointment of a research officer.

Areas identified of high priority for nursery propagation and silvicultural research include seed handling and storage, seedling nutrition, pot and field host selection, weed control, irrigation regimes and heartwood formation studies.

Germ plasm conservation research of *Santalum* species include provenance trials of *S. austrocaledonicum* and progeny trials of *S. album*. It is perceived that a larger representation of the *Santalum* species will be included into this research component. Germ plasm conservation is an important ACIAR research component as most *Santalum* species are threatened by extinction.

Forth coming Sandalwood Research Newsletter issues will summarise methodologies, results and conclusions of *S. album* and other *Santalum* species research conducted within the ORIA, Kununurra.

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The Sandalwood Research Newsletter invites all readers to write to the article authors to acquire additional information concerning *Santalum* species research and/or management work outlined in these articles. An aim of the SRN is to promote and increase the level of liaison between researchers and managers of *Santalum* species.

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ACIAR PROCEEDINGS OF SANDALWOOD SYMPOSIUM AVAILABLE

The Australian Centre for International Agricultural Research has published the proceedings of a symposium on sandalwood held at the XVII Pacific Science Congress in Hawaii, in June 1991. Edited by F H McKinnell, the proceedings contains papers from Australia, Indonesia, Vanuatu, Fiji, New Caledonia, French Polynesia and Hawaii. It is entitled Sandalwood in the Pacific Region, ACIAR Proceedings No. 49, and the publication is available from:

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Sandalwood Research Newsletter

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The Need for Increased *Santalum* Species Research Collaboration for Germplasm Conservation

Editor: Andrew Radomiljac

From every indication the first issue of the Sandalwood Research Newsletter (SRN) has been very well received throughout South East Asia and Pacific island nations currently involved in *Santalum* species management and research. This highlights the strong interest generated in this important genus. Sandalwood timber products have considerable cultural importance and its high economic value highlights the importance for continual research and collaboration to develop suitable silvicultural techniques for plantation establishment and species conservation. *Santalum* species have the potential to make a considerable contribution to the rural economies of several countries (McKinnell 1993).

Sandalwood oil, from *S. album* in particular, is a perfumer's jewel. It possesses unique fragrance characteristics and has a special position in the perfume industry. Sandalwood oil has been utilised for thousands of years as a fragrance source (Muller 1984). This essential oil is one of the oldest, most valuable and expensive of the raw materials available to the perfumer (Hall 1985).

Demand for *Santalum* species oil and various forms of timber products - wood and joss sticks is very strong with no indication of assuagement. Strong demand for this high valued resource increases harvesting pressures on decreasing *Santalum* species populations. Hence, the need for research collaboration on *Santalum* species throughout the South East Asian and Pacific region is critical. Species conservation through the establishment of germplasm reserves is of high priority. Researchers at the Balai Penelitian Kehutanan (Forestry Research Institute) Kupang, Indonesia acknowledge the importance of *S. album* conservation through germplasm reserves. Harisetijono and Surimihardja (1993) indicate the commencement, with the Australian Centre for International Agricultural Research (ACIAR), of establishing representative ranges of *S. album* genetic resources in Nusa Tenggara Timur (NTT) to enable the selection of high yielding genotypes for future reforestation programs. Selection of plus trees and the establishment of seed orchards is of high priority.

A short paper described within this SRN issue summarises the ongoing efforts of establishing germplasm reverses. However, efforts are not always fruitful and increased collaboration between researchers, managers and organisations involved with *Santalum* species will increase the effectiveness of attempts to achieve satisfactory germplasm conservation.

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Genotypic Variation in *Santalum album*

Jonathan E Brand

Jonathan Brand has completed his M(Sc) thesis at Curtin University, Western Australia.
M(Sc) Thesis: Phenotypic and genotypic variation within Santalum album in West Timor.
Supervisor: Dr J E D Fox
A/ Supervisor: D Coates

Through allozymic studies it has become clear that most species are not single panmictic units. Instead, limited gene flow and genetic drift have resulted in genetic differentiation between and within populations (Schwaegerle, Garbutt and Bazzaz, 1986). Isozyme activity in *Santalum album* was investigated by Egerton-Warburton (1990), but genetic variation within the species has not been studied. The genetic association between sandalwood growing in India and Indonesia is also unknown (Rai, 199). Indian's settled in Indonesia over a thousand years ago and it has been hypothesised that *Santalum album* was introduced to India from West Timor (Rajagopal Shetty, 1977).

The aim of this study was to examine the level of genetic diversity within and between populations of *Santalum album* in West Timor. *Santalum album* populations from West Timor and India were also compared to determine the level of genetic differentiation between the two countries.

Materials and methods

Santalum album seeds were obtained from 10 populations in West Timor and two populations in India.

The West Timor populations sampled were Ajaubaki, Buat, Netpalen, Niki Niki, Oenutnanen, Oinlasi and Siso. From each population, seed was collected from 12-20 trees, except Netpalen where seed was collected from four separate populations of 20 trees. Within India, bulk seed collections were obtained from Bangalore and Rayalpad. Seeds were germinated at Curtin University, Western Australia, and juvenile leaf tissue from 18-23 seedlings per population were used in isozyme analysis. Twenty three different isozyme systems were tested and of these, eight were sufficiently active in *Santalum album*. The active isozyme systems were: *Acp, Gdh, Lap, Mdh, Mdr, Pgi, Pgm* and *Sdh*. From these isozyme systems a total of 12 different isozyme loci was obtained.

Genetic variation measures were calculated using BIOSIS-1 (Swofford and Selander, 1989) and GENESTAT-PC (Lewis and Whitkus, 1989) computer programs.

Results

The mean genetic diversity measures for the *Santalum album* populations from West Timor and India are shown in Table 1. Within West Timor, the mean number of alleles per locus *(A)* ranged from 1.7 at Niki Niki to 2.0 at Oinlasi. The mean percentage of polymorphic loci per population was 52.5% and ranged from 50.0 to 58.3%. Populations with the highest expected heterozygosity (H_e) were Ajaubaki (0.20), Oinlasi (0.20) and Siso (0.20). The lowest H_e values came from Oenutnanen (0.13), Netpalen C (0.14) and Niki Niki (0.15). The mean observed heterozygosity (H_o) averaged over all populations was 0.14, which was

Table 1 Mean genetic diversity estimates (Nei, 1973) based on 12 loci in 12 populations of *Santalum album*

Population	*N*	*A*	*P*	H_e	H_o
West Timor					
1. Ajaubaki	21	1.9	58.3	0.20 (0.06)	0.17 (0.05)
2. Buat	23	1.8	50.0	0.18 (0.06)	0.13 (0.04)
3. Niki Niki	18	1.7	50.0	0.15 (0.05)	0.11 (0.04)
4. Oenutnanen	22	1.8	50.0	0.13 (0.05)	0.11 (0.05)
5. Oinlasi	22	2.0	58.3	0.20 (0.06)	0.15 (0.05)
6. Siso	23	1.9	50.0	0.20 (0.07)	0.15 (0.05)
7. Netpalen A	20	1.8	50.0	0.18 (0.06)	0.14 (0.04)
8. Netpalen B	19	1.9	50.0	0.19 (0.06)	0.16 (0.05)
9. Netpalen C	20	1.8	58.3	0.14 (0.04)	0.11 (0.03)
10. Netpalen D	20	1.9	50.0	0.16 (0.05)	0.13 (0.04)
Mean		1.8	52.5	0.17	0.14
India					
1. Bangalore	22	1.8	41.7	0.18 (0.07)	0.16 (0.06)
2. Rayalpad	21	1.7	41.7	0.13 (0.05)	0.10 (0.04)
Mean		1.8	41.7	0.16	0.13

N - sample size per locus; *A* - mean number of alleles per locus; *P* - percentage of polymorphic loci per population (0.99 criterion); H_e - expected heterozygosity; H_o - observed heterozygosity; standard errors in parentheses.

lower than the mean H_e (0.17). The two Indian populations had mean genetic diversity measures as follows: *A* (means 1.8, range 1.7-1.8); *P* (mean 41.7%); H_e (mean 0.16, range 0.13-0.18); and H_o (mean 0.13, range 0.10-0.17). Mean *P*, H_e and H_o values from the Indian populations were lower than the West Timor populations.

Within West Timor, the genetic distance between populations was generally low, ranging from 0.000 to 0.074 (Table 2). The genetic distance between the two Indian populations was 0.076. The mean genetic distance between the West Timor and Indian populations was 0.447, and ranged from 0.394 to 0.527. This high genetic distance clearly shows that the West Timor populations and the Indian populations are well differentiated.

Discussion

Within West Timor, the mean expected heterozygosity (H_e) from all *Santalum album* populations was 0.17, which is lower than that reported from other long-lived woody perennials (H_e = 0.267; Hamrick, Linhart and Mitton, 1979).The low level of genetic diversity within *Santalum album* may be related to its localised distribution. Plant species growing over a widespread range generally have significantly higher levels of genetic diversity than more narrowly distributed or localised species. Widespread plant species often have large continuous populations that are less susceptible to losses of genetic variation due to genetic drift (Hamrick and Godt, 1990). The *Santalum album* populations examined were small and isolated, which may have made them more prone to genetic drift. The relatively low H_e level found in *Santalum album* is comparable to other plant species growing over a similar geographic region. Two examples are *Eucalyptus diversicolor* (H_e = 0.15; Coates and Sokolowski, 1989) and *Eucalyptus crucis* (H_e = 0.19; Sampson, Hopper and James, 1988).

West Timor and Indian *Santalum album* populations had a mean genetic distance *(D)* of 0.447, which is very large compared with intra-specific distances in other species. Yacine and Lumaret (1989) examined 16 populations of *Quercus ilex* from around the Mediterranean and found a mean *D* of 0.023. Joly *et al.* (1992) found that the average genetic distance between western and eastern populations of *Acacia albida* in Africa was 0.273, and hypothesised that they were different races. The large genetic distance between the West Timor and Indian *Santalum album* populations indicates that they should be considered, at least, as separate varieties or races.

If sandalwood was introduced to India from West Timor over a thousand years ago (Rajagopal Shetty, 1977), a bottleneck effect may have caused genetic differentiation. Rapid speciation can occur if a population is founded by a small number of individuals. When population size is very small, random genetic drift affects gene frequencies (Nei, Maruyama and Chakraborty, 1975). Sandalwood descendants within India could be derived from a small portion of the species gene pool in Timor.

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Table 2 Estimates of Nei's (1972) genetic distance *(D)* among the 12 populations of *Santalum album.*

Population		*West Timor*										*India*	
		1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*1*	*2*
West Timor	1	-											
	2	0.060	-										
	3	0.064	0.004	-									
	4	0.031	0.137	0.139	-								
	5	0.073	0.066	0.065	0.116	-							
	6	0.004	0.051	0.052	0.047	0.047	-						
	7	0.005	0.068	0.070	0.056	0.051	0.001	-					
	8	0.000	0.064	0.067	0.043	0.060	0.000	0.000	-				
	9	0.004	0.073	0.072	0.058	0.067	0.003	0.001	0.000	-			
	10	0.002	0.074	0.074	0.051	0.062	0.002	0.000	0.000	0.000	-		
India	1	0.460	0.432	0.472	0.527	0.403	0.465	0.436	0.480	0.476	0.484	-	
	2	0.404	0.427	0.437	0.551	0.422	0.429	0.394	0.412	0.398	0.428	0.076	-

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Germplasm Conservation of Sandalwood

Peter Burgess

Peter Burgess is with the Australian Tree Seed Centre, CSIRO Division of Forestry, Canberra. His position is to advise on aspects of species selection and tree breeding.

The Australian International Development Assistance Bureau (AIDAB) funded a cooperative project, with the Australian Tree Seed Centre (ATSC), CSIRO Division of Forestry and the Western Australian Department of Conservation and Land Management (CALM), aimed to help collect and conserve germplasm of the rare and often endangered Pacific species of *Santalum*. The genus comprises 16 species and 17 varieties, many of which are geographically and probably reproductively isolated (Applegate *et al.* 1990).

The aims of the program are:

- Coordinate seed collections of *Santalum* species from the Pacific region. Store the seed in Canberra for the later establishment of a gene conservation bank/seed orchard, by CALM in Kununurra, Western Australia.
- Literature survey to cover growing conditions and cultural requirements of the various species.

Contact was established with ten countries in the Pacific region but seed was only available from four countries (Table 1). The Cook Island's *S. insulare* has not carried a crop for the last few years, while the Japanese *S. boninense* is reproduced only vegetatively.

Further attempts to obtain seed from other areas will be made. Personal contact has proven to be far more rewarding than mailed requests.

Table 1: Origin of *Santalum* species seed collection

Species	*Origin*	*Results*
album	Australia	0.3 kg
austrocaledonicum	New Caledonia	10 tree collection 200 seed bulk
lanceolatum	Australia	0.05 kg
yasi	Tonga	10 tree collection

Literature survey

A search, concentrating on species other than *S. album* was conducted. This together with DFR library accessions was compiled into a list of 46 references. Copies of all references are held by ATSC.

As a result of a recent visit by Stephen Midgley to India, ATSC expects to receive a collection of *S. album* in the near future. Although the Indian populations were not targeted in the program this will be a valuable addition to the project.

Gene pool and species/ provenance trials

The Department of CALM has commenced establishing *Santalum* species gene pool/family trials. In 1993 a *S. austrocaledonicum* gene pool/ family trial was established under flood irrigation, Kununurra. This trial consists of 10 *S. austrocaledon-icum* families collected from the New Caledonian island of Ile des Pins by the Cirad Foret.

Nursery propagation of this *S. austrocaledonicum* and *S. yasi* seed from New Caledonia and Tonga commenced in late 1993 and trials will be planted in 1994.

Collection of *Santalum* species seed for gene pool conservation is an important component of the Australian Centre for International Agricultural Research (ACIAR) *Santalum* species research program. Consequently, it is actively ongoing.

Germination tests

S. lanceolatum, after surface sterilisation, nicking the endocarp and using a medium of vermiculite, incubated at 25°C resulted in 90 percent germination. *S. austrocaledonicum* also responded well to the nick treatment with 80 percent germination. *S. yasi*, on the other hand, was more recalcitrant. The nick treatment or soaking in 30 percent hydrogen peroxide gave no germination. Overnight soaking in 0.25g/L GA3 has resulted in 10 percent germiantion after three weeks. Seedlings have grown quite well, in pots, in a heated glasshouse in Canberra for over a year. *Casuarina* has been a suitable host as it does not grow too vigorously.

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Determining Heartwood Oil Content within *Santalum album* and *S. spicatum*

Deanne Haffner

Deanne Haffner has completed her M(ForSc) thesis at the University of Melbourne, Victoria. M(ForSc) Thesis: The Quantity and Quality of Heartwood in two species of sandalwood. Supervisor: Dr W E Hillis

Sandalwood oil is produced commercially by steam distillation. The average commercial oil yield from *S. album* varies between four and six percent (Hughes and Richmond, 1980; Rai, 1990) but individual tree estimates have varied from 0.2 to 7.25 percent (Iyengar, 1968; Parthasarathi *et al.*, 1986). The reported average oil content of *S. spicatum* is two percent (Applegate *et al.* 1990) but individual oil content estimates have varied between 0.5 and 6.1 percent (Fleming and Uren, 1981).

Such variation in oil content has been attributed to the age of the tree (Shankaranarayana and Parthasarathi, 1984), the site or provenance (Sinha, 1961, Quemin, 1988) or the grade of the heartwood (Shankaranarayana and Parthasarathi, 1987). To examine this variation in more detail, a simple method of determining the content of sandalwood oil is required.

In this paper I have presented a method of estimating the content of sandalwood oil and have suggested a way in which the oil content in *S. album* can be predicted by a simple Soxhlet extraction.

Method

Two cross-sections, each 5 mm thick, were cut at 150 mm aboveground level and at crown break (*S. spicatum*) or below the first fork (*S. album*), from 39 *S. spicatum* trees from Western Australia and 30 *S. album* trees from West Timor, Indonesia. The bark and sapwood were removed and the heartwood was chipped into 5 x 5 x 20 mm pieces and ground in a Wiley mill until it passed through a size 20 mesh.

Two 10g samples of heartwood sawdust from each cross-section were placed into 25 x 80 mm cotton extraction thimbles, plugged with cotton wool and "conditioned" over super-saturated $CaCl_2$ at 25°C to a constant weight (about one week). This ensured that all samples had a similar moisture content.

Simultaneous Distillation and Extraction (SDE)

One 10g sample from each cross-section was extracted by SDE in a Likens Nickerson apparatus (Koedam, 1987). The sawdust sample and 100 ml distilled water were stirred in a 2L Erlenmeyer flask immersed in a 140°C silicon oil bath. Ten ml hexane and two angular bumping granules were added to a 25 ml pear-shaped flask which was immersed in a 90°C water bath. SDE proceeded for 24 hours. The oil/hexane mix was transferred to a clean weighed flask, the hexane evaporated and the oil dried over $CaCl_2$ in an evacuated desiccator for two days before weighing. The empty thimble was conditioned for one day and weighed.

The content of sandalwood oil in the sawdust sample was expressed as a percentage of the "air-dry" or conditioned wood mass using the formula:

$$\text{oil \%} = \frac{\text{oil}}{\text{wood}_{\text{COND}}} \times 100$$

where:
oil = mass of flask and oil - mass of flask
woodCOND = mass of conditioned thimble and sawdust - mass of conditioned thimble

Estimation of the Total Ethanol Soluble Extractives (TEE)

The other 10g sawdust sample was extracted in a Soxhlet with 100 ml ethanol for 24 hours, oven-dried at 103°C for two days and weighed. The sawdust was discarded and the empty thimble oven-dried at 103°C for one day, weighed, conditioned for one day and weighed. The TEE% was calculated using the formula:

$$\text{TEE \%} = \frac{\text{wood}_{\text{COND}} - \text{wood}_{\text{EXT}}}{\text{wood}_{\text{COND}}} \times 100$$

where:
woodCOND = mass of conditioned thimble and sawdust - mass of conditioned thimble
woodEXT = mass of oven-dried thimble and extracted sawdust - mass of oven-dried thimble

This estimate of TEE percentage includes the extractives (such as polyphenols, tannins, etc.), the sandalwood oil and water.

Results

The mean heartwood oil content was significantly lower in *S. spicatum* than *S. album*, whereas the mean TEE was significantly higher in *S. spicatum* (Table 1). The mean sandalwood oil content of *S. spicatum* was nearly twice that reported by Applegate *et al.* (1990), whereas the mean oil content of *S. album* was similar to that reported by Hughes and

Richmond (1980) and Rai (1990).

The TEE estimates is a combination of oil, water and other extraneous compounds. If the oil and water (about seven percent moisture content) are subtracted, *S. spicatum* heartwood contains about 10.4 percent extraneous compounds compared with only 4.5 percent in *S. album* heartwood. Therefore the proportion of oil in the TEE estimate is lower in *S. spicatum* (17 percent) than *S. album* (34 percent). This last statistic is very important for the accuracy with which the oil content of sandalwood may be predicted from TEE. A poor relationship was found between the TEE and the oil content of *S. spicatum* (Figure 1a), whereas a much stronger relationship was found between these variables in *S. album* (Figure 1b). Linear regression produced the model.

Conclusions

The oil content of *S. album* is well correlated with the TEE and this model could be used to predict the oil content (Figure 1b). The advantages with this method are that 1) Soxhlet extraction is a very simple, cheap and rigorous laboratory procedure compared with SDE or other methods of distillation; and 2) the method only requires 10g of sawdust, which could be bored from the side of a tree with little effect on tree health.

Since no relationship was found between the oil content and TEE in *S. spicatum*, the oil content must be determined by SDE.

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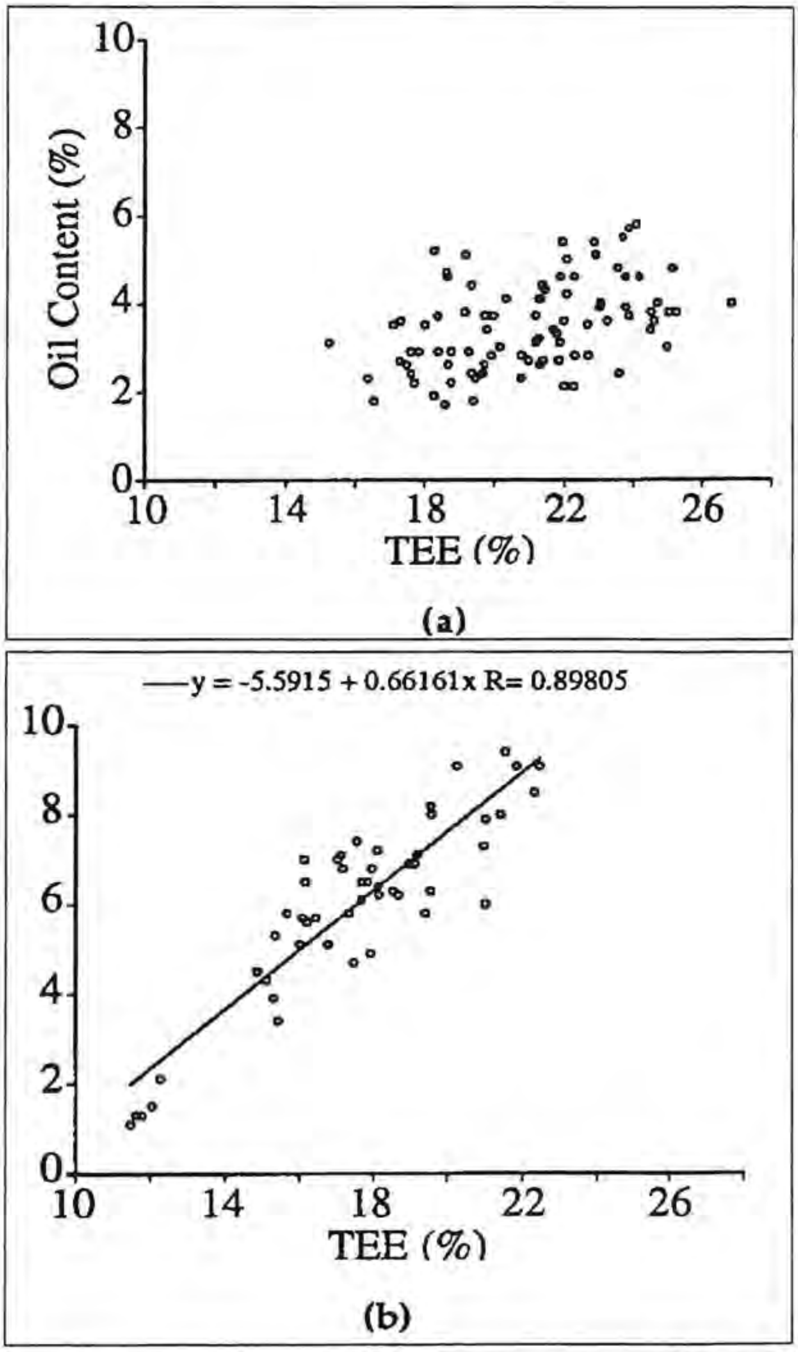
Table 1:
The mean oil content (oil%) and the amount of total ethanol soluble extractives (TEE%), expressed as a percentage of the "air-dry" wood weight at 150 mm aboveground level in *S. spicatum* and *S. album*. The standard deviation is given in parentheses.

Species	*Oil %*	*TEE %*
S. spicatum	3.69 (1.15)	21.1 (2.3)
S. album	6.07 (1.96)	17.6 (2.6)

Figure 1:
Relationship between the oil content and TEE in (a) *S. spicatum* and (b) *S. album*.



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The Sandalwood Research Newsletter

The SRN aims to promote the awareness of *Santalum* species and increase the exposure of *Santalum* species literature, the SRN is an avenue through which researchers and managers of *Santalum* species can achieve this. It is hoped articles will be received on a range of *Santalum* species research and management issues throughout the South East Asian and Pacific region. If you wish to contribute an article or wish to be included on the SRN mailing list, please write to the Editor giving your name, organisation and mailing address. All articles on relevant topics are welcomed.

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The Sandalwood Research Newsletter Editor invites all readers to write to the article authors to acquire additional information concerning *Santalum* species research and/or management work outlined in this SRN issue. An aim of the SRN is to promote collaboration between researchers and managers of *Santalum* species.

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Sandalwood Research Newsletter

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The effect of host plants on the growth of sandalwood seedlings (*Santalum album* Linn.)

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Abstract

The necessity for sandalwood seedlings to gain acceptable growth rates through the propagation of pot host plants is important. An experiment was undertaken to evaluate the performance of sandalwood seedlings under the effects of *Desmanthus virgatus, Alternanthera spp., Crotalaria juncea, Sesbania grandiflora, Cajanus cajan, Capsicum frutescens, Breynia cerua, Lycopersicum esculentum, Acacia oraria, Duranta repens, Erigeron linifolius, Acacia holocericea, Acacia auriculiformis, Elephantopus scaber, Desmodium trifolium* and *Andropogon subtitis* pot host treatments.

The results showed that sandalwood seedling growth is considerably enhanced with an adequate pot host. The best host in terms of dry weight, height and diameter of sandalwood seedlings was with *Alternanthera spp., D. virgatus* and *C. juncea*.

Introduction

Almost all sandalwood logging in NTT still comes from natural forests. However, since the population level of natural sandalwood stands is decreasing and demand for sandalwood products is increasing it is necessary to establish sandalwood plantations.

Repeated attempts to establish sandalwood plantations has been largely unsuccessful, this being primarily due to low seedling quality for out planting. Therefore it is necessary to make improvements in the technology of raising seedlings.

The use of a pot host plant is critical to improve the quality of sandalwood seedlings. Information obtained from various publications shows that pot hosts plants increase the growth of sandalwood seedlings. According to Rama and Rao (1911) more than 70 species of plants have been found to have the capacity to become hosts to sandalwood seedlings, however, the hosts have varying influences on the growth of the sandalwood plants. For that reason the selection of pot hosts species must be made on the ability of the pot host species to increase sandalwood seedling growth and as well as being readily available.

Results

The treatment means for height, diameter and dry weight of the seven month old sandalwood seedlings are summarised in Table 1. A statistical analysis shows that the height, diameter and dry weights of the seedlings vary significantly.

With the 16 host plant species that were tested, some clear variations in sandalwood growth occurred. The *Alternanthera spp., D. virgatus* and *C. juncea* treatments were best in increasing the sandalwood diameter and dry weights. Conversely, the *A. holocericea, A. auriculiformis, E. scaber, D. trifolium* and *A. subtitis* proved the least effective in increasing height, diameter and the dry weight of the plants.

Discussion

The growth of the sandalwood seedlings varied according to the pot host species treatment. It is seen in the results that the *Alternanthera spp., D. virgatus, C. juncea* and *S. grandiflora* are the best host plants from the 16 species treatments tested (Table 1). The growth variations occur because the primary host plants have varying capabilities of absorbing nutrients. According to Barrett (1988) only the nutrients N, P and amino acids are derived from the host plant, whereas Ca and K are absorbed through the sandalwood root system direct from the soil.

D. virgatus, C. juncea and *S. grandiflora* are leguminous plant species whilst *Alternanthera spp.* is not. According to Srimathi *et al.* (1982) the leaves of sandalwood seedlings fostered by a leguminous host plant have a higher concentration of basic amino acids than when parasatising a non-leguminous host. The level of sandalwood growth is dependent on the level of amino acid availability.

Previous research undertaken by Balai Penelitian Kehutanan in Kupang indicated the pepper plant

(*C. frutescens*) to be the best primary host and consequently it is being commonly used in establishing sandalwood plantations. However, the results of this research indicate better sandalwood growth with five other species than with *C. frutescens*. Very large increases in sandalwood growth can be achieved if correct pot host species are utilised.

Suitable pot host species should not only increase growth but also have a low level of competition, a small above ground biomass, succulent root system, able to withstand pruning, not short lived and readily available (Rai 1990 and Barrett 1990).

Following the above criteria *Alternanthera spp.* is a very good pot host species. Additionally, *Alternanthera spp.* is easily propagated by cuttings. *D. virgatus* and *C. juncea* is widely distributed and seed is readily available from May to June.

Table 1: Average height, diameter and dry weight of sandalwood seedlings at the age of seven months

Host Species	*Height (cm)*	*Diameter (cm)*	*Dry Weight (g)*
Desmanthus virgatus	44.60 a	0.40 ab	4.024 a
Alternenthera spp.	43.77 a	0.45 a	4.118 a
Crotalaria juncea	43.43 a	0.39 ab	3.779 ab
Sesbania grandiflora	33.31 b	0.34 ab	2.667 bc
Cajanus cajan	28.86 bc	0.29 ab	2.265 c
Capsicum frutescens	27.40 cd	0.31 ab	2.222 c
Breynia cerua	25.65 cd	0.27 ab	2.022 c
Lycopersicum esculentum	23.96 cde	0.28 ab	1.857 cd
Acacia oraria	23.27 cde	0.30 ab	1.804 cd
Duranta repens	21.64 de	0.24 ab	1.557 cd
Erigeron linifolius	18.45 ef	0.25 ab	1.312 cd
Acacia holocericea	15.42 fg	0.21 b	1.140 d
Acacia auriculiformis	15.16 fg	0.21 b	1.140 d
Elephantopus scaber	14.23 fg	0.23 b	1.079 d
Desmodium trifolium	11.18 g	0.19 b	0.851 d
Andropogon subtitis	10.52 g	0.18 b	0.784 d

Footnote: Average values followed by the same letter are not significantly different at the five per cent level by the HSD test.

Conclusion

The experiment suggests that up to the age of seven months the best growth of sandalwood seedlings is achieved with *D. virgatus, Alternenthera spp., C. juncea* and *S. grandiflora* pot hosts. Sandalwood seedlings with these pot hosts have increased growth rates which is greater than that of *C. frutescens* as a pot host.

It is necessary to do further field research on the effect of pot host species on the growth rate of sandalwood seedlings.

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The Sandalwood Research Newsletter

The SRN is a quarterly newsletter with distribution throughout all nations that have an interest in *Santalum* species. The SRN aims to increase *Santalum* species awareness through the dissemination of *Santalum* species information. Increasing the awareness of *Santalum* species will promote the conservation of *Santalum* species, stimulate plantation establishment and increase research and management collaboration between organisations.

It is hoped that articles will be received on a range of *Santalum* species research and management issues. If you wish to contribute an article to the SRN or wish to be included on the SRN mailing list please write to the Editor giving your name, organisation and postal address. All articles relevant to *Santalum* species are welcomed.

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Selection of sandalwood (*Santalum album*) candidate plus trees in Timor Tengah Selatan District

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Summary

Selection is a key factor of applied tree improvement programs. Selection of sandalwood candidate plus trees has been done in natural stands of sandalwood (*Santalum album*) in Ajaubaki, Oenutnanan, Siso, Buat, Niki-Niki, Kokoi, and Netpala (District of Timor Tengah Selatan).

The parameters in this selection program are: heartwood volume, total height, stem diameter at breast height, crown base height, clear bole height, crown diameter, and straightness. The trees which have the highest 10 per cent of the parameter values are regarded as candidate plus trees.

From this selection program 108 sandalwood candidate plus trees have been selected. The variations between candidate plus trees are more influenced by genetic factors than environmental factors.

Introduction

Sandalwood is an indigenous tree in Indonesia, its distribution ranges from Java to the archipelago of Nusa Tenggara Timur (Kramer in Sri Qanarto and Winarni, 1987).

Almost all the present sandalwood harvesting in Nusa Tenggara Timur (NTT) comes from natural forest stands; and so, as a means of conservation, it is necessary to increase the plantation resource of sandalwood. The objective of tree breeding is to establish highly productive plantations. However, due to high mortality levels in plantations silvicultural research is still required to refine plantation establishment techniques.

On the completion of selecting candidate plus trees from natural stands progeny testing is required to select superior parent trees on the basis of desired characteristics, such as high survival and growth rates. Then the tree breeding program requires the cross-breeding of superior parent trees to increase the genetic gains of desired characteristics, such as disease resistance and heartwood formation.

Information on genetic variation is necessary in the tree-breeding program. This research is done to discover superior sandalwood parent trees.

Results and Discussion

The analysis of variances of the heartwood volume, the total height, the height to crown base, the clear-bole height, the diameter at breast height, the heartwood diameter, and the crown diameter are presented in Table 1. From the results of the analysis variances, it is seen that each of the selection parameters show clear variations.

Selection has been done in uneven aged natural stands. In a forest with trees of variable ages qualitative traits cannot be compared.

Tree breeding improvement programs start with the selection of candidate plus trees.

Geographic variations (provenance), local variations and variations within the tree exist in tree species (Soerianegara, 1970). These may be caused by environmental differences or via genetic variations. Environmental variables like rainfall, temperature, soil, slope and elevation from sea level, have an influence on the phenotype of a tree (Zobel and Talbert, 1984). Variations caused by environmental differences must be determined in tree breeding selection programs.

Appropriate selection can given genetic results to the extent of 3 to 10 per cent of each generation (Wright, 1962).

Heritability values of sandalwood are presented in Table 2. It can be seen that each selection parameter has a moderate to high heritability value. Heritability values range from 0 to 1. The value 1 occurs when individual variations are absolutely caused by genetic factors (Zobel and Talbert, 1984).

It can be seen in Table 2 that tree diameter and heartwood diameter have high heritability values, 0.91 and 0.92 respectively. Indicating the process of heartwood formation gets more influence from genetic factors than from environmental factors.

Since the economic value of sandalwood depends on the quantity and quality of heartwood, heartwood formation is therefore the main criterion in the selection program of superior sandalwood candidate plus trees.

Conclusions and Suggestions

Conclusions

(a) This selection program has succeeded in obtaining 108 sandalwood candidate plus trees in the area of South Central Timor with the selection parameters of heartwood volume, total height, tree diameter, height up to the crown base, clear bole height, crown diameter, and the straightness of the trunk. These selection measures are an early step towards a sandalwood tree-breeding program.

(b) Each selection parameter has been found to vary greatly. This variability is caused by the interaction between genetic and environmental factors. The former has a greater influence than the

Table 1: Averages of heartwood volume, total height, stem diameter, clear bole height, crown base height, heartwood diameter and crown diameter

Location	*Heartwood Volume* m³	*Total Height* m	*Stem Diameter* cm	*Clear Bole Height* m	*Crown Base Height* m	*Heartwood Diameter* cm	*Crown Ddiameter* m
Ajaubaki	0,04656 a	14,80 a	24,05 a	3,94 a	5,98 a	17,56 a	8,04 a
Oenutnanan	0,02705 b	12,95 b	18,83 b	4,73 b	6,08 b	11,81 b	6,11 b
Siso	0,02493 b	10,87c	23,06 c	2,94 c	5,12 c	11,53 b	6,56 c
Buat	0,04119 c	13,98 d	27,44 d	3,58 d	5,29 d	17,11 a	9,96 d
Niki-Niki	0,07249 d	12,62 e	31,76 e	2,52 e	5,96 a	22,94 c	7,33 c
Kokoi	0,09340 c	11,13 f	30,30 f	2,47 e	6,13 d	21,63 d	9,89 d
Netpala	0,05233 f	10,62 g	32,66 g	2,93 f	4,23 e	24,58 c	10,49 f

(Figure on the same column marked with the same letter denote non-significant differences at 5% according to HSD test)

latter, which indicates a possibility that results from genetic measures are going to be considerably greater in a tree breeding program.

Suggestions

(a) It is necessary to make a selection of superior candidate sandalwood trees in other regions in Nusa Tenggara Timur. The more of these superior sandalwood trees there are, the more variability among these trees there will probably be, and so genetic studies will get more extensive.

(b) It is necessary to progeny test candidate plus trees across a number of sites.

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Table 2: Heritability values of selection parameter

Parameter	*Heritability*
Heartwood volume	0,5908
Tree height	0,8032
Tree diameter	0,9105
Clear bole height	0,6455
Height to crown base	0,6701
Heartwood diameter	0,9220
Crown diameter	0,8975

The Sandalwood Newsletter invites all readers to write to the article authors to acquire additional information concerning *Santalum* species issues outlined in these articles. As an aim of the SRN is to incresae the level of liaison between relevant organisations.

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Sandalwood - Scope for commercial propagation on community lands in India

by Dr UV Singh IFS

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Sandalwood *(Santalum album L.)* is economically and culturally important to many parts of India and Indonesia. *S. album* is mainly distributed throughout India, Nepal, Sri Lanka, the Indonesian islands of Timor, Sumba, Flores, Java, Bali, and along the extreme northern Australian coastline.

S. album site specifity is highly variable. It is found in a rainfall range from 300 to 3000 millimetres, an altitude range of 0 to 2000 metres and it is capable of growing in different soils, such as, laterite, loam, sand, clay and black cotton soils. *S. album's* distribution is restrained by water logged areas, but the species is able to tolerate a pH range from 6.0 to 8.0. Sandalwood also has extreme temperature tolerance where temperatures can range from 4°C to 46°C throughout its distribution.

Due to this high range of tolerances of environmental factors, it is easily thought that *S. album* could grow in a range of locations through most tropical and sub-tropical regions, but this is not so. One factor limiting the distribution of *S. album* is the vegetation type and the nature of its hosts. Even though it is reported that for adequate *S. album* survival and growth any green tree can be a parasitised and act as a host. Rai (1990), reported a series of host plants used for *S. album* in India. Sandalwood is mainly dependent on the host plants for the absorption of nutrients which it is unable to absorb through its own the root system. Particularly phosphorous, magnesium potassium and nitrogen. Hence, a good host plant for *S. album* is a tree which efficiently absorbs these nutrients and translocates them to *S. album*. According to Rai (1990) for *S. album* growth *Casuarina equisitifolia* is the best host plant.

A recent inventory of *S. album* in the southern States of India, including Karnataka, Maharastra and Andhra Pradesh was undertaken. The purpose of this inventory was to understand the association and distribution of *S. album* in relation to *Prosopis juliflora* (Bellary jali). The survey concentrated on the Bellary, Chitradurga, Bangalore, Kolar, Dharwad, Belgaum, Biljapur, Gulbarga, Bidar and Raichur districts of the Karnataka State; and the Pune, Ahmed Nagar, Satara, Kolhapur districts of Maharastra State; and the Anantpur, Mahboob Nagar, Kurnool districts of Andhra Pradesh State.

P. juliflora is a native legume of Central America and the West Indies. This species can spread rapidly due to their easy propagation and remarkable ability to withstand both adverse conditions that reduce competition of other plant associations and heavy grazing. The *Prosopis* genus is well adapted to the heat and poor soils of dry regions (BOSTID 1981).

Listed below are the climatic conditions of these three states:

1. Annual rainfall ranges from 500 to 1200 millimetres, mainly caused by the south west monsoon, but occasionally the north east monsoon causes significant rainfall.
2. Soil types range from sand, loam, red soil, black cotton, alluvial and rocky, skeletal soil types.
3. Temperature ranges from 8°C to 46°C.
4. Forest types are classified as dry scrub forests.

A major species of the predominant vegetation type in the states is *P. juliflora*. *P. juliflora's* distribution is wide spread, occurring across the entire landscape of the three States, except on land utilised for agriculture. Fallow or vacant

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land is covered by *P. juliflora*, in particular road sides, canal sides, community land, field boundaries in and around the villages and other fallow lands.

The three States comprising the survey are the main sandalwood producing states of India. *P.juliflora* is a new introduction to the Indian landscape, perhaps in the last 30-40 years. However, the occurrence of sandalwood with the association of *P. juliflora* has gone relatively unnoticed. From this survey study it is reported that *P. juliflora* is one of the best 'natural' host plants for *S. album*.

Listed below are the advantages of host-parasite relationship between *P. juliflora* and *S. album*:

1. *P. juliflora* is an evergreen plant and never sheds leaves. At all times it provides good shade to *S. album*.

2. It coppices after grazing very vigorously. Continued pruning does not reduce the vigour of its coppice.

3. It generally has a bushy habit and thorns which protects the *S. album* seedling.

4. It grows in all types of soil and remains green even in drought conditions which in turn provides a continuous nutrient and water supply to *S. album* for growth throughout the year.

An interesting observation in the study is that no spike disease was recorded from sandalwood trees found in association of *P. juliflora*. This indicates tremendous potential for sandalwood growing on lands which are not used for agriculture and are highly colonised by *Prosopis* spp.

P. juliflora offers wide scope for the planting of *S. album* in areas of low *S. album* occurrence, due to its relationship with the non-occurrence of spike disease. *P. juliflora* is found in every State of India. It may aid the establishment and spread of *S. album* from the traditional production areas of Karnataka and Tamil Nadu.

Table 1: State-wide distribution of sandalwood in India

Karnataka	5245 km^2
Tamil Nadu	3040 km^2
Andrapradesh	175 km^2
Madyapradesh	35 km^2
Orissa	25 km^2
Maharastra	8 km^2
Kerala	7 km^2
U.P. less than	1 km^2
Other private holdings	500 km^2

The relationship between the (*S. album*) spike disease and nutrient deficiencies have been studied in detail. It apepars that micronutrients do not influence the control of the disease.

Spike disease is present in the areas of high density growing sandalwood like Chickmangalore, Mysore, Hassan, Hunsur, Shimoga, Tumkur, Bangalore and Kolar districts of Karnataka and Salem, Coimbatoor and other adjoining districts of Tamil Nadu. But spike disease is either absent or negligible in the northern district of Karnataka and southern parts of Maharastra and in *S. album* associated with the *P. juliflora*. Is this caused by increased nitrogen supply to *S. album* by *P. juliflora*? This remains an unsolved problem and requires further study.

Since the *P. juliflora* is extremely thorny *S. album* establishment is difficult. How to plant *S. album* over such a vast area in such difficult spiny bushes? Dibbling seed underneath the canopy of *P. juliflora* appears the logical method. Seeds should be well treated and cool stored in advance for dibbling. The *S. album* seeds take 30 to 45 days to germinate, constant moisture is required for that period. Hence, seeds should be dibbled just before the onset of monsoon. Seeds should be treated with an insect and rodent repellent. Germination percentage by this method is likely to be low, hence profuse dibbling is required. It is advisable to dibble 4 to 6 kilograms seeds per hectare. Seeds should be dibbled about 0.5 to 1 mëtre away from the origin of roots of *P. juliflora*.

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The Sandalwood Research Newsletter invites readers to write to the article authors to acquire aditional information concerning issues disseminated in these articles. Increased internaitonal cooperation and liaison between sandalwood researchers and managers is encouraged.

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Sandalwood Workshop, 1-11 August 1994, Noumea, New Caledonia.

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A sandalwood workshop, 1-11 August 1994, hosted by CIRAD-Foret, was held in Noumea, New Caledonia. The workshop was an outstanding success in achieving its main objectives of promoting the awareness of Pacific Island sandalwood.

The existing global upsurge in sandalwood demand and the limited recovery of sandalwood reserves has re-created considerable interest in Pacific Island sandalwood management, such as in Vanuatu where sandalwood is a highly prized forest product by local landowners (Tacconi 1994). Increased sandalwood awareness has lead to a greater focus on sandalwood silvicultural research, natural resource assessment, gene pool conservation and utilisation, on some of the previously little known *Santalum* species. This has prompted the need to disseminate acquired *Santalum* species information to developing Pacific nations to ensure the rejuvenation of sandalwood interests is sustainable. The sandalwood workshop was a timely event in promoting the social, commercial and ecological importance of sandalwood.

The sandalwood workshop consisted of paper presentations on a range of sandalwood issues including species distribution and ecology, seed and germination, pot host selection, nursery propagation, genetic variation, plantation establishment, heartwood formation and economic analysis. This was complemented by relevant field trips to research plots, nurseries, natural stands, plantations and value adding processing plants. Sandalwood conservation, natural stand management, plantation silviculture research and value adding processes are well abreast in New Caledonia. Papers encompassed most species comprising the *Santalum* genus. Participating country representatives presented country reports on recent sandalwood developments including research, management and utilisation. Participating countries included Vanuatu, Fiji, Western Samoa, Tonga, Cook Islands, Indonesia, Federated States of Micronesia, Solomon Islands and several representatives from New Caledonia. Main resource speakers attended from New Caledonia, Vanuatu and Western Australia.

As an outcome of the workshop considerable benefit should be gained from countries where sandalwood exploitation has increased and natural resources are substantial enough to encourage plantation establishment of either native or exotic *Santalum* species, such as in Vanuatu and Fiji. In Pacific countries where sandalwood resources are unsubstantial or where sandalwood management is limited the workshop should give a thorough insight into the value of sandalwood and the initial requirements of plantation research. However, seed acquisition will remain a large obstruction to many sandalwood research programs. This should be overcome with international cooperation and localised persistence.

Participating country paper presentations highlighted the severe plight of several Pacific *Santalum* species. The Cook Islands' *S. insulare* has only a small remaining population on the island of Mitiaro which has not seed viable seed for several seasons (Koroa 1994) . In Fiji severe cyclones have caused the failure of recent *S. yasi* seed crops and a method of vegetative propagation via shoot cuttings has been developed to increase the nursery growing stock for the development of seed orchards (Bulai 1994) .

The workshop detailed the substantial progress international aid research programs have achieved in relatively small time frames. The CIRAD-Foret attempts to introduce the exotic *S. austrocaledonicum* to Rarotonga of the Cook Islands have proved very fruitful where trial plots have demonstrated good growth on very exposed raised coral terraces. Additionally, the ACIAR *S. album* research program in Indonesia has assisted with the rapid progress achieved in the selection of *S. album* candidate plus trees, nursery propagation and field establishment research. It is perceived that continued international aid programs are of high importance to ensure that other threatened *Santalum* species can be conserved and infant sandalwood export industries developed for the benefit of small Pacific island rural economies.

A 'state of knowledge' from the workshop has been compiled formulating concepts on sandalwood conservation, propagation and planta-

Several workshop participants observe Jean-Paul Chauvin demonstrate techniques for nicking the seed coat of sandalwood seed at the Technique du Centre de Semences Forestieres, New Caledonia.

tion establishment. This will form a component of the workshop proceedings currently being compiled and published by CIRAD-Foret and the South Pacific Forestry Development Programme (SPFDP).

The workshop emphasised several universal similarities between the silvicultural regimes of different *Santalum* species. These included the use of *Alternanthera* spp as a pot host, immediate seed defleshing and cold storage, leguminous field hosts (*Acacia* and *Sesbania* spp) and the high conservation importance of remaining populations and the inherent high value of sandalwood.

The importance of information dissemination, the exchange of germ plasm (seed) and continued international cooperation were reiterated at the workshop. The workshop was well conceived as all country participants were medium level forestry professionals. Hence, technical details acquired during the workshop should be implemented in field situations with comparative ease. Proposals on research collaboration were raised focusing on an international *Santalum* species/provenance trial. A proposal will be developed by CIRAD-Foret for distribution to relevant forest organisations for endorsement.

Even though the sandalwood workshop's 'terms of reference' was to concentrate on Pacific Island sandalwood notable non-attendants of the workshop were Hawaii, PNG and India where significant sandalwood resources exist. Future workshops of a similar nature (at another venue) with a 'terms of reference' to include global sandalwood interests may be beneficial, including representatives from sandalwood utilisation industries to ensure future plantation sandalwood is encouraged.

Once again I reiterate the value of the sandalwood workshop in the dissemination of sandalwood research information. I commend the considerable effort that CIRAD-Foret placed into the organisation and smooth running of the sandalwood workshop.

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Articles on a range of *Santalum* species research and management issues are welcomed by the Sandalwood Research Newsletter. If you wish to contribute an article to the SRN or wish to be included on the SRN mailing list please write to the Editor stating your name, organisation and postal address.

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