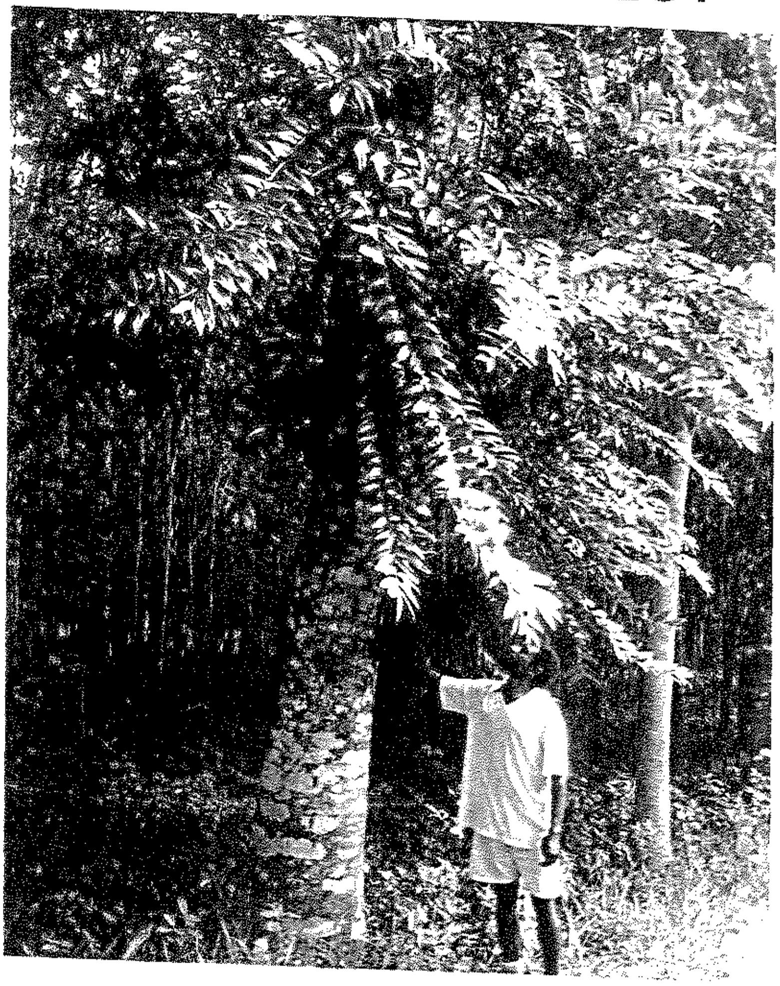
SANTO INDUSTRIAL FOREST PLANTATION PROJECT



Technical Booklet No. 3

A Compilation of Results from Forestry Trials established on Espiritu Santo, Vanuatu

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Final Version

ACKNOWLEDGEMENTS

The research at Santo IFP Project could not have been conducted without funding from the Vanuatu Government, the European Development Fund and the British Government's Overseas Development Administration.

This report describes the work of many people involved in forestry research on Santo. I would like to acknowledge the work of research staff of the Department of Forestry and of the British Government's Overseas Development Administration, who established the first forestry trials on Santo in the 1970's and 1980's. At Santo Industrial Forest Plantation Project (Santo IFP Project) I would like to recognise the research conducted by the two previous Research Officers, Joanna Secker Walker and Alan Vira. They established most of the trials described in this report. I would also like to acknowledge the work of those involved in the establishment of the trials of pulp species, notably Steve Strand of Chandler, Fraser and Keating (CFK) and Andy Dick of the then Plantation Development Ltd (PDL).

Most of the essential work of data collection at Santo IFP Project has been undertaken by two staffmembers, Kasen Alick and Seth Mesek.

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September 1994

Cover Photograph: Research Technician, Seth Mesek by a twenty two year old Kauri (*Agathis macrophylla*) at Monbiftek.

CONTENTS

SECTION 1 INTRODUCTION AND BACKGROUND

1.1 Introduction

This report is a compilation of results of trials conducted in the first phase of the Santo IFP Project (1989 - 1994). Results of trials on Santo established by Department of Forestry and those formerly managed by Carter Holt Harvey are also included.

1.2 Santo IFP Project Site

The island of Espiritu Santo, or Santo as an abbreviation is located at about 15° S and 167°E and is the largest island in Vanuatu, with a land area of 4,248 km^2 (See Map 1.2.1). Climatic information, from Luganville, the main town on the island is shown in Figure 1.2.1.

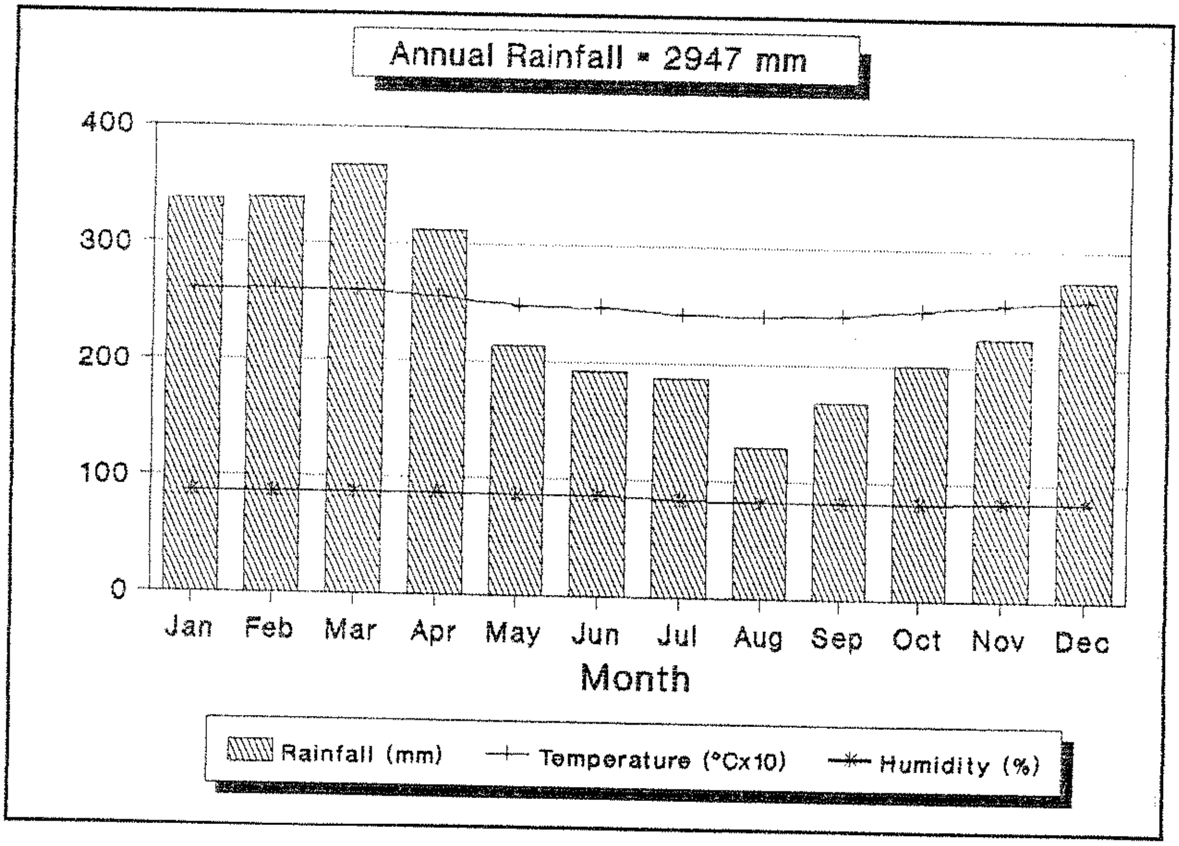
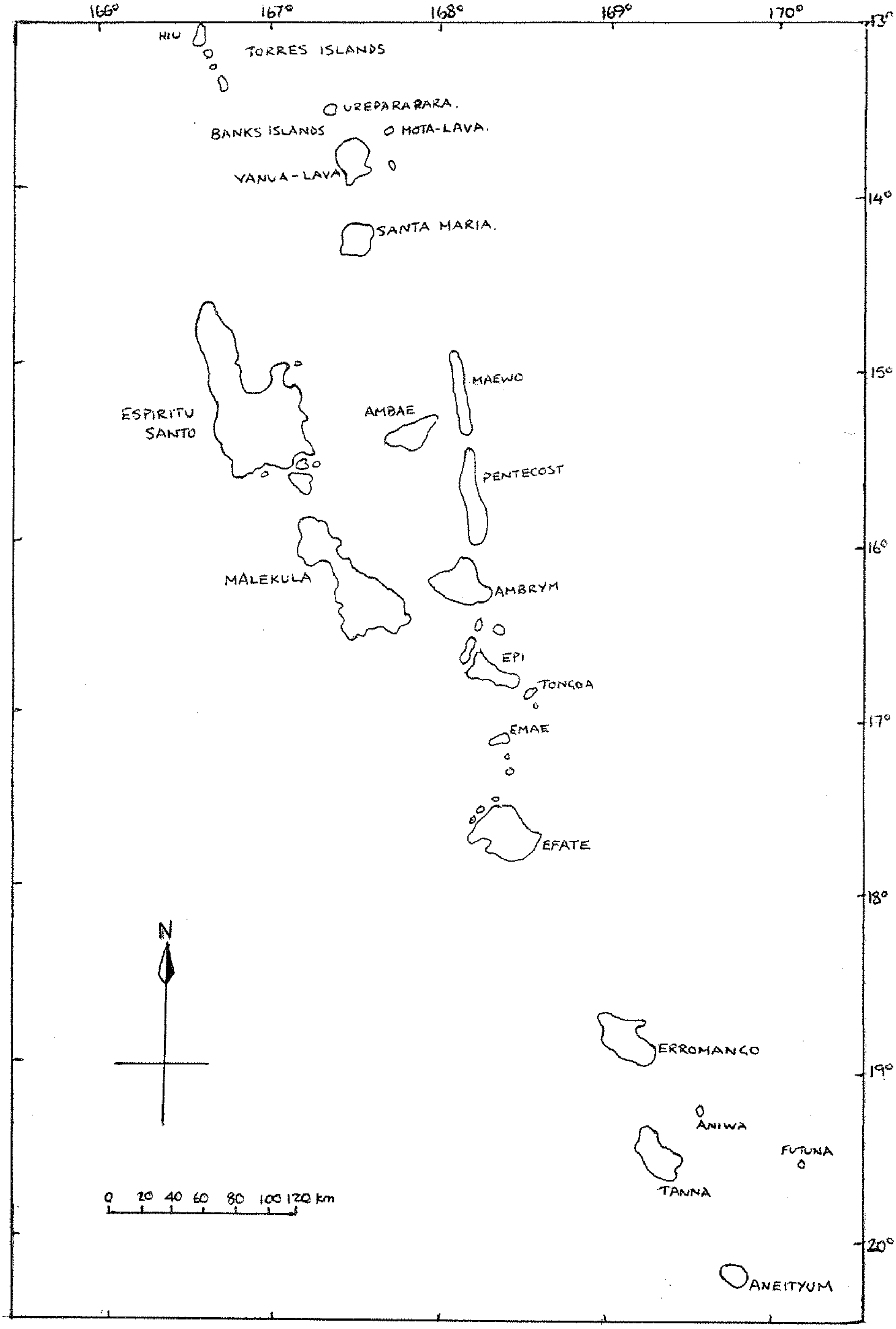
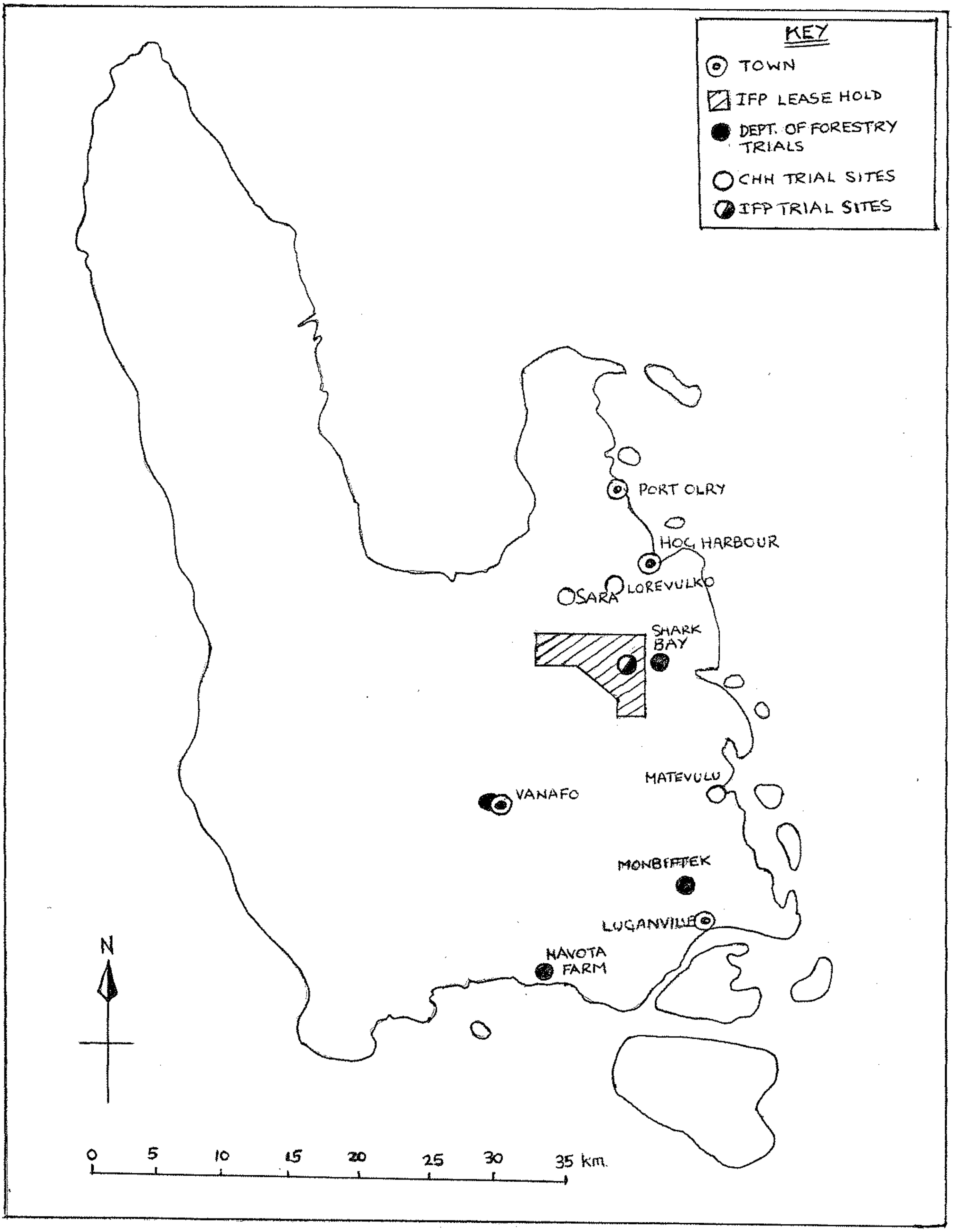


Figure 1.2.1. Climatic Information

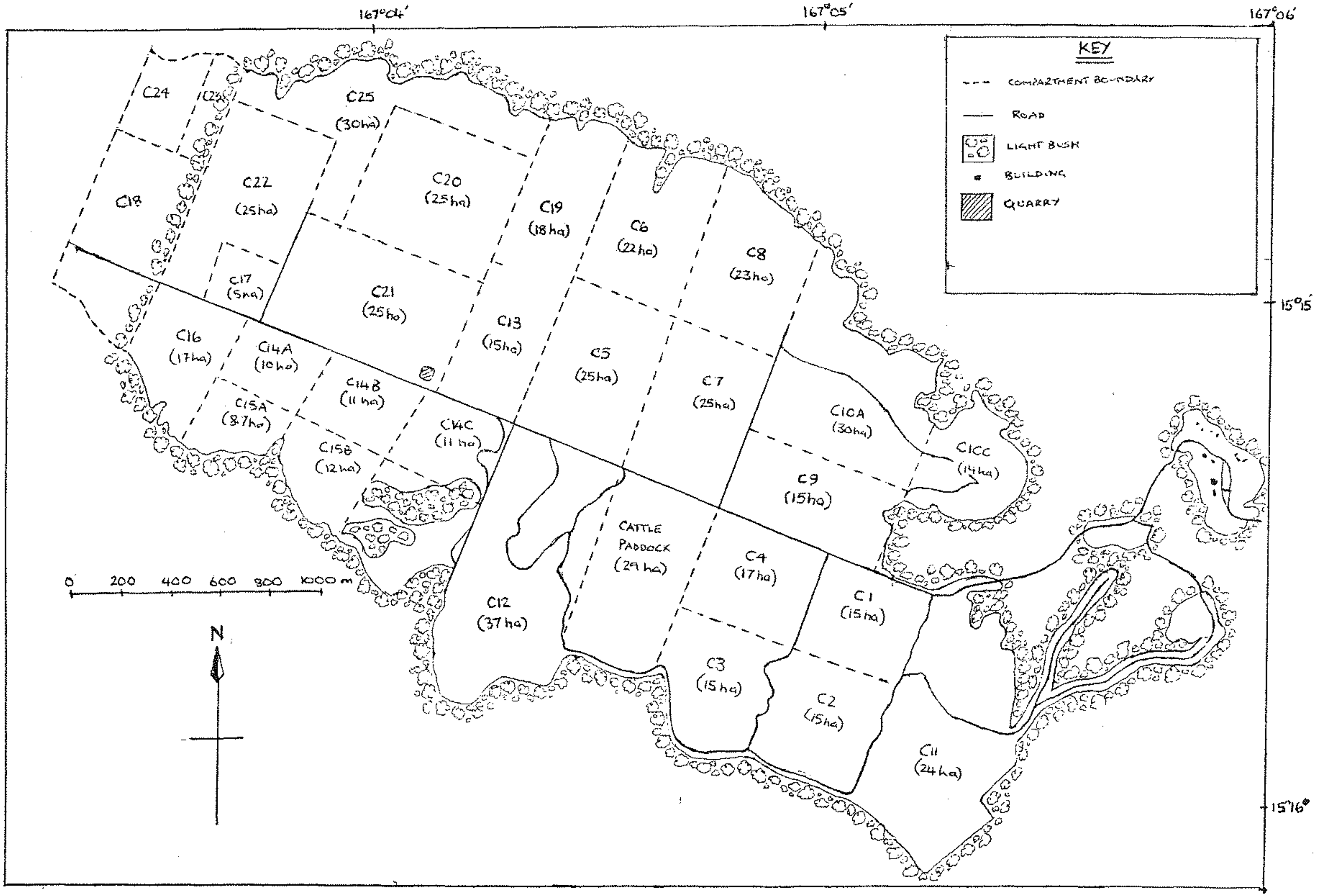
The Santo IFP Project site is a leasehold situated about 32 km north north west of Luganville. The location is shown in Map 1.2.2 and the layout of planted area of the project site is shown in Map 1.2.3. Other trial sites mentioned in the report are also shown on Map 1.2.1 and a description is given in Table 1.2.1. Total area of the Santo IFP leasehold is approximately 5,490 ha, with about 350 ha having been planted.



Map 1.2.1 Vanuatu



Map 1.2.2 Location of IFP and other Trial Sites on Santo



Map 1.2.3 Layout of Cleared Area at IFP

Site	Altitude	Mean Annual Rainfall	Soil Type	Vegetation	Comments
Monbiftek	80 m	3,000	Ferralic Cambisols - humic weakly unsatrurated ferralitic soils	Rainforest with scattered dominants of Kleinhovia, Antiaris and thickets of Hibiscus tiliaceus.	Exceptionally good site in prime agricultural land. tends to be clayey in areas where water gathers.
Navota Farm	20 m	3,000	Rendzina - derived from recently emerged coral reef deposits. The soil is thin, fairly fertile and has outcrops of coral present.	Relatively open forest with scattered large trees. Hibiscus tiliaceus common with small Urticaceae and Moraceaea. Banyans are also common.	Rooting of trees on this site is generally limited to the top 50 cm and wind throw has occured with a number of species. Climbers have caused few problems, but cattle have damaged trees in the past.
Shark Bay	50 m	3,500	Ferralitic cambisols - humic weakly. Unsaturated ferralitic soils foirmed on a low limestone plateau. Good fertility.	Open canopy rainforest with Hibiscus tiliaceus but scattered areas of Klienhovia, Castaneospermeum and Antiaris.	Level area which has poor drainage in places. Surrounded by coconut plantations.
Vanafo	150 m	3,000 +	Xanthic orthic ferrasols - humic moderately unsaturated ferralitic soils. Very clayey and rich in halloysite or kaolinite clay minerals. Moderate fertility.	Degraded forest due to cyclone damage. Scattered areas of large trees - Klienhovia, Antiaris etc. Climbers frequent in cyclone damaged areas - Merremia, Ipomea and Mikania	Cultivation and bulldozer site preparation has lowered fertility and disturbed soils. Rebellion of 1980 prevented normal maintenance and allowed climbers to damage trees.

Table 1.2.1 Description of Other Experimental Sites (From Neil, 1983).

Soils are ferralitic clays, formed from volcanic ash and fertility is "moderately limited". The constraints to tree growth being variable soil depth overlying limestone, chemical fertility being concentrated near the surface and the pH of 5.5 to 6 (Forestry Service, 1988). Over most of the area potassium deficiency was thought to be the only nutritional constraint to growing *Cordia alliodora* (Bennett, 1989).

Topography is mostly plateau at between 200 and 300m altitude, with a broad river valley draining to the south and three flat topped hills along the eastern boundary rising to about 200m.

Natural vegetation over the central part of the project area is open bush with woody lianes and shrubs about 4 to 5 m high. Clumps of high forest, dominated by Milktree, (*Antiarus toxicara*) and Whitewood (*Endospermum medullosum*) are scattered over the whole area, with Nakatambol (*Dracontomelon vitiense*), Stinkwood (*Dysoxylon amooroides*) and Bluwota (*Pterocarpus indicus*) also being common. Vine growth, of Merremia, Mikania and Ipomea is considerable over most of the site. There was some logging of the site by the US Army during World War 2 (Forest Service, 1986) and there has been cattle ranching on the site since. Towards the west of the project are areas of high forest again dominated by Milktree and Whitewood.

1.3 Objectives of Research

The objectives of the first phase of the Santo IFP Project were described in the Project Proposal (Forest Service, 1986). The main goal was to produce a 6,000 ha forestry plantation by 2006, to supply quality saw and veneer timber to local and foreign markets.

Research was a prominent feature of the programme, as there had been little experience of large scale plantation forestry in Vanuatu. Silvicultural research was to concentrate on cost effective solutions to problems encountered in plantation establishment and growth. Three species were to be used for most of the plantings; 70% of the trees were to be *Cordia alliodora*, while *Sweitenia macrophylla* and *Agathis macrophylla* were to make up the other 30%. Studies would continue for identifying superior species and provenances for veneer and quality timber production.

Agroforestry was also to be investigated. Timber would provide long - term returns and agricultural crops grown under the trees would provide short - term returns. If results from the trials were favourable, growing cash crops with the trees would be practised over most of the project area. Cash crops favoured due to their shade tolerance were coffee (*Coffea robusta*), Kava (*Piper methysticum*) and Cocoa (*Theobroma cacao*). Other crops mentioned included garlic (*Allium sativum*) and cardomon).

Silvopastoral research was also to be included in the research programme. Grazing cattle would be used to clear the existing vegetation before planting and might also be used to control weeds during establishment of the forest crop. Legumes and grasses were also to be tested as cover crops and as a source of cattle feed. Like agricultural crops, cattle raising would provide short - term returns.

1.4 Research Staff

There have been a total of three Research Officers during the first phase of the Santo IFP project and one Research Technician. The Research Officers have been Joanna Secker Walker (1991 - 1993), Allan Vira (1992 - 1993) and Andrew Leslie (1993 - 1994). Kasen Alick joined the Project in 1992 as the Research Technician, being transferred from Carter Holt Harvey. Seth Mesek was employed in 1992 as a Research Labourer.

Other staff members have been involved in research activities, notably Rossina Mabon (Administrative Assistant) and Mesek Setty (Nursery Manager).

Five trainees, Alick Berry, Eric Jonah, Simon Naupa, Mandes Kilman and Michael Tapi from the Department of Forestry have also been placed with the project and conducted research work. Also, Elianeth Ephraim a student from Matevulu College has assisted in experiments.

SECTION 2 SEED COLLECTION AND HANDLING RESEARCH

2.1. Information on Seed of Native Timber Species. (075-6)

Information on seed collection of native species has been compiled to produce a seed collection timetable in Secker Walker, (1993m) which is reproduced in Appendix 1. In the same document numbers of seed per kilogramme and recommended pretreatments were also described.

2.2. Seed Dormancy and Pretreatment Trials. (077)

In 1993 a trial was conducted to test a variety of techniques such as soaking, boiling, scarifying, as possible pre-treatments for seed of six native species. Nine treatments were tested, although all nine were not applied to seed of any of the species (See Table 2.2.1). Treatments were as follows:

(i) No treatment
(ii) Soak in water for 24 to 48 hours
(iii) Soak in alkali (Andrew's Alkali); seed of some species soaked for 15 ½ hours other species for 21 hours.
(iv) Boil in water for two minutes
(v) Soak in acid (Corn Wells White Vinegar): seed of some species soaked for 1 hour others for 1 ½ hours and others for 21 hours.
(vi) Oven dried for 21 hours
(vii) Cleaned and air dried
(viii) Alternative soaking and drying; 2 days in water, 1 day out, 1 day in water and 1 day out.
(ix) Part of seed coat being removed

Species	Treatment
Nakatambol (Dracontomelon vitiensis)	(i), (ii), (iii) for 15 ½ hours, (iv), (v) for 1 ½ hours, (vi), (viii)
Stinkwood (Dysoxylon amooroides)	(i), (ii) for 24 hours, (v) for 1 hour, (vi)
Beantree (Castaneospermum australe)	(i), (iv), (v) for 1 ½ hours (viii)
Milktree (Antiaris toxicara)	(i), (ii) for 24 hours, (iv), (ix)
Wild Natapoa (Terminalia sepicana)	(i), (ii) for 24 hours, (iii) for 15 ½ hours, (iv), (v) for 1 ½, 15 ½ and 72 hours, (viii)
Navasvas (Alphitonia zizyphoides)	(i), (ii), (iv)

Table 2.2.1 Treatments Applied to Each Species

Results of the best treatment (Mabon, 1993) are shown in Table 2.2.2.

Species	Best Treatment	Days to germinate	% Germination
Nakatambol (Dracontomelon vitiensis)	Soak in vinegar for 72 hours	18 - 28	52
Stinkwood (Dysoxylon amooroides)	No treatment gave satisfactory results	Not recorded	0
Beantree (Castaneospermum australe)	Soaking and drying	Not recorded	50
Milktree (Antiaris toxicara)	Soak in water for 24 hours	Not recorded	54
Wild Natapoa (Terminalia sepican)	None	31 - 41	72
Navasvas (Alphitonia zizyphoides)	No treatment gave satisfactory results	Not recorded	0

Table 2.2.2 Best Treatments

Recommended treatments obtained through informal trials are shown in Appendix 1.

SECTION 3 NURSERY RESEARCH

3.1. Nursery Cuttings Trial

A nursery cutting trial was established in November 1993 and assessed in January 1994. The cuttings were treated with two commercial rooting hormones, Seradix and Planofix. Seradix, which contains the active ingredient Indolybutic Acid (IBA) was applied following the manufacturer's instructions. Planofix, which contains B Naphthylacetic Acid (NAA) was applied at several dilutions as instructions were not available.

Five species were used, although most of the cuttings were from two species, Bluwota (*Pterocarpus indicus*) and Kauri (*Agathis macrophylla*). Three other species were tested, Wild Natapoa (*Terminalia sepicana*), Whitewood (*Endospermum medullosum*) and Navasvas (*Alphitonia zizyphoides*). Seradix only was applied and the cuttings placed only in trays in the shade.

For Bluwota the following treatments were applied to cuttings:

(i) Seradix, Trays in the Shade

(a) Old wood cuttings with waxed tops

(b) New wood cuttings with waxed tops

(c) New wood cuttings with waxed tops

(ii) Seradix, Trays in the Open

(iii) Planofix at concentrations of 100%, 50%, 33%, 25% and 1%, Trays in the Open

For Kauri a similar set of treatments was applied:

(i) Seradix, Trays in the Shade

(ii) Seradix, Trays in the Open

(iii) Planofix at concentrations of 50%, 33%, 25%, 10% and 1%, Trays in the Open

Trays in the "open" were lightly shaded by a single layer of transparent polythene. Those in the "shade" were placed in a wooden framed box covered in a layer of 90% shade netting.

The number of cuttings that were green (still living), brown (dead), showing root development and/or shoot development were recorded for each treatment. Where roots or shoots had developed the number of roots and/or shoots was recorded and the length of the longest root and/or shoot.

There was some success with the cuttings of Wild Natapoa, of which 33% developed roots and healthy shoots. Unfortunately the Whitewood cuttings developed no roots or shoots and had begun to rot by the end of the experiment. Cuttings of Navasvas also showed no root development, which is unfortunate as this species is difficult to raise from seed.

Bluwota is known to strike readily from cuttings and staves directly planted into the ground and is used widely as living posts for fencing and other purposes (Wheatley, 1992). From the IFP Project trial raising Bluwota from cuttings is relatively straightforward (See Tables 3.1.1 and 3.1.2). The lack of success with Planofix may be due to all treatments with this hormone being in trays left in the open. Certainly shade increased the success of rooting with Seradix. From observations it also appeared that larger diameter cuttings (> 1cm) produced more vigorous root and shoot growth.

Use of cuttings of Bluwota trees of excellent form may be worthwhile, instead of seedling stock, which may yield trees of poor form. A further argument for using cuttings is the reduced time in the nursery. To produce a transplant of 40cm height it would take about 2 - 3 months with cuttings and about 4 - 5 months through seed. (Setty, pers.comm.) Present recommended practices for Bluwota are to use Seradix on large dimension, new wood cuttings with wax applied to protect the top.

Kauri has been successfully raised from cuttings (Neil, 1987) in Vanuatu in high humidity propagators. Three main factors could have prevented rooting in the IFP Nursery Cuttings Trial (See Table 3.1.1 and 3.1.2):

(i) <u>That the wrong rooting hormones were used or the correct ones, but at the wrong concentrations</u>.

Neil, (1987) found that IBA at 0.4% solution in alcohol or no hormone gave best results, with 35% rooting. Neither of these treatments was tested at the IFP Project trial and it is possible that water was used instead of alcohol to dilute the hormones. Seradix treatments were found to give poor results, with rooting of 5% of cuttings. NAA in 0.4% solution, (the active ingredient in Planofix) promoted rooting in 25% of the cuttings (Niel, 1987). Later trials conducted by Neil, (1987) increased rooting with 0.4% IBA to 100% and with 0.4% NAA to 60%. The poor results in the IFP Project trial, suggests that humidity and age of cuttings have also had an influence. With Planofix none of the cuttings showed either root or shoot development. With Seradix some cuttings produced shoots (See Table 2.2.3) but none started rooting.

(ii) <u>That even in the shaded area the humidity was not sufficiently high to stimulate rooting</u>.

The cuttings in the "open" were watered by the nursery irrigation system for about 2 minutes every 1 ½ hours and were shaded by polythene only. Humidity was low.

Those cuttings in the shaded box experienced a more humid environment and lower temperatures. However, it is still likely that the humidity was not sufficient to promote rooting. A high humidity propagator should be tried.

(iii) That the cuttings were taken from material that was too old or of the wrong size.

Cuttings from older parts of branches of seedlings of Kauri were found by Neil, (1987) to have poorer ability to root than younger parts. The cuttings used in the IFP Project trial were taken from trees about 1m tall. In future it would be worth trying cuttings from younger plants, preferably small seedlings. Despite no root development, some Kauri cuttings developed small shoots, most about 2mm long, with one growing to 33mm.

Species/ Treatment	Number of Roots	Length of Longest Root (mm)	% Cuttings Rooted
Shade, Waxed*	11.2	31.3	36
Open, Waxed*	20.7	43.7	12
Shade, New, No Wax	2.5	13	4
Shade, New, Waxed	13.5	34.7	77
Shade, Old, Waxed	14.6	120.5	42

Table 3.1.1 Means for Bluwota Treated with Seradix

Species/ Treatment	Number of Roots	Length of Longest Root (mm)	% Cuttings Rooted
100% Planofix	23	32	5
50% Planofix	2	32	15
33% Planofix	0	0	0
25% Planofix	0	0	0
1% Planofix	0	0	0

Table 3.1.2 Means for Bluwota Treated with Planofix in Trays in the Open

3.2. Container Trials. (081.1)

In October 1991 a nursery trial was established to test the growth of *Cordia alliodora* seedlings in 8 different containers. Unfortunately, *C. alliodora* no longer features in the IFP planting programme but the results may be useful as a basis for other container trials for other fast growing exotics.

The trial was a completely randomised design with each treatment having three replications. Numbers of seed sown for the different containers was not recorded in the experimental file. The bare rooted treatment was replicated three times as with the others but the plots were not randomly located. It was assumed the numbers noted on the data sheets in brackets following the short paper pot sizes denotes the number of pots in each plot.

Container types and their dimensions and volumes are shown in Table 3.2.1.

Container	Length (cm)	Diameter (cm)	Volume (cc)
Plastic Pot	22	6	622
Seed Trays	6 (depth)	37.5 x 58.5 (length x breadth)	151
Long Root Trainer	20	5	393
Small Root Trainer	11.5	3.5	110
Short Paper Pot (80)	9.5	5.5	226
Short Paper pot (130)	9.5	4.5	151
Tall Paper Pot	15	5.5	356
Bare Rooted	Not recorded	Not recorded	Not recorded

Table 3.2.1 Dimensions and Volumes of Containers

Volume for the seed tray was calculated as volume of seed tray divided by average number of seedlings per tray.

Mean heights at 4 months are shown in Table 3.2.2.

Container Type	Height (mm)
Plastic Pot	137
Seed tray	96
Long Root Trainer	105
Small Root Trainer	71
Short Paper Pot (80)	142
Short Paper Pot (130)	109
Tall Paper Pot	134
Bare Rooted	29

Table 3.2.2 Mean Height of Seedlings in Different Containers

Best treatment for seedling height was the plastic pot, which has the largest volume of any of the containers. Those with smaller volumes appeared to have smaller height growth.

Differences in growth between the plastic pots and the other containers were examined statistically through t-tests. Only three containers had statistically significant differences in seedling height compared with plastic pots. These were small root trainers, bare rooted and seed trays.

Container Type	Height/Container Volume*
Plastic Pots	22.0
Seed Trays	63.7
Long Root Trainers	26.7
Small Root Trainers	63.9
Short Paper Pots (80)	62.9
Short Paper pots (130)	72.1
Tall Paper Pots	37.5
Bare Rooted	Not known

* x 100

Table 3.2.4 Height: Container Volume Ratios

The statistical analysis indicates that a smaller container can be used than the plastic pot, without compromising growth. The smaller size of short paper pot gives the best ratio of height: container volume (See Table 3.2.4) and a container of this size should be recommended for raising *C. alliodora* in Vanuatu.

Smaller containers have correspondingly smaller costs, such as soil collection, container filling and transport costs. A smaller nursery will be required also for storing the same number of seedlings. In response to a visual assessment of this trial *C. alliodora* was raised in smaller pots than other species.

3.3. Combined Growth medium/ Fertiliser Trials. (081.2)

A Growth Media Trial was established at the IFP Nursery on 9 October 1991 to examine the effect of different growing media and fertiliser regimes on germination and growth of seedlings of *Cordia alliodora*.

Seeds were sown in trays and pots containing the different growing media/ fertiliser treatments. There were 14 treatments in total, 13 in trays and 8 in pots:

1 Soil/Sand mixture 50/50
2 Soil only
3 Top Dressing 1: 20g NPK applied to soil 2 weeks before seeds sown and placed 1/3 depth from top.

4 Top Dressing 2: 20g NPK applied to soil same day as seeds sown and placed 1/3 depth from top.
5 Top Dressing 2 and 10g NPK:
6 Bat guano: A mixture of soil, sand and bat guano from Aore in equal proportions by volume.
7 20 g NPK added to soil.
8 Cattle Manure: A mixture of soil, sand and cattle manure from the Abattoir in equal proportions by volume.
9 Top Dressing 1 and 10g NPK added 10 weeks later
10 40g NPK added to soil and 20g NPK added 10 weeks later
11 20g NPK added to soil and 20g NPK added 10 weeks later
12 40g NPK added to soil and 10g NPK added 10 weeks later
13 20g NPK added to soil and 10g NPK added 10 weeks later
14 40g NPK added to soil.

Some treatments were replicated others were not.

The NPK fertiliser was the standard used by the IFP Project. This is produced by mixing three commercial fertilisers, urea (46% N), double super phosphate (40% P) and muriate of potash (60% K) in proportions to produce a fertiliser with 1:1:1 NPK with a concentration of 47%.

Trays were those used by the IFP Project for testing germination. These are 37.5 cm wide by 58.5 cm long and are 7 cm deep (volume = 0.01536 m^3). The heights of the seedlings were assessed twice during the experiment. Results from the second assessment at 15 weeks are described in this report.

In addition a similar trial was established using small paper pots of 9cm length and 4.5cm diameter (volume = 0.00014 m^3). These were placed 120 to a tray. There were fewer treatments with treatments 1,2,3,4,6,7,8 being applied and also a further treatment (treatment 14) not used in the tray trial; 40g NPK added to the soil. Three seeds per pot were sown to ensure adequate germination. Results at 9 weeks are described.

A summary of the height results is shown in Figure 3.3.1. A significance test was used to separate those treatments that were statistically different from one another. Those that were not significantly different at P= 5% in trays are shown Table 3.3.1.

13 + 11	12 + 7	12 + 9	12 + 10	12 + 11	11 + 10
11 + 7	11 + 5	10 + 7	9 + 8	9 + 7	8 + 7
7 + 6	7 + 5	7 + 4	6 + 5	4 + 3	2 + 1

Table 3.3.1. Treatments in Trays Not Significantly Different at P= 5%

Treatments that were not significantly different at P= 5% in pots are shown below:

8 + 14 7 + 3 6 + 2 6 + 1

Germination rates in the pots are shown in Table 3.3.2. Three seeds per pot were sown and germination is therefore expressed

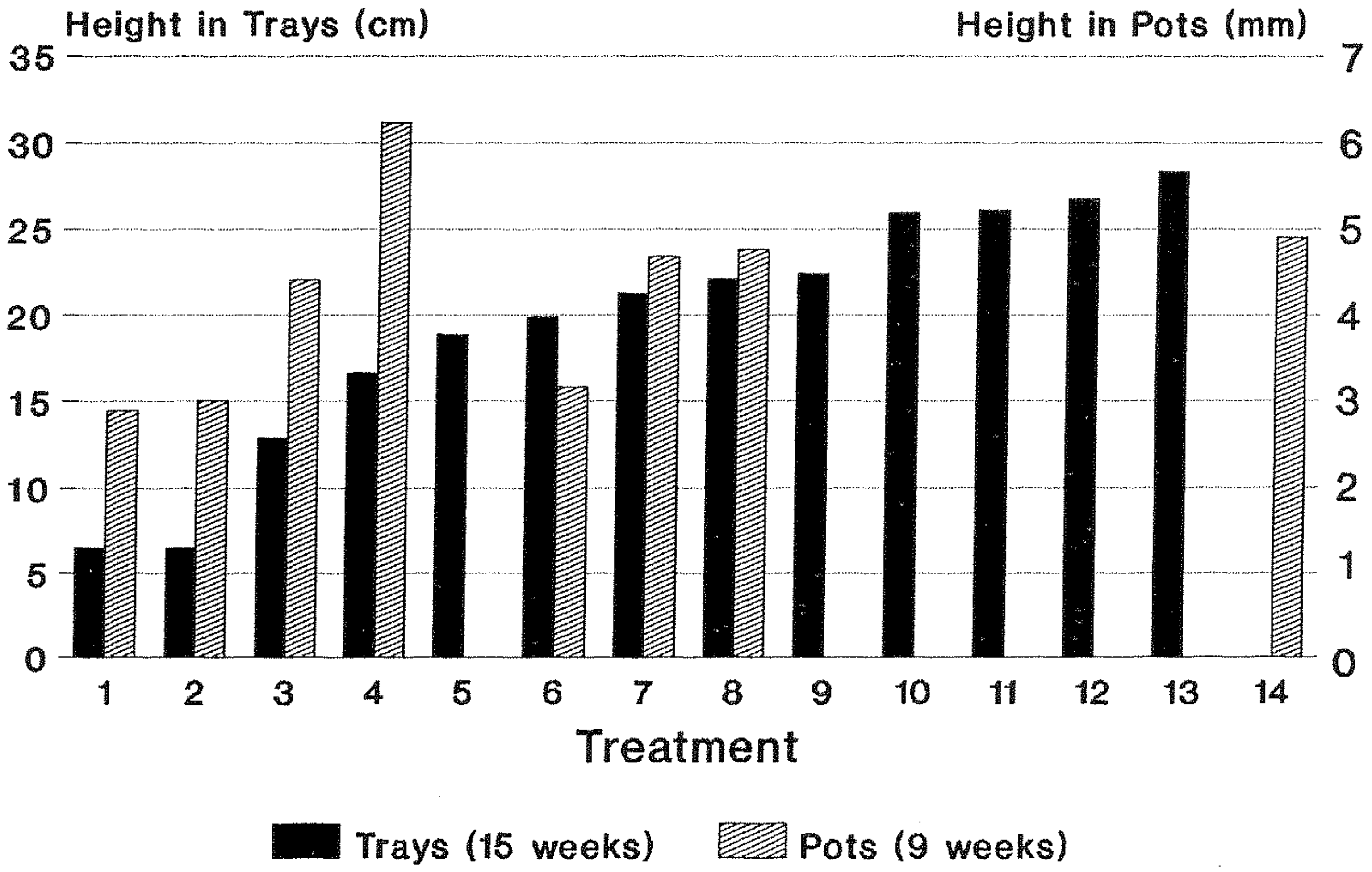


Figure 3.3.1 Growth for Different Treatments

as a percentage of 240. Numbers sown into the trays was not recorded.

Omitting to apply fertilisers to the growth medium depresses growth of the seedlings. This was found in both trays and in pots. Heights in trays for the soil and soil/sand treatments were significantly smaller than those of all other treatments and heights in pots were significantly worse than all other treatments except bat guano (Figure 3.3.1.).

In trays the 20g NPK with by 10g NPK added 10 weeks later was significantly better than all other treatments except two more expensive regimes; 40g NPK followed by 10g NPK 10 weeks later and 20g NPK followed by 20g NPK 10 weeks later.

In pots where a smaller range of treatments were tested, treatment 4, Top Dressing 2 gave significantly better height growth than the other treatments. The poorer growth of the bat guano treatment in pots, compared with trays could be due to variation in the nutrient concentration of the media.

Table 3.2.2 Germination for Treatments

Treatment	% Germination
1	50
2	50
3	46
4	59
6	21
7	35
8	62
14	30

Differences in the ranking of treatments tested in both trials could also be explained by the longer duration of the tray trial. Some treatments, such as Top Dressing 2 may give good initial growth but then the nutrients may be completely assimilated by the growing seedling and growth may then decline. It would be wise to base recommendations on the tray trial because it was over a longer period.

Prices of the fertiliser for the different treatments were calculated and, for trays are shown in Table 3.4.2 and for pots in Table 3.4.3. This is based on the cost of the last order of fertiliser, which was priced at 80vt/kg.

A Cost/(height with fertiliser - height without fertiliser) was calculated. Height without fertiliser was calculated from using results for the soil only treatment. Results are shown in Table 3.3.3 and Table 3.3.4.

Treatment	Cost per Tray (vt)	Mean No. of Seedlings	Cost per 100 seedlings	Cost/ (height with fertiliser - Height without Fertiliser)*
3. TD1	1.6	17	9.4	0.25
4. TD2	1.6	144	1.1	0.15
5. TD2 + 10NPK	2.4	64	3.8	0.19
6. Bat	Not available	61		
7. NPK20	1.6	51	3.1	0.11
8. Cattle	Not available	87		
9. TD1 + 10NPK	2.4	47	5.1	0.15
10. NPK40 + 20NPK	4.8	21	22.8	0.25
11. NPK20 + 20NPK	3.2	50	6.4	0.16
12. NPK40 +10NPK	4.0	14	28.6	0.20
13. NPK20 + 10NPK	2.4	82	2.92	0.11

* = Cost per tray for every extra cm growth (cf Soil only)

Table 3.3.3. Cost of Different treatments and Cost per cm extra growth in Trays

Treatment	Cost per Tree (vt)	Cost/ (height with fertiliser - Height without Fertiliser)*
3. TD1	1.6	2.3
4. TD2	1.6	9.9
6. Bat	Not available	
7. NPK20	1.6	19.1
8. Cattle	Not available	
14. NPK40	3.2	-33.8

* = Cost for every extra mm growth (cf Soil only) x 100.

Table 3.3.4. Cost of Different treatments and Cost per mm extra growth in Pots

The growth medium trial presents several problems when trying to determine the optimum fertiliser treatment. Large variations in survival in the trays meant that some seedlings had access to much larger volumes of soil than others. The pots may give a better indication as each seedling has a finite space in which to grow. However the duration of this trial was shorter. Examining the results from pots, there were no statistical differences between the 20g application and the 40g application. Although fertiliser is a small cost there would appear to be no point in applying it at the higher rate. There were statistical differences between Top dressing 1 and the 20g NPK application. Therefore, the fertiliser should not be applied two weeks before the seed is sown.
In the pots, the TD2 treatment where the fertiliser was applied to the soil one third of the way down the pot gives a better cost: growth ratio. However in the trays the normal 20g top dressing gave better results for cost than the TD2 treatment. As a normal top dressing is easier to use in plantation scale operations it should be the preferred method of application.

Recommended treatment for raising cordia seedlings within 3 - 4 months is 20g NPK added to soil. Converting this application rate to m^3 of soil, this represents 1.2kg NPK. Per 100 pots this application rate is approximately 17g NPK, which costs about 1.4 vatu. If the seedlings are in the nursery for lonegr than 10 weeks it may be worthwhile applying the extra 10g NPK per 120 pots.

These treatments are suitable for raising cordia seedlings within 3 to 4 months.

3.4 Nursery Fertiliser Trials. (081.3)

A collaborative nutrition trial was established with ACIAR (Project 9114) to investigate the effect of 8 different fertiliser regimes on the nursery growth of whitewood raised in soil from the IFP planting site.

Seven treatments were tested:

(i) No nutrients applied (0)
(ii) Complete nutrients applied (T)
(iii) Complete minus N (N)
(iv) Complete minus P (P)
(v) Complete minus K (K)
(vi) Complete minus Ca, S, Mg (CaSMg)
(vii) Complete minus trace elements (-T)

Details of these treatments can be found in Appendix 2.

Pots were filled with 1kg of air dried soil, which had a volume of 0.00128 m^3.

The trial consisted of 8 replications, 4 blocks, the two replications for each treatment being randomly arranged in each block. Placement of treatments within blocks was randomly changed every week.

Results for mean height at 3 months are shown in Table 3.4.1

An ANOVAR was applied to the means for each treatment and no significant differences were found.

Table 3.4.1 Mean heights by Treatment

Treatment	Height (cm)
O	13.22
F	14.01
N	13.98
P	13.19
K	12.27
-T	14.04
CaSMg	14.13

Responses to fertiliser were found in the *C. alliodora* growth media trial (Section 3.3). A comparison between the ACIAR treatment and the 20g NPK and 10g NPK treatment are shown in Table 3.4.2. The application rates of the ACIAR trial per tree are in general greater, except for P. The rates per unit soil however are much less in the ACIAR trial.

The other difference between the trials is the species tested and it may be that *E. medullosum* has different requirements for nutrients in its early growth than *C. alliodora*. The amount of nutrients in the soil may have been sufficient before adding the fertiliser treatments. Luxury nutrients would not increase growth and it would appear that the amounts added were not sufficient to have a toxic effect.

Treatment	Pot Size (m^3)	N (mg)	P (mg)	K (mg)
ACIAR	0.00128	100	22.7	62.9
20g NPK + 10g NPK	0.00014	39	39	39

Table 3.4.2. Nutrient applications in the Two trials

SECTION 4 FIELD FERTILISER TRIALS

Fertiliser application can influence the economics of tree growth in two main ways:

(i) Increasing growth, thereby producing more wood in a given time or reducing the rotation length.

(ii) Increasing growth, thereby attaining closed canopy in a crop more quickly than otherwise. This can reduce weeding costs.

All of the IFP trials have concentrated on examining the influence on production of the trees rather than weed suppression, as they are at present less than two year old.

For combined fertiliser and site treatment trials see Section 5.

4.1. Whitewood Fertiliser Trial in Cut Lines

A fertiliser experiment was established in May 1993 in whitewood (*Endospermum medullosum*) planted in cut lines. Trees were planted on 15 May and fertiliser was applied on the 12 October 1993. The design of the trial was a randomised complete block design, with four treatments. These were:

(i) 1:1:1 NPK (50) Fertiliser applied at 50g/ tree
(ii) 1:1:1 NPK (50) Fertiliser applied at 100g/ tree
(iii) 1:1:1 NPK (50) Fertiliser applied at 250g/ tree
(iv) No fertiliser

Each plot was a line of ten trees with a spacing of 2m between trees and 10m between lines. In April 1994 height of all trees within the plot was measured using a height pole. Results of mean height and survival for each treatment are shown in Table 4.1.1.

Treatment	Height (m)	Survival (%)
50g fertiliser	1.403	77
100g fertiliser	1.356	60
250g fertiliser	1.185	20
No fertiliser	1.253	57

Table 4.1.1. Results of Height and Survival at 11 months

Differences between height of different treatments were tested with an ANOVAR. No statistically significant differences were found. Survival appeared to be related to growth of Merremia vine on the site and the statistical differences between treatments was not tested.

Poor maintenance and rampant weed growth in some areas of the trial have made any differences in growth or survival due to fertiliser treatments difficult to detect. Fertilisers will not increase growth if other factors, such as light and moisture are limiting. It is likely that the competition from weeds has reduced any beneficial effects from the fertiliser.

Furthermore, applying fertiliser 5 months after the trees were planted may also have reduced any beneficial effect. Fertiliser should generally be applied as close to the time of planting as possible.

4.2 Mahogany Fertiliser Trial in Cut Lines

The same layout as the trial in whitewood was adopted for a fertiliser trial in mahogany (*Swietenia macrophylla*). Results of mean height at age 11 months for each treatment are shown in Table 4.2.1. Survival was very good with only one mortality in one plot.

Treatment	Height (m)
50g fertiliser	2.294
100g fertiliser	2.257
250g fertiliser	2.223
No fertiliser	2.341

Table 4.2.1. Height and Survival at age 11 months

Differences between height of different treatments were tested with an ANOVAR. No statistically significant differences were found.

Poor weeding may have made any differences in growth or survival due to fertiliser treatments difficult to detect. Also, the fertiliser was applied 5 months after the trees were planted which may also have reduced any beneficial effect. A suitable fertiliser regime cannot be identified from this trial nor even if applying any fertiliser is worthwhile.

4.3. Study of Effectiveness of Slow - Release fertiliser Tablets

A small replicated trial was established in C10 to test slow release tablets "Fertimel", supplied as a free sample on the growth of *C. alliodora* (San Carlos, Costa Rica provenance). As the tablets were provided in small quantities only four plots testing them were added to a fertiliser and ripping trial.

Results were described in Secker Walker, (1993g). Two plots tested tablets only while two plots tested tablets in conjunction with ripping. The tablets which weighed 15g contained nutrients in the following concentrations: 20% nitrogen, 15% phosphate, 10% potassium, 2% calcium, 1% Magnesium, 3% sulphur and 1% of trace elements. Tablets were buried in the ground 15cm from the tree. When the trees were less than 25 cm tall one tablet was applied, when the trees were 25 - 50 cm tall an additional 2 tablets were applied and when over 50 cm tall an extra 3 tablets were applied.

One year old results showed a greater mean height in the fertimel plots, compared with those with no fertiliser, but the difference was not significant. Growth of the 150g NPK (50g each) was found to be better than Fertimel though not significantly so.

SECTION 5. ESTABLISHMENT RESEARCH

5.1. Landclearing and Site preparation

5.1.1. Cattle-bulldozer time study (105.1)

Using cattle before bringing in the bulldozer was found to slightly reduce the time (41 hours versus 47 hours) taken to clear one area compared to another where cattle were not used. The areas were of similar size and vegetation cover. No difference in ease of the operation was reported by the driver.

5.1.2. Line planting study (106.1)

Between the 28 and 30 March 1994 an assessment was made of the growth of six species in cut lines and open areas. A further species, stinkwood was only represented in cut lines. Mean survivals and heights at age 2 years are shown in Figure 5.1.2.1. Mean height for stinkwood in cut lines was 184.5 cm and

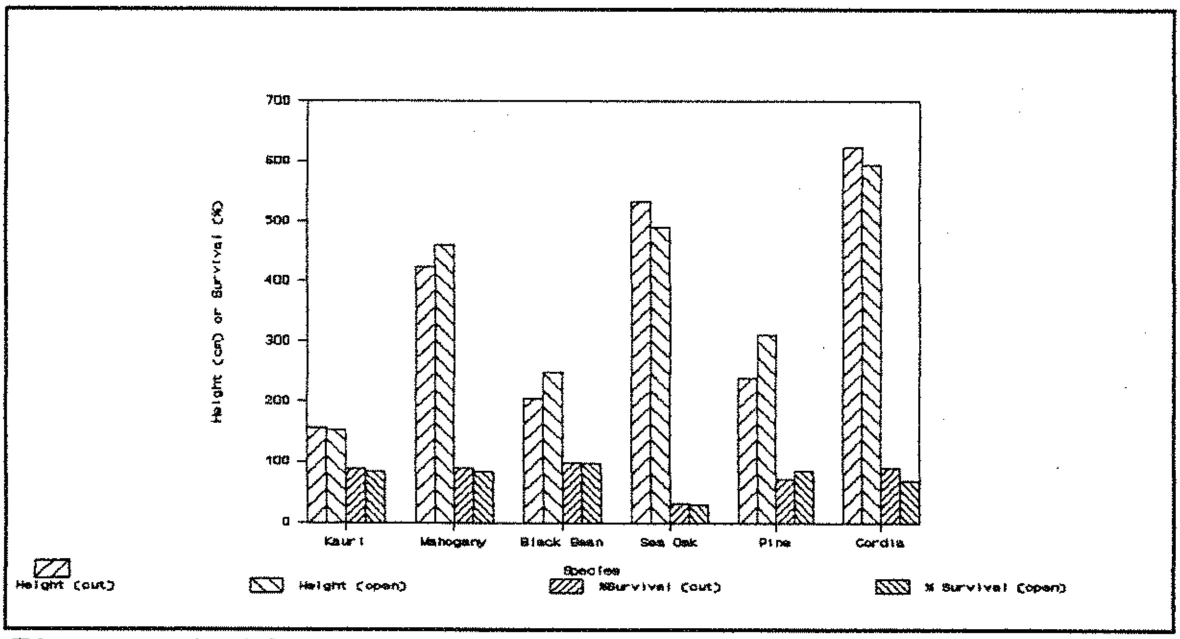


Figure 5.1.2.1 Growth and Survival in Cut Lines and in the Open

survival was 85%.

There are large differences between the site preparation costs in cut lines and open areas. Cost for cut lines is about 7,500 vt per ha (500 stems/ha) and for open areas about 45,000 vt (400 stems/ha). At age two years height growth and survival are similar for the two preparation methods.

5.1.3. Site capture techniques study (107.1)

A trial was established to test mahogany (*Swietenia macrophylla*) growth with 5 different cover crops and with no cover crop. Nine trees were measured in 3 randomly located plots for each cover crop. Cover crops were made up of the following species:

SS - *Sorghum* sp - Hybrid with Silk (Silk Sorghum)
Set - *Setaria sphacelata* var. *sericea*
GL - *Desmodium intortum* (Greenleaf Desmodium)
CS - *Stylosanthes quianensis* var. *cook* (Cook's Stylo)
DO - *Desmodium ovalifolium*
HAM - *Panicum maximum* var. *hamil*
LLB - Lab Lab
SIG - Signal grass

Proportions of each species in each cover crop are shown in table 5.1.3.1.

Cover Type	SS	Set	GL	CS	SIG	LLB	DO	HAM
Setaria	3.0	2.0	1.5	1.0				
Greenleaf			2.5	1.5			1.0	
Hamil	3.0		1.5	1.0				4.0
Signal	5.0				2.5	5.0		
Silk	3.0		2.0	1.5				

Table 5.1.3.1 Components of Cover Crop

Measurements were made of root collar diameter (RCD) and height. For results at final assessment see Table 5.1.3.2. Smalian's formula was used to calculate a volume for the trees and results of volumes of mahogany with different cover crops are shown in Figure 5.1.3.1.

The no cover crop treatment was found to give good results and produce the most uniform stand (See Table 5.1.3.2). When the trees were 33 weeks old hamil, signal and setaria grasses slowed growth of mahogany, whereas greenleaf and silk sorghum gave similar growth to no cover crop. Variability of growth of the trees was greater, however (See Table 5.1.3.2).

Means and 95% Confidence Limits for no cover, greenleaf, hamil and silk are shown in Figure 5.1.3.2. There were not significant differences in volume at 85 - 87 weeks between these treatments. However differences between Hamil and the others are large and a larger sample may give statistically significant differences.

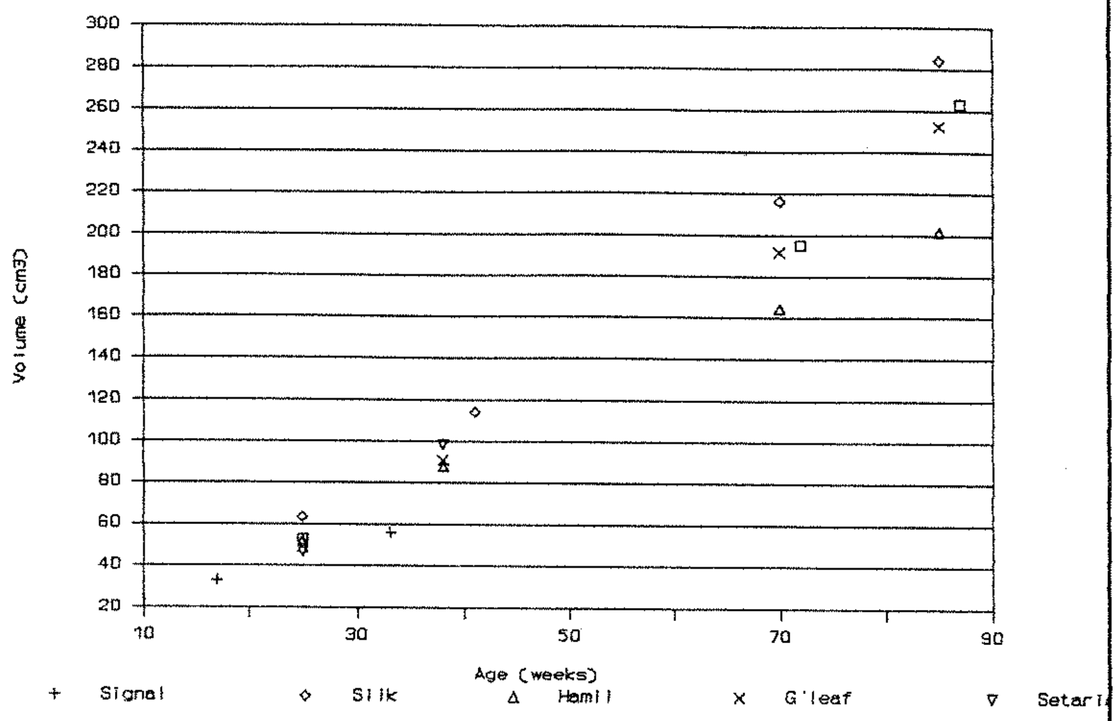


Figure 5.1.3.1 Volume of Mahogany vs Age with different Cover Crops

Cover Type	Age in weeks	Height (cm)	RCD (cm)	% Survival	Stem Volume (cm^2)	Var. ratio Volume
None	87	263	4.81	74	586	0.79
Setaria	38	99	1.88	93	83	9.47
Greenleaf	85	253	5.68	70	579	40.36
Hamil	85	202	4.09	85	363	42.26
Signal	33	56.2	1.37	74	28	9.47
Silk	85	284	5.20	81	606	19.67

Table 5.1.3.2 Growth with Different Cover Crops

5.1.4. Legume cover crop versus Chemical Weedkiller (107.2)

A replicated randomised trial was assessed at 1 year old to compare the differences in growth of *C. alliodora* with a legume cover crop and with a glyphosate weedkiller sprayed at 2 litres/ha. The trees were planted at a 5m spacing. Results of height growth, between age 7 months and Age 12 months and survival at 12 months are shown in Table 5.1.4.1 (Secker Walker, 19931).

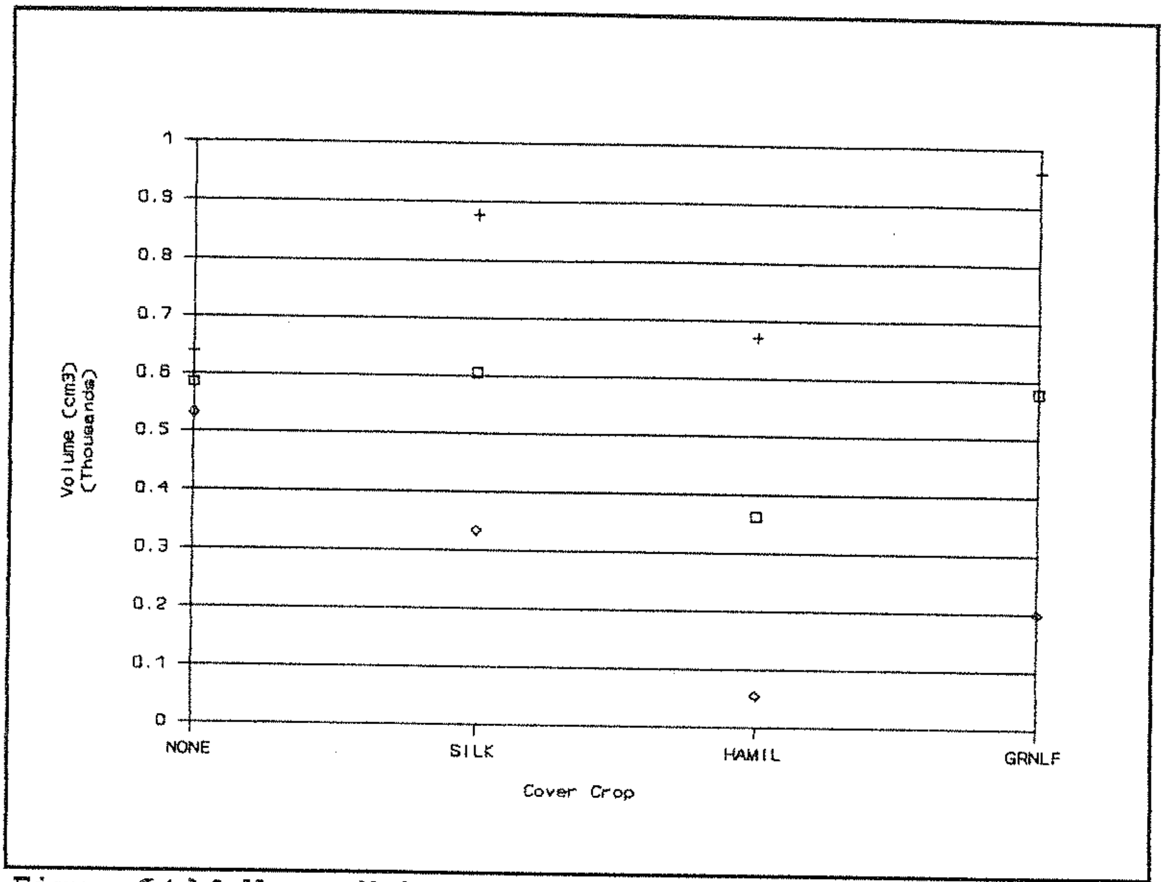


Figure 5.1.3.2 Mean Volumes of Mahogany with 95% Confidence Limits with different Cover Crops

Site Capture Method	Age (months)	% Survival	Height Growth per week (cm)
Mixed legume	7 - 12	89.8	5.68
Glyphosate Weedkiller	7 - 12	96.8	8.00

Table 5.1.4.1. Growth and Survival with Cover Crop and Herbicide.

Height growth was 41% greater in the weedkiller plots and the difference was significant at the 5% level. Survival was not significantly different.

Details including costs in vatu in 1991 of the different treatments are shown in Table 5.1.4.2. The cost of Bulldozing and stickraking the sites was the same at 30 - 40,000 vt/ha

Glyphosate was found to be effective in reducing weed growth over a period of 7 to 8 months after planting. This reduced competition between weeds and trees and enhanced the growth of the trees. The legume plots were completely covered by the legumes and by some weeds, which must have competed with the trees and slowed growth.

Site Capture method	Cost/ha Site Capture	Weeding labour md/ha/mth	Weeding Costs
Mixed Legume	7,328 vt/ha	0.7 at ages 0 - 8 mths 0.52 at ages 8 - 12 mths	11, 479 vt/ ha
Glyphosate weedkiller	4,900 vt/ha	None at ages 0 - 8 mths 1.03 at ages 8 - 12 mths	7, 114 vt/ ha

Table 5.1.4.2 Cost of Cover Crop and Herbicide

There were some factors that may affect the reliability of the results:

(i) Areas in the Compartment were estimated, which affects the weeding costs per ha.

(ii) weeding costs in the legume plots were assessed in 1991, two years before the weedkiller plots.

(iii) By the time of the second measurement two of the plots had been invaded by vegetation from plots with the other treatment. Legumes invaded one weedkiller plot and weeds from the weedkiller plot invaded one legume plot.

Even when weed cover had established itself in the weedkiller plots trees in those plots grew faster than with legumes. This was thought to be because the trees in the weedkiller plots were much larger and because of the marked difference in growth it was thought that the legumes were offering more competition to the trees than the weeds.

Where mechanical land clearance, especially with the rootrake, which provides a relatively clean planting site was used it was doubtful whether the glyphosate would be needed. However, this method is more expensive than manual clearing or roller crushing.

The conclusion of this trial was that glyphosate is a more cost effective way of controlling weeds than legume cover crops. This experiment was conducted on a fairly fertile site and it may be that on poorer sites the nitrogen from the legumes may compensate for their competitive nature (Secker Walker, 19931).

5.2. Establishment; Other

5.2.1. Direct sowing studies (111.1/2/3)

Direct sowing is a financially attractive alternative to potted transplants. Nursery costs and planting costs are avoided, although there will be sowing and ground preparation costs. Also, weeding costs may be greater; between 22/10/92 and 4/1/93 99 mandays were spent weeding the 15 ha area of this trial.

Unfortunately, experience with direct sowing of indigenous species has not been encouraging. Table 5.2.1.1 shows the species, number of seeds sown and the dates of sowing for a direct sowing trial established in Compartment 10C.

The compartment had a legume cover crop and the seeds were buried 4 to 6cm deep to keep them moist.

Dates of Sowing	Species	Number sown	Area (ha)
28/09 - 12/10/92	*Castaneospermum australe*	4,515	4.0
30/09/92	*Dysoxylon amooroides*	600	0.9
30/09 - 01/10/92	*Dracontomelon vitiense*	1,831	5.0
02/10/92	*Antiaris toxicara*	882	1.1
12/10/92 - 21/10/92	*Alphitonia zizyphoides*	7,031	4.0

Table 5.2.1.1. Numbers, Species and Dates Sown.

By the end of February 1993 three Blackbean (*C. australe*) had germinated and were growing. However, these later died because of weed competition. It may be that the seeds were buried too deep and of those that germinated the legume cover crop may have been too aggressive for the seedlings to survive.

Direct sowing of mahogany has also been tried. Two seeds were sown at a depth of about 7.5 cm in each sowing hole during April 1992. A handful of cut legume was placed over the hole to try and retain moisture. About a month later the trial was assessed. In general direct sowing gave successful germination, with 65 sowing holes with no germination, 150 sowing holes with 1 seed germinating and 160 sowing holes with 2 seeds germinating. Seven holes were recorded having 3 seedlings and four having 4 mahogany seedlings, presumably more than two seeds were sown in some holes.

5.2.2. Direct Planting of Cuttings (111.3)

In addition to raising transplants from cuttings in the nursery (See Section 3.1) a trial was established in December

1992 to test planting staves of bluwota (*P. indicus*) directly into the ground. This was prompted by the success others have had establishing Bluwota as living fence posts. Also, Des Parkes on Erromango has had good results from using 1m long staves of about 2.5cm diameter (Anon, undated). Staves used in the IFP trial were atleast 2.5cm in diameter and atleast 1.5m long.

By April 1993, 22 of the 100 cuttings established had flushed. From the trial history some of the cuttings fell down and there may be a need to try shorter staves or to plant them deeper in the ground. An examination of the area in August 1994 showed no survivors.

5.2.3. Use of beef cattle to weed cordia plantation. (117)

In the last week of May 1990 Compartment 1 was cleared by using 100 Wiener cattle. Any trees remaining, except those with a dbh greater than 30cm were cleared manually. The compartment was planted with *Cordia alliodora* at a 5m x 5m spacing.

Trees were sampled in January 1992 and no damage was found. On February 11 about 10ha of Compartment 1 was fenced off and 15 Wiener cattle (aged 12 - 13 months) were introduced. After 1 month a visual assessment showed that the cattle had not damaged the trees. Although they had not cleared the ropes (Merremia and Mikania) they had cleared the areas under them. Access was easier in the cattle cleared area than outside (Secker Walker, 1993f).

In the last week of April, 2½ months after the cattle were introduced a detailed damage assessment was made. The only damage was to some of the lower branches on some of the trees. The ground vegetation was low in some places and so 5 cattle were removed from the compartment later in the week.

A second detailed damage assessment was made in the second half of July. The only damage was to the lower branches and foliage. Towards the end of July the cattle made several escapes from the enclosure. This was thought to be due to the batteries for the electric fence being low due to cloudy weather preventing the solar charger from operating efficiently. All the cattle were removed from the area on 31 July 1992 about 4½ months after first being introduced. Later, on 7 September six cattle were reintroduced to the area.

Later introductions of cattle into 2 to 3 year old trees have been less successful with most *S. macrophylla* in Compartment 9 having bark chewed by the cattle.

5.2.4. Time and Motion Study of Weeding time in Cut lines and Open Areas. (119)

From observations weed growth in open areas was worse than in cut lines (Secker Walker, 1993i). Trees were completely covered in weeds and it took a longer time to carefully clear the weeds, without damaging the trees. In the cut lines the main weed was Merremia, which although it climbs the tree can be easily removed by cutting through a section of thick rope with a bush knife.

The legume cover crop in Compartment 10 had not established itself well and so the cleared site was ideal for weed growth. This was compared with the cut line area, which was dominated by two ropes, *Merremia peltata* and *Mikania micrantha*.

The results showed that weeding trees in cut lines was quicker than weeding trees in open areas, with 40.8 seconds/ tree in cut lines and 44.9 seconds/ tree in the open. The differences were not statistically significant. These results reinforce the financial attractiveness of cut lines as compared with open planting. Initial costs are much cheaper with cut lines costing about 7 - 10,000 vt/ha and open areas costing 42 - 45,000 vt/ha (1993 prices).

5.2.5. Weeding Time and Costs for Different Site Preparation Methods

Two compilations were made of information on weeding times and costs. These can be found in Secker Walker, (1993j) and Secker Walker, (1993k). The first is a preliminary examination of times taken to weed areas with three different site preparations over the first 4 $^{3}/_{4}$ months after planting. Results are shown in Table 5.2.5.1. Weeding cordia appears to take longer than weeding eucalypts, although no statistical analysis was applied to the data to test significance.

Sub Compartment	Treatment	C15 Eucalypts	C14 Cordia	Means
1	Legumes	0.68	0.67	0.67
2	Legumes	0.83	1.71	1.27
3	Roll-Weed	1.24	1.76	1.50
Means		0.92	1.38	

Table 5.2.5.1 Weeding Times (mandays/ha/month)

The second compilation of data on weeding times, costs and assumptions is reproduced from Secker Walker, (1993k) and are shown in Appendix 3. Prices are averages covering a period from 1991 to 1993. Full details are described in Secker Walker, (1993k). Some growth rates are also shown in the compilation.

5.2.6. Fertiliser & Ripping Trial (128.1)

The growth of *C. alliodora* in Compartment 10 was examined using two cultivation techniques and three different nutrients in a factorial design. This gave 16 different treatments:

R = Ripping
N = Nitrogen (50g/tree) = 109g Urea
P = Phosphorous (50g/tree) = 125g Double supers

K - potassium (50g/tree) - 83g Muriate of potash

These are descibed below in Table 5.2.6.1.

Treatment	R	N	P	K
1. Treatment 0000	-	-	-	-
2. Treatment 000K	-	-	-	yes
3. Treatment 00P0	-	-	yes	-
4. Treatment 00PK	-	-	yes	yes
5. Treatment 0N00	-	yes	-	-
6. Treatment 0N0K	-	yes	-	yes
7. Treatment 0NP0	-	yes	yes	-
8. Treatment 0NPK	-	yes	yes	yes
9. Treatment R000	yes	-	-	-
10. Treatment R00K	yes	-	-	yes
11. Treatment R0P0	yes	-	yes	-
12. Treatment R0PK	yes	-	yes	yes
13. Treatment RN00	yes	yes	-	-
14. Treatment RN0K	yes	yes	-	yes
15. Treatment RNP0	yes	yes	yes	-
16. Treatment RNPK	yes	yes	yes	yes

Table 5.2.6.1 Description of Treatments

Ripping was to a depth of 45 cm. Planting was undertaken from the 7 to 24 April 1992 and fertiliser was applied between 10 and 28 July, three months after planting. Fertiliser was applied at 15 cm distance from the tree into a 15 to 20 cm deep cut made by a yam spade. The cut was then closed by pressing down the heel of a boot.

Plots were 5 x 5 trees with the inner 3 x 3 being measured. At 3 months, height was measured and at 1 year old the heights and dbh were measured. The trial was partially replicated with two blocks.

Height growth was calculated and addition of phosphorous gave an increase in growth of 48.6%, which was significant at P= 1%. Adding nitrogen also increased growth, by 30.36% which was significant at P= 5%. Height growth between blocks was also found to be significantly different at P= 1% (Secker Walker, 1993h).

Results of height growth are shown in Figure 5.2.6.1.

An economic analysis was undertaken to investigate the costs and benefits of the different fertiliser treatments.

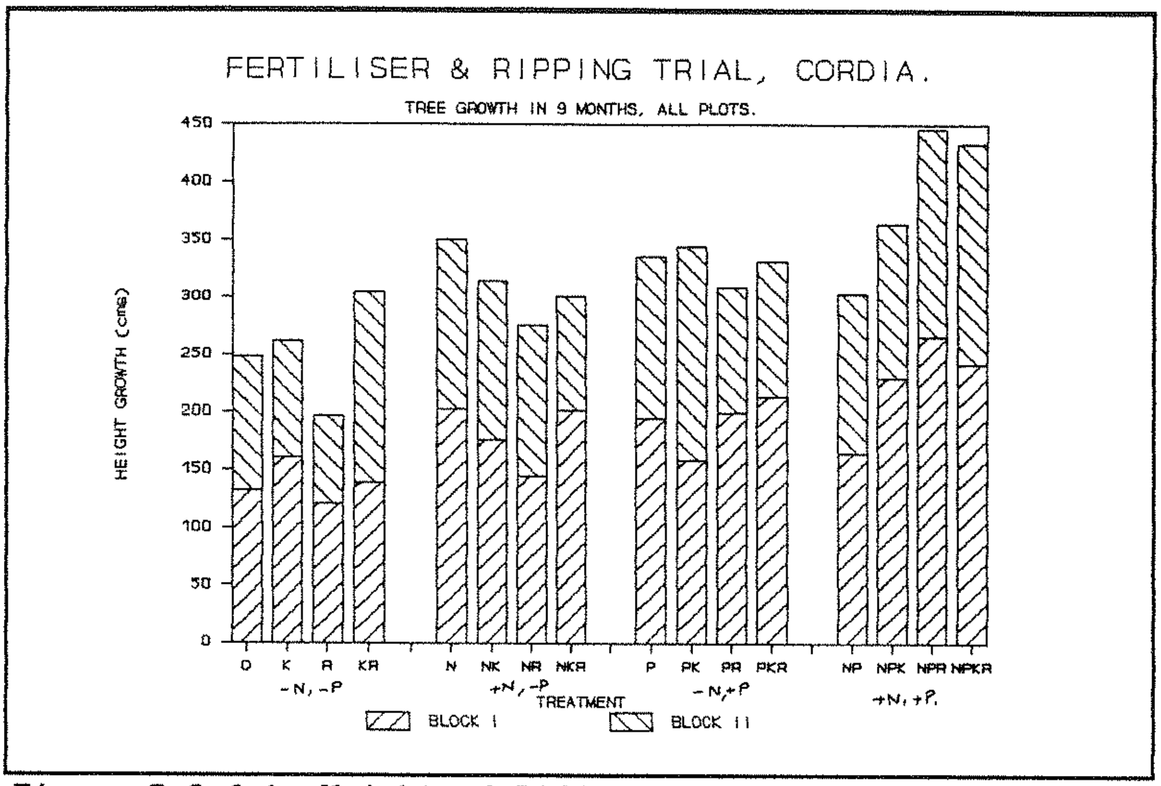


Figure 5.2.6.1 Height of Different Treatments

Assumptions included that the effect of the fertilisers would only last during the period that the growth was measured (35 weeks). However, this is a conservative assumption as the increase in growth is likely to persist until canopy closure.

The reduction in the rotation was then calculated for addition of nitrogen and of phosphorous. This is shown in Table 5.2.6.2.

Nutrient	Growth without (cm)	Growth with (cm)	Rotation Reduction (wks)
Nitrogen	145.6	174.1	6.84
Potassium	140.7	179.0	9.52

Table 5.2.6.2 Reduction in Rotation Length

Other assumptions were:

Interest Rate:	3.5% per year
Felling age without fertiliser:	20 years
Stumpage value:	1,300 vt/m^3
Volume of tree at felling:	1 m^3 / tree

Assuming that the only increase in growth due to the fertiliser application was that during the first 35 weeks it was not worth applying N or P fertiliser. However the effects on growth are likely to be longer term.

5.2. . IFP Cordia Spacing Trial

An unreplicated spacing trial was established with *Cordia alliodora* at the IFP site on 25 July 1988. Four square spacings were tested 3m, 4m, 5m and 6m. In addition the plots were divided in half and so two provenances were planted in each plot. The provenances were San Carlos, Costa Rica (1849) and San Francisco, Honduras (20/77). Plots were roughly the same size and so the number of trees in each varied:

6 x 6 m - 64 trees
5 x 5 m - 100 trees
4 x 4 m - 144 trees
3 x 3 m - 256 trees

Data collected in early 1991 (age about 30 months) was assessed to examine the effect of spacing on cordia growth. The data from the first 64 trees in each plot were used.

Results are shown in Table 5.2.8.1.

Although the trees were still young there would already appear to be a relationship between dbh and growing space. This is likely to become more pronounced as the trees get older and as competition between trees becomes greater.

Spacing (m)	Growing Space (ha) per tree	Dbh (cm)	Height (m)
3	0.0009	14.09	11.07
4	0.0016	17.48	13.72
5	0.0025	18.05	14.18
6	0.0036	20.42	16.04

Table 5.2.8.1 Results at 30 months of IFP Spacing Trial.

For an economic appraisal more growth data is required and also information on the costs, such as weeding and thinning of the different treatments. It was also unfortunate that the species used was cordia which is unlikely to feature prominently in future planting programmes.

SECTION 6 SPECIES TESTING

There are several problems associated with most of the species trials. The older trials were neglected for a long period of time and high mortality in some plots has made initial spacing of normally 3m x 3m irrelevant, as has copious natural regeneration of some species, such as cordia. The small size of many of the plots in the trials established in the 1970s, such as Monbiftek and Navota Farm makes the results indicative at best. They do however, show that valuable timber trees can be grown for almost a whole rotation in plantation conditions on Santo. Most line plantings were originally established at 10m between lines with 2.5m spacing within lines.

Files of most of the trials are still available although records of previous assessments for some trials were missing.

None of the species trials established by the IFP project are more than a couple of years old. Some of those previously managed by Carter Holt Harvey date as far back as 1988.

6.1 Forestry Dept Species Research (071.2)

The Forestry Department Trials comprise unreplicated plots in four locations on Santo (See Map 1.2.1 and Table 1.2.1). The oldest, Navota Farm and Monbiftek date from 1972. Growth of some species at the Monbiftek site is likely to be slower than can be achieved due to heavy competition in some plots from natural regeneration of *Cordia alliodora* and *Gmelina arborea*. A more detailed discussion of results from Monbiftek can be found in Leslie, (1994a). Spacings are not shown as many of the older trials have poor survival or have been sporadically thinned. For many of the plots the original number of trees planted is not known and so survivals cannot be calculated. Results of growth of species arranged in alphabetical order are shown below.

Agathis macrophylla

Relatively slow growing but highly cyclone resistant.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Block	80	18.0	8.9
Monbiftek	Block	228	37.9	21.4
Navota Farm	Block	263	35.5	21.6
Monbiftek	Line	266	40.9	20.4

Antiaris toxicara

The only species used on Santo for plywood production. Not durable, but if treated is sometimes used as a cheaper alternative to whitewood for construction purposes where little strength is required. Establishment of this species has proved to be difficult on open sites and it may be that it needs some shade in its early years.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Block	76	9.9	--------

Araucaria columnaris

A fairly fast growing species. Many of the trees at Navota Farm have a sweep to the stem. Seed for the trees at Vanafo originated from Coen, Queensland (Batch No. 13856).

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	275	39.3	24.8

Araucaria cunninghamiana

Trees of this species look healthy and growth is reasonable. Perhaps a bit faster than *A. columnaris*.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Line	251	39.8	26.1

Cassia siamea

Grown in a plot at Navota Farm. Many have died from unknown causes.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	275	39.8	26.1

Castaneospermum australe

Growth is slow and conversion rates are poor compared with some other native species, even Rosewood (*Pterocarpus indicus*) (Croucher, pers. comm.). Also, at present the international markets are poor for the dark brown wood this tree produces.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Line	251	31.5	16.4
Monbiftek	Block	228	18.8	19.3

Cedrella angustifolia

A promising South American timber tree with growth rates better than *C. alliodora* or *S. macrophylla*. Trees at the Vanafo trial were spaced at 3 x 3 m and have not been thinned.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Prov. Trial	75	20.0	15.8

Cedrella odorata

Three provenances tested at Vanafo (ST3/86SON) showed excellent survival and growth. Better growth rate than *C. alliodora* or *S. macrophylla*. Trees are still at the initial spacing of 3m x 3m. The table below shows the average dbh and height for the three provenances. Survival of over 90% at Vanafo but at Ipota on Erromango it suffered severe cyclone damage. For details of provenance performance see Section 7.4.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Prov. Trial	75	19.1	15.0

Cordia alliodora

Although fast growing in its early years growth of this species slows after about 12 years. Compared with initial predictions long term growth rates of this species were disappointing.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Shark's Bay	Prov. Trial	107	20.4	--------
Monbiftek	Block	244	34.8	26.7
Navota Farm	Block	263	38.8	25.0
Monbiftek	Line	266	45.9	26.8

Graphs of cordia dbh and height growth across Santo are shown in Figures 6.1.1 and 6.1.2.

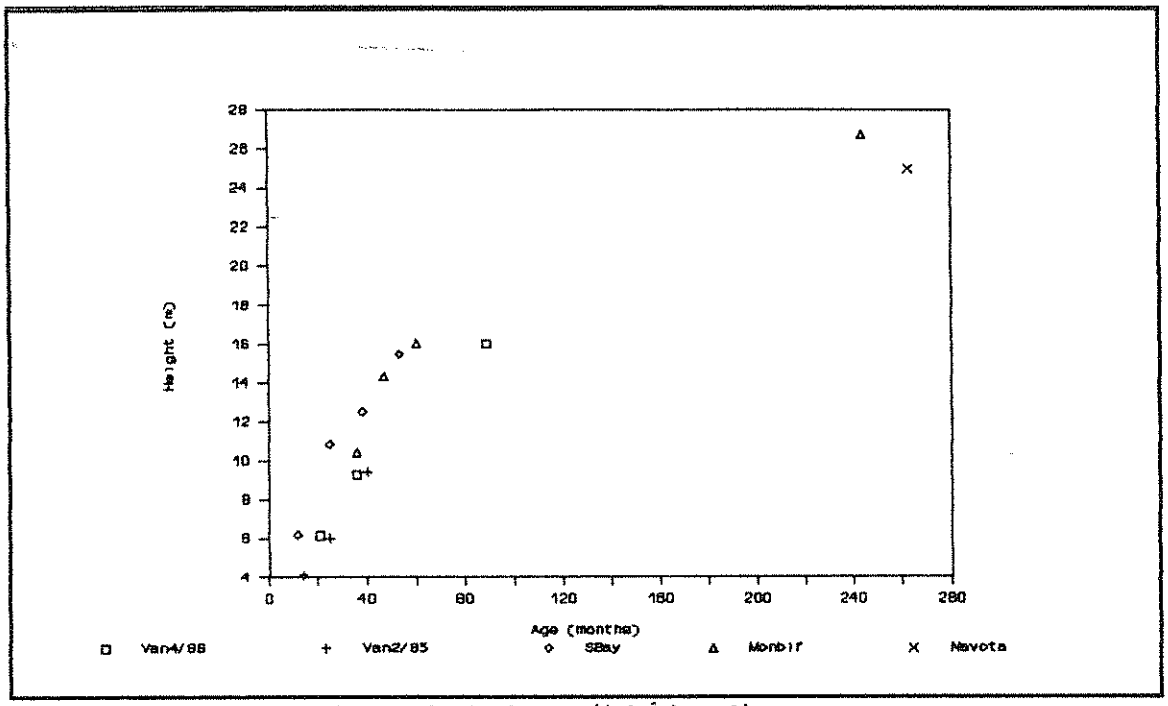


Figure 6.1.1 Cordia alliodora Height vs Age

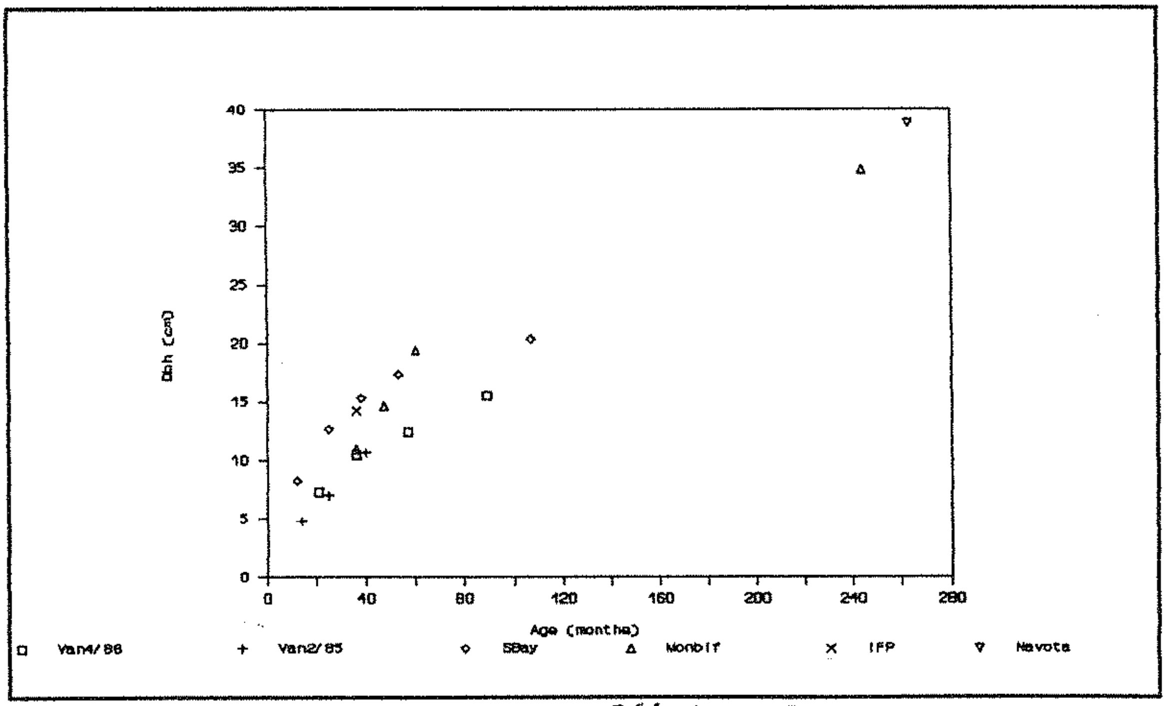


Figure 6.1.2 Cordia alliodora Dbh vs Age

Dracontomelon vitiense

A slow growing indigenous species with a valuable timber.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Block	82	11.9	6.7

Eucalyptus camaldulensis

Slower growing than other eucalypts, such as *E. deglupta* and *E. urophylla*.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	228	26.7	23.5
Navota Farm	Block	275	34.7	29.9

Eucalyptus deglupta

Fastest growing eucalypt on most sites on Santo.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	243 - 244	43.3	31.4
Monbiftek	Line	266	38.4	25.5
Navota Farm	Block	275	53.2	31.2

Eucalyptus grandis

Planted at Monbiftek in 1972 but no trees surviving by September 1975. Planted at the IFP site by PDL where growth is not as good as *E. deglupta* or *E. urophylla* (See 6.3). Susceptible to a foliar fungus, *Cylindrocladium quinqueseptatum*, as is *E. urophylla*.

Eucalyptus torellana

Only planted on Santo at Navota Farm, much slower growing than *E. deglupta* and cyclone resistance not known. Stem form not particularly good.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	275	26.4	23.9

Flueggia flexuosa

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	275	22.9	14.6

A much favoured tree for poles and posts.

Gmelina arborea

A very fast growing species producing profuse natural regeneration. Unfortunately the wood is relatively soft and the stem tapers considerably and is often crooked.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	243	45.4	26.4

Gyrocarpus americanus

A native species used for canoe building and tested in one small plot at Vanafo. Growth is slow.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Block	90	11.5	6.8

Intsia bijuga

A desirable hardwood, with good international and local markets. Growth is a lot slower than mahogany (*S. macrophylla*) and the timber is unlikely to command a premium over mahogany.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	228	28.5	19.6

Khaya ivorensis

Growth of this mahogany is much slower than *S. macrophylla* and it does not appear to have any advantages over that species.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	243	20.2	19.7
Navota Farm	Block	263	24.5	21.0

Liquidambar styraciflua

A provenance trial of this timber tree was established in 1986 and the means for all provenances shown below:

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Vanafo	Prov. Trial	82	15.1	13.8

Performance of the different provenances are described in Section 7.3.

Nauclea diderichii

A tall, straight timber tree with light branching and a clear bole. Unfortunately, tends to have poor diameter growth.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	244	16.3	18.5
Monbiftek	Line	266	36.1	24.8
Navota Farm	Block	263	16.0	28.0

Pinus carribaea

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	239	35.3	24.06
Monbiftek	Prov. Trial	241	27.9	-----

Pinus oocarpa

Four trees were thought to have been planted at Monbiftek of which one survives. Growth and stem form is good.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Block	228	40.0	29.2

Swietenia macrophylla

A promising species for Santo there are several small plots of trees over twenty years old. Graphs of height and dbh growth over Santo are shown in Figures 6.1.3 and 6.1.4. Provenence performance is discussed in Section 7.1.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
IFP Site	Prov. Trial	70	15.75	13.09
Monbiftek	Block	244	35.9	24.6
Monbiftek	Line	266	52.0	24.2
Navota Farm	Block	275	52.8	27.1

Tectona grandis

The trees at Monbiftek are thought to have been planted in April or May 1978. Stem form is poor and branching heavy, although growth rate has been quite good. Considered by Niel, (1987) to be very windfirm but moderately susceptible to wind

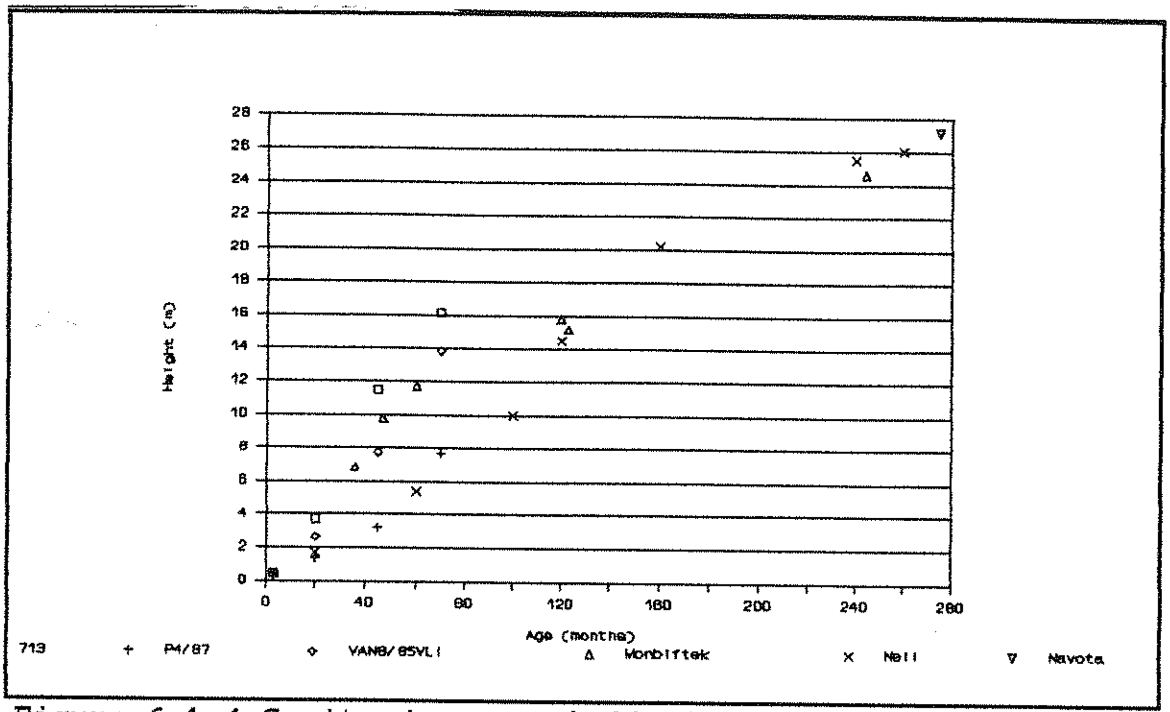


Figure 6.1.4 Sweitenia macrophylla Height vs Age

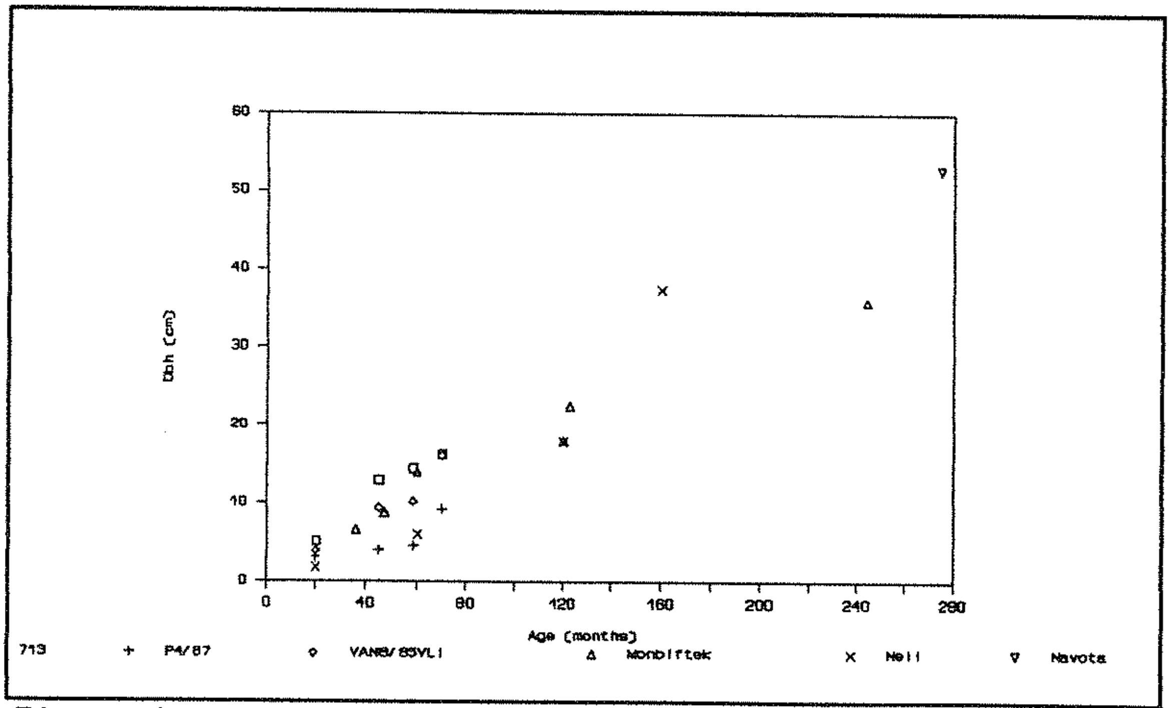


Figure 6.1.3 Sweitenia macrophylla Dbh vs Age

snap and very susceptible to leaf loss. However in 1985 older trees on Santo suffered considerable wind snap in Cyclone Eric and Nigel (Barrance, 1988). Unfortunately, too little has been planted in Vanuatu to give concrete recommendations regarding this species.

Barrance, (1988) suggested that many of the problems with the quality of teak in Vanuatu may be provenance related and suggested establishing provenance trials of this species. Certainly the species has established markets and even small roundwood is durable and suitable for posts. Thus thinnings could also have a local market. Further work is warranted.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Monbiftek	Line	196	37.5	-------

Terminalia calamansanai

In the Solomon Islands, this species has been found to grow exceptionally fast on sites but is very site sensitive and so is not considered suitable for large plantations.

Growth on the sites in Santo where it has been tested has been excellent but it is a species considered to be highly susceptible to damage by cyclones (Niel, 1987).

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Sharks Bay	Block	69	25.9	14.6
Monbiftek	Block	228	41.6	27.4

Terminalia ivorensis

Stems are tall, straight and clean. Cyclone resistance not known. Worth further investigation.

Site	Type of Planting	Age (months)	Dbh (cm)	Height (m)
Navota Farm	Block	263	49.5	26.8

6.2. IFP Project Species Trials

Three formal species trials have been established by the project. Growth information on species is also being collected through the Permanent Sample Plot Programme described in Section 13.

6.2.1. Species Trial, IFP Compartment 12. (071.3)

This trial was planted in January 1993 with 9 species: 5 indigenous; *Endospermum medullosum, Agathis macrophylla, Flueggia flexuosa, Terminalia sepicana* and *Castanospermum australe* and 4 exotics: *Samanea saman, Grevillea robusta, Cordia alliodora* and *Schizolobium parahybum*. The layout was a randomised block design with 3 replications. Plots are 25 trees (5 x 5) at 5 m spacing.

Preliminary results, at age 1 year indicate that there may be species that can be planted that grow as fast as *Cordia alliodora*.

Species	Height(cm)	% Survival
Schizolobium parahybum	208	100
Cordia alliodora	206	100
Samanea saman	192	100
Grevillea robusta	177	100
Endospermum medullosum	163	96
Flueggia flexuosa	153	96
Castaneospermum australe	126	100
Terminalia sepiceana	81*	74
Agathis macrophylla	79*	93

* statistically different from *Cordia alliodora* @ 1%

Table 6.2.1.1 Results of Species Trial in C12F, Age 1 year

6.2.2. Pine and Casuarina Species Trial, Compartment 12

In November 1993 a small replicated trial testing three species was established. Design was completely randomised with four replications. Species tested and their origin are shown in Table 6.2.2.1.

Seedlot	Species	Origin	Supplier
36/84	Pinus carribaea var Hondrensis	Los Limones, Honduras	Oxford Forestry Institute
65/83	Pinus patula var Tecuamanii	Yucul, Nicaragua	Oxford Forestry Institute
------	Casuarina equisetifolia	Palekula, Santo	Kasen Alick

Table 6.2.2.1 Origin of Seedlots

Originally it was hoped to test six provenances covering three species of pine. Unfortunately poor germination meant only two of the pine seedlots yielded sufficient plants for even a small trial.

An assessment at age 9 months, see Table 6.2.2.2. showed the *C. equisetifolia* and the *P. carribaea* to have similar growth and survival. The other species tested, *P. patula* was poorer in growth and survival and from these early results would not seem to be well suited to the site. Results for Table 6.2.2.2 are means from three of the four plots for each species as the identity of the last plots was uncertain.

Species	Height (cm)	% Survival
P. carribaea	16.7	87
P. patula	4.9	47
C. equisetifolia	14.7	86

Table 6.2.2.2. Height and survival at Age 9 months

6.2.3. Species Trial, Compartment 17B

A small trial testing four indigenous species and an exotic, *Cordia alliodora* was planted on 23 June 1993. The indigenous species include two nut trees, *Canarium indicum* and *Aleurites mollucana* and two trees which produce high grade timber, *Dracontomelon vitiense* and *Dysoxylon amooroides*.

The trial is a randomised complete block design with three replications, testing five species. Each plot is 5 x 5 trees with the inner 3 x 3 trees being measured. Spacing is 5m between trees. Origin of seedlots is shown in Table 6.2.3.1.

Species	Origin	Supplier
C. alliodora	San Carlos, Costa Rica	CATIE, Turrialba, Costa Rica
D. vitiense	Chapuis, Santo	IFP, Santo
C. indicum	Kole II, Santo	IFP, Santo
D. amooroides	Vanafo, Santo	IFP, Santo
A. mollucana	Malekula	Daniel Leyang

Table 6.2.3.1 Origin of Seedlots

Results of the assessment at 12 months are shown below in Table 6.2.3.2.

Species	Height (cm)	% Survival
C. alliodora	250.5	96
D. vitiense	49.1	44
C. indicum	62.1	85
D. amooroides	78.4	100
A. mollucana	315.0	89

Table 6.2.3.2 Results of Dbh and Survival at age 12 months

An ANOVAR showed no significant differences between survival of seedlots, but highly significant differences in height. Height of all species except *A. mollucana* was significantly smaller (@ P<0.2%) than *C. alliodora*. There were no significant differences between blocks.

As the trial is only 12 months old all results should be viewed as preliminary. For volume of wood produced *C. alliodora* and *A. mollucana* would be the preferred species. However, if high grade timber was required both of these species have shortcomings. *C. alliodora* can produce high grade joinery timber and veneer but has a habit of retaining dead knots. It is also relatively susceptible to Brown root Rot, *Phellinus noxius*. The wood of *A. mollucana* is only noted as being an ordinary fuelwood and the nuts it produces are not considered particularly tasty. Of the two indigenous timber trees, *D. amooroides* would appear to be faster growing than *D. vitiense*. Both have good markets in Vanuatu and also abroad. The remaining species, *C. indicum* is a favoured nut tree and the slow growth in plantation conditions may not reflect its potential. It would probably grow better if considered as an horticultural crop and be incorporated into a home garden where more intensive weeding and tillage should increase growth. In the Solomon Islands this species has averaged 2.8m height growth per year (Evans, 1993). When the trees begin to produce nuts, amounts produced should be assessed. In the Solomon Islands trees start to produce nuts after three to five years and continue up to an age of about 50 years. Timber is a fine textured non-durable wood.

Growth of all species may have been reduced due to the late planting of this trial. It was planted in June, at the end of the rainy season.

If the slow growth of the two native timber species continues it will limit their use in plantations, unless a high premium is paid over exotic timber species, such as mahogany (*Swietenia macrophylla*). Unfortunately, *A. mollucana* does not appear to provide a useful and valuable product or service and so despite its impressive growth it cannot be recommended for planting. The nut tree, *C. indicum* should be assessed for nut production and quality and compared in a trial with other nut trees. The remaining species *C. alliodora* has, from older trials, disappointing growth rates later in the rotation and the timber has proved to be difficult to market. It is also a weed under certain conditions and is relatively prone to attack by *Phellinus noxius*. However, It may still have a role as a tree producing timber for local markets.

6.3 Carter Holt Harvey Managed Trials

The trials previously managed by Carter Holt Harvey originate from plantings by Plantation Development Ltd and CFK. They were established to test the growth and wood properties of species considered suitable for pulp plantations. In early 1994 Carter Holt Harvey handed over these trials to the Santo IFP Project.

6.3.1. Lorevulko, Sara and Port Olry Trials

The trials are a randomised design with all species being represented by four plots. plots were planted 10 x 9 trees at 3 x 3 m spacing. At Lorevulko the plots of the Brazillian *E.*

grandis x *urophylla* hybrid were placed in one block and were not randomised. The trials were established in June 1988.

Seedlots are described in Table 6.3.1.1.

Species/ Clone	Seedlot No	Origin
E. grandis	-----------	Transvaal, South Africa
E. grandis x urophylla	-----------	Brazil
E.deglupta	15615	Geshes Clone Orchard, PNG
G. arborea	-----------	local collection
C. alliodora	-----------	local collection
A. mangium	15644	Oriomo, PNG
A. crassicarpa	15645	Boite, PNG

Table 6.3.1.1 Seedlots used in CFK Trials

The results at 6 years for dbh and top height are shown for the Lorevulko and Sara trials in Table 6.3.1.2 and for survival in Table 6.3.1.3.

Species	dbh (cm) Lorevulko	dbh (cm) Sara	Top Height (m) Lorevulko	Top Height (m) Sara
E. grandis	Not planted	11.8	Not planted	14.5
E. grandis x urophylla	13.9	Not planted	18.1	Not planted
E. deglupta	16.9	17.1	21.6	23.9
G. arborea	16.7	17.0	16.7	17.8
C. alliodora	15.4	17.1	17.9	21.1
A. mangium	21.3	No survivors	17.3	No survivors
A. crassicarpa	18.0	19.9	18.2	20.3

Table 6.3.1.2 Dbh and top heights, Age 6 years

Species	% Survival Lorevulko	% Survival Sara
E. grandis	Not planted	52
E. grandis x urophylla	38	Not planted
E. deglupta	53	87
G. arborea	96	98
C. alliodora	52	87
A. mangium	10	No survivors
A. crassicarpa	5	10

Table 6.3.1.3 Survival at Age 6 years

Results from the Port Olry trial at age 5 years are shown in Table 6.3.1.4.

Species	Dbh (cm)	Top Height (m)	% Survival
C. alliodora	13.89	17.16	83.3
E. deglupta	15.51	20.75	76.7
G. arborea	15.26	16.23	97.5

Table 6.3.1.4 Results at Age 5 years

In the acacia plots at Port Olry there were only one or two alive. Survival of *G. arborea* was exceptional on all sites and dbh was not significantly different from the best performing species. Top height of *G. arborea* however was often significantly smaller than the best species, in all trials except Port Olry.

C. alliodora showed good growth at all sites but survival was poor at Lorevulko due to attack by the pathogen *P. noxius*. Of the eucalypts, *E. deglupta* has the best growth and survival of those tested. Other experience in Vanuatu has shown eucalypts to be relatively susceptible to wind damage, although not as much so as the acacias.

6.3.2 Carter Holt Harvey Trials at IFP

In Compartment 7 a balanced lattice design trial was established in April 1991 with 16 treatments and five replications. The same design was used in the Matevulu Pico trial described in 6.3.3. Plot size was 6 x 6 trees with a 3m square spacing.

Seedlots are described in Table 6.3.2.1. Results at age 30 months are described in Table 6.3.3.2.

Anovars were applied to the plot means and significant differences (@ 5% or less)were found between dbh, top height and survival for treatments and blocks.

Acacias have proven themselves to be susceptible to wind damage and despite good growth should not be planted. Eucalypts are slightly more resistant to damage and a good choice would be *E. urophylla* (14532). Survival, dbh and top height were not significantly different to the *E. deglupta* (15615) and the wood has better pulping properties.

6.3.3. Other Carter Holt Harvey Trials

Three trials were established on land leased by Matevulu College. One tested growth on a "bush" site, one on a "coral" site and one on a site previously dominated by the weed pico (Solanum sp.). The coral and bush sites test five seedlots in a randomised complete block design with four replications, whereas the pico site tests 16 seedlots in a balanced lattice design with five replications. All are planted at a 3m square spacing. The coral and bush sites have plots 4 x 4 trees whereas the pico site has plots 6 x 6 trees.

Seedlots tested are the same as those tested at IFP.

Latest results for these trials are described below in Tables 6.3.3.1, 6.3.3.2 and 6.3.3.3.

Species	Seedlot	Origin
E. deglupta	15615	Clonal Orchard, PNG
E. deglupta	15311	Phillipines
E. urophylla	16682	Mt Egon, Flores, Indonesia
E. urophylla	14532	Mt Lewotibi, Flores, Indonesia
E. grandis	15244	NE Atherton, Quenensland, Australia
E. grandis	14838	WNW Cardwell, Queensland, Australia
E. pellita	13999	NE Wenlock, Queensland, Australia
E. pellita	16120	Keru, Mata, Papua New Guineau
A. crassicarpa	13682	Oromo River, PNG
A. mangium	15644	Oromo River, PNG
A. mangium	15677	Iron Ra. Queensland
A. auriculiformis	16485	Kings Plain, Queensland
A. auriculiformis	16684	Bensbach River, WP, Papua New Guineau
C. junghamiana	16872	Botanic Garden, Indonesia
C. grandis	15923	Toma, Papua New Guineau

Table 6.3.2.1. Origin of Seedlots

Species	dbh (cm)	Top Height (m)	% Survival
E. deglupta 15615	10.5	13.1	91
E. deglupta 15311	9.3	10.5	93
E. urophylla 16682	8.8	10.2	65
E. urophylla 14532	10.3	11.7	77
E. grandis 15244	9.3	10.0	49
E. grandis 14383	10.1	10.8	47
E. pellita 13999	6.2	6.6	69
E. pellita 16120	6.8	6.5	30
A. crassicarpa 13682	9.2	7.7	60
A. crassicarpa 15646	7.7	7.2	18
A. mangium 15644	8.9	8.5	91
A. mangium 15677	10.6	8.3	81
A. auriculiformis 16485	9.2	9.0	92
A. aurculiformis 16684	9.8	7.6	84
C. junghamiana 16872	7.5	7.3	76
C. grandis 15923	7.3	8.7	89

Table 6.3.2.2 Results from IFP C7 PDL, Age 30 months.

Species/ Seedlot	dbh (cm)	Top Height (m)	% Survival
E. deglupta 15311	11.75	11.54	58
E.deglupta 15615	12.9	13.85	69
E. urophylla 16682	10.15	11.56	42
A. crassicarpa 13682	11.5	9.39	44
A. mangium 15644	12.06	11.22	58

Table 6.3.3.1 Results from Matevulu Bush at Age 3 years.

An Anovar showed no differences (@ 5%) between dbh and top height between seedlots at the Matevulu bush site.

The only significant differences (@ 5%) between treatments at the coral site were:

- dbh between *A. crassicarpa* and *C. grandis*
- top height between *A. mangium* and *C. grandis*
- Survival between *E. deglupta* and *C. grandis* and *E. deglupta* and *E. urophylla*

Species/ Seedlot	dbh (cm)	Top Height (m)	% Survival
E. deglupta 15311	9.54	10.98	55
C. grandis 15923	7.08	7.47	23
E. urophylla 16682	9.79	9.99	27
A. crassicarpa 13682	10.57	10.75	63
A. mangium 15644	12.47	11.51	41

Table 6.3.3.2 Results from Matevulu Coral at Age 39 months.

Species	dbh (cm)	Top Height (m)	% Survival
E. deglupta 15615	14.05	15.78	66
E. deglupta 15311	12.44	16.24	75
E. urophylla 16682	14.77	16.63	50
E. urophylla 14532	14.97	16.55	64
E. grandis 15244	13.64	15.01	36
E. grandis 14383	15.01	15.39	49
E. pellita 13999	11.16	12.94	61
E. pellita 16120	11.65	13.16	30
A. crassicarpa 13682	10.57	12.27	65
A. crassicarpa 15696	12.03	12.33	60
A. mangium 15644	14.71	13.14	59
A. mangium 15677	13.54	13.74	60
A. auriculiformis 16485	13.22	15.2	41
A. aurculiformis 16684	12.98	14.33	75
C. junghamiana 16872	9.60	12.31	76
C. grandis 15923	8.80	13.13	75

Table 6.3.3.3 Results from Matevulu Pico, Age 38 Months

The dbh and top heights of the *E.deglupta* and *E. urophylla* seedlots at the Matevulu Pico site were compared and no significant differences were found and also in top height and dbh between the two *E. urophylla* seedlots and between the two *E. deglupta* seedlots.

The fastest growing *E. pellita* provenance was compared with the fastest growing *E. urophylla* provenances and both dbh (@ P = 0.2%) and top height (@ 5%) were found to be significantly different. Top height of *E. pellita* was also found to be statistically different (@ P = 2%) from the fastest growing *E. deglupta*.

No significant differences were found in dbh and top height between the fastest growing *E. grandis* and the fastest growing E. deglupta or *E. urophylla*.

A statistical examination of the data from the acacias was not undertaken as they have proved to be susceptible to wind damage.

significantly smaller (@ P = 2%) than the fastest growing *E. deglupta.*

No significant differences were found in dbh and top height between the fastest growing *E. grandis* and the fastest growing E. deglupta or *E. urophylla*.

A statistical examination of the data from the acacias was not undertaken as they have proved to be susceptible to wind damage.

SECTION 7 PROVENANCE RESEARCH

At the IFP there are provenance trials of two species, *Swietenia macrophylla* and *Cordia alliodora*. Comparisons of provenances can be made in some of the PDL plots, where two seedlots of *Eucalyptus deglupta* and *E. urophylla* were tested. A further four *C. alliodora* provenance trials were established by the Department of Forestry on Santo. Three other Department of Forestry provenance trials were established on Santo; one of *Liquidambar styraciflua*, one of *Cedrella odorata* and another of *Pinus carribaea*.

7.1. IFP Mahogany Provenance Trial. (072.1)

This trail was planted in 1988 and tests 8 seedlots in a Randomised Complete Block design trial with 4 replications. Plots contain 5 x 5 trees at a square spacing of 4m, of which the inner 9 trees were measured. Origin of seedlots is shown in Table 7.1.1. Results of height, dbh and survival are shown in Table 7.1.2. Survival is poor, due to cyclone damage and high infection rates of Brown root rot, *Phellinus noxius*.

Seedlot	Species/ Hybrid	Details of Origin
322	*S. macrophylla x S. mahogani*	PR 30, Guarabo, Puerto Rico
320	*S. macrophylla x S. mahogani*	Guarica Forest, Puerto Rico
319	*S. macrophylla*	Rio Piedras, UPR Botanic Gardens, Puerto Rico
B/34/87	*S. macrophylla*	Lancetilla, Honduras
713	*S. macrophylla*	Bacaramanga, Colombia
P/4/87	*S. macrophylla*	La Venta, Honduras
23/85/F	*S. macrophylla*	Colo - i - Suva, Fiji
VAN8/85VLI	*S. macrophylla*	Tagabe, Efate, Vanuatu

Table 7.1.1 Origin of Seed

Height, dbh and % survival of provenances relative to a trial mean are shown in Figure 1. Two seedlots, 322 of hybrid mahogany from Puerto Rico and P/4/87, a *S. macrophylla* seedlot from La Venta, Honduras are not suited to Santo conditions and have very poor survival and growth. Of those with relatively good survival; seedlot 319, from Puerto Rico; 713 from Colombia and B/34/87 from Honduras have fastest growth. Seedlot 319 is also noted as being one of the provenances most resistant to cyclone damage in a damage assessment after Cyclone Betsy (Secker Walker, 1993).

In the previous assessment, at 58 months, seedlot 319 had the largest dbh and was significantly better (@ 1%) than the other seedlots (Santo IFP, 1993). In the most recent assessment, at

70 months, this seedlot no longer has the largest dbh but has better survival than 713, the seedlot with the largest diameter. As a compromise between good growth and survival, seedlot 319 and B/34/87 are a good choice.

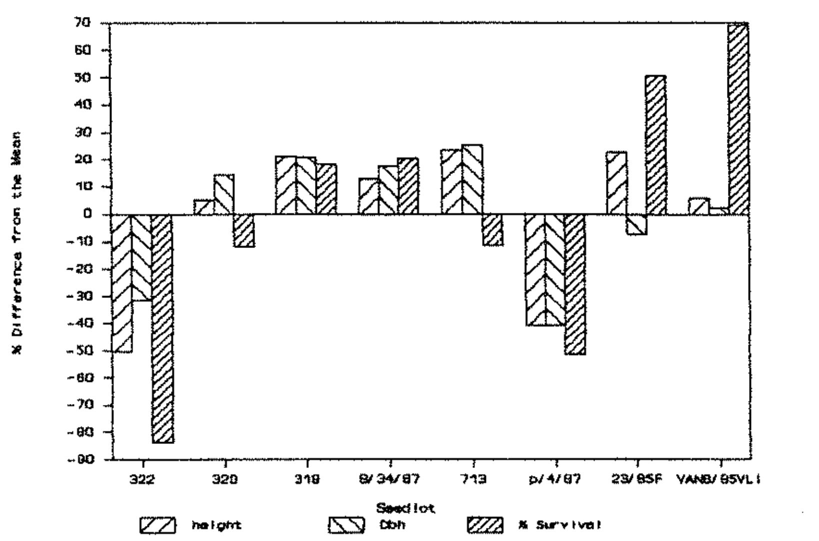


Figure 7.1.1 Performance of Seedlots relative to a trial mean

Some imports of seed for management plantings of *S. macrophylla* at Santo IFP have been from Lancetilla in Honduras. This provenance (B/34/87) has shown above average growth and survival was considerably better than average and was a good choice. The other promising seedlot , 319 from Rio Piedras, Puerto Rica may not be as suitable for wide scale planting. It originated from a Botanic Garden and may therefore have a limited genetic base, possibly being represented by few trees.

Seedlot	Height (m)	Dbh (cm)	Survival (%)
322	6.50	10.8	6
320	13.75	18.0	31
319	15.86	19.0	41
13/34/87	14.78	18.5	42
731	16.16	19.7	31
P/4/87	7.73	9.3	17
23/85/F	16.08	14.6	52
VAN 8/85 VLI	13.86	16.1	58

Table 7.1.2 Results of Assessment at Age 70 months

Records on file for other management seedlot comprise seedlots from Poptun - Peten Region in Guatemala, Fijian seedlots and a seedlot from Sardinal Puntarenas, Costa Rica.

7.2. Cordia provenance Trials. (072.2)

Cordia alliodora was the favoured tree species in the 1980s and this is reflected by the relatively large number of provenance trials of this species. Since then cordia has fallen out of favour mainly due to poor marketability, timber quality and susceptibility to some pathogens, notably *Phellinus noxius*. Future planting of *C. alliodora* in Vanuatu is therefore unlikely, at any large scale. The results may however be of interest and are described for each trial.

7.2.1. IFP Project Cordia Provenance Trial

This trial was planted in 1988 to test both provenance and mother tree performance. Seed was imported from CATIE and originated predominantly from Costa Rica, as provenances from this country appeared to have superior growth in other cordia provenance trials. It was intended that the results would be used to find the best trees for seed of *C. alliodora* for Santo conditions.

The trial is a relatively complex design with provenances being randomised within blocks and mother trees randomised within provenances. Nine replications were used, each mother tree being represented by a line plot of six trees within each block.

Seedlots are identified by the name of their place of origin. No further records could be located in the files.

Data from three blocks from a 1991 assessment was analysed. The trial was 36 months old. Means for the provenances are shown in table 7.2.1.2. No significant differences were found for dbh or survival by block or treatment.

Provenance	Dbh (cm)	% Survival
Talamanca	15.0	41
Guapiles	13.1	27
Noche	13.1	56
Honduras	14.8	45
Pascua	14.1	47
San Carlos	14.3	51
Upala	15.8	25
La Suiza	13.4	43
Guacimo	15.5	56

Table 7.2.1.2 Performance of provenences

For the 39 trees reresented in all of the 3 blocks examined there were found to be no significant differences. Should seed be collected from the cordia provenence trials it would be better to collect from those trials that superior seedlots can be identified rather than the IFP trial. Furthermore growth rates are similar to those at the Sharks Bay trial.

7.2.2. 1978 Vanafo Cordia Provenance Trial

A trial established in 1978 was clear felled in June 1985 due to poor maintenance and heavy losses from Cyclone Nigel in January 1985. No records were available of the assessments.

7.2.3. 1985 Sharks Bay and Vanafo Cordia Provenance Trials

Cordia alliodora provenance trials were established at Sharks Bay and Vanafo in 1985 and five of the seedlots were common to both trials. These trials and another one at Vanafo established in 1986 were designed to identify superior seedlots of *C. alliodora*. Unfortunately, it is unlikely that this species will be planted widely in Vanuatu in the future due to lack of markets for the timber, a tendency to retain dead knots in the wood and disease problems, particularly from *Phellinus noxius*.

Both trials are randomised complete block designs. The Sharks Bay trial has three replications, plot size being 7 x 7 trees with the inner 5 x 5 trees being measured. Spacing between trees was 3 m but was thinned in June and July 1987 leaving about half the number of trees. The Vanafo trial has five replications, plot size being 7 x 7 trees with the inner 5 x 5 trees being assessed. Spacing between trees was 3m but death, mainly due to *P. noxius* has left the spacing and survival very patchy.

Seedlots tested in the trials and their origin are shown in Table 7.2.3.1.

Seedlot	Trials	Origin
14/77	Vanafo, Sharks Bay	Esteli, Nicaragua
20/77	Vanafo, Sharks Bay	San Francisco, La Ceiba, Honduras
67/78	Vanafo, Sharks Bay	Lago Agrio, Ecuador
80/3237	Vanafo, Sharks Bay	Turrialba, Costa Rica
34/78	Sharks Bay	Columbia
1849	Sharks Bay	San Carlos, Costa Rica
Monbiftek	Vanafo, Sharks Bay	Monbiftek Plantations, Santo (originally from Fiji)

Table 7.2.3.1 Origin of seedlots

Results for survival and dbh at 109 months from Sharks Bay are shown in Table 7.2.3.2 and relative to a trial mean in Figure 7.2.3.1.

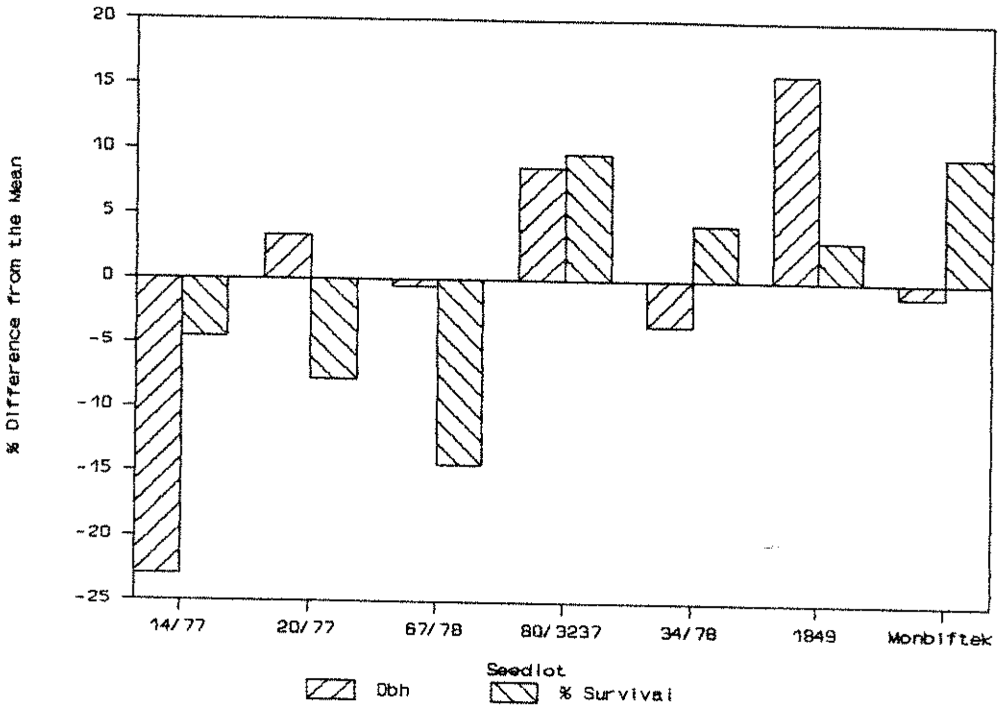


Figure 7.2.3.1 Dbh and Survival relative to a Trial Mean

Seedlot	Dbh Sharks Bay	Dbh Vanafo	% Survival Sharks Bay	% Survival Vanafo
14/77	17.08	16.65	87	36
20/77	22.35	20.5	84	19
67/78	18.63	15.8	78	36
80/3237	21.82	23.6*	100	37
34/78	20.21	---------	95	---------
1849	21.95	---------	94	---------
Monbiftek	20.83	20.7	100	37

Table 7.2.3.2 Results *from* Latest Assessments

* Biased by one plot containing two large trees only.

There were difficulties in the latest assessment of the Sharks Bay trial in assigning trees to plots and so the results from the previous assessment at 77 months were used for further analysis. Two seedlots have above average growth and survival, 80/3237 and 1849. A significanace test was applied to the survival data and no differences (@ P= 5% or less) were found between seedlots. Statistically significant differences in dbh were found between seedlots. However, significance tests, comparing all seedlots against 1849 showed only 14/77 to be significantly different (@ P= 5%).

At Vanafo the trial had been badly infected by Brown Root Rot (*Phellinus noxius*) and there were 13 plots with no trees surviving, compared with 12 plots with survivors.
The latest results of survival and dbh from Vanafo at 110 months are shown in Table 7.2.3.2 and are compared with a trial mean in Figure 7.2.3.2. Again, seedlot 80/3237 exhibits relatively good growth and survival. However, if one plot with

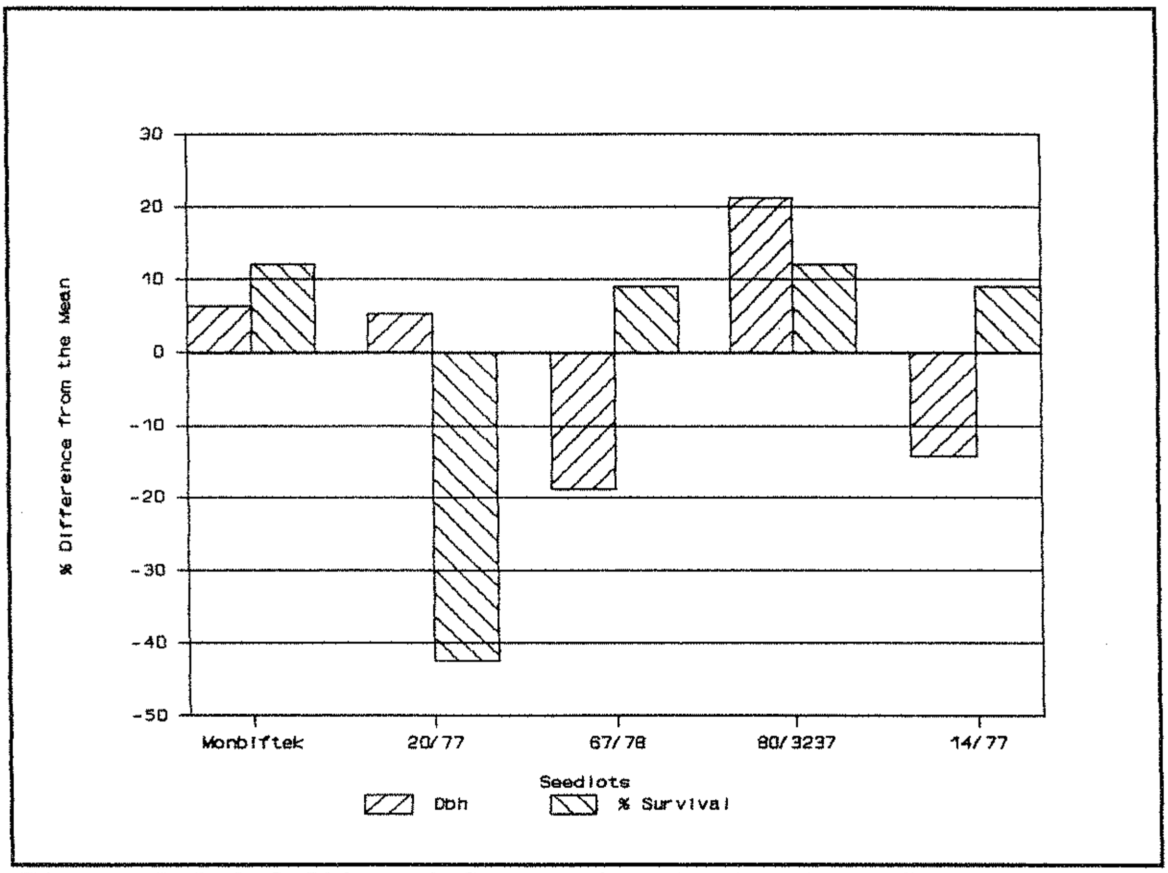


Figure 7.2.3.2 Dbh and Survival relative to a Trial Mean

only two large trees surviving is excluded from the mean then mean dbh of this seedlot falls below that of the Monbiftek seedlot and seedlot 20/77.

As with the Sharks Bay trial a statistical analysis was conducted on the data from the previous assessment, taken at 55 months. An ANOVAR showed differences between dbh and height of seedlots were statistically significant (@ P = 1%). Seedlots were compared with 80/3237 to examine if there were statistically significant differences. The Monbiftek and 20/77 were found to have significantly better dbh growth than 80/3237 but height of the Monbiftek seedlot was significantly poorer. The dbh of the other two seedlots was significantly smaller than 80/323 and the height of 14/77 was also significantly smaller.

At both trials the local seedlot from Monbiftek gave good results. Seedlots 80/3237 and 1849, both from Costa Rica showed above average growth and survival. Growth of seedlot 20/77 was good at both sites but is not recommended due to poor survival at Vanafo. The high mortality could be related to high susceptability to *P. noxius*, which is prevalent on that site. This seedlot was noted as growing well over a wide range of sites in a review of *C. alliodora* provenance trials (Greaves and McCarter, 1990).

Fortunately, should importing seedlots be difficult there would be little loss in production by using seed from the local land race from Monbiftek.

7.2.4. 1986 Vanafo Cordia Provenance Trial

This Cordia Provenance Trial (ST4/86SON) at Vanafo was established in October 1986 by the Department of Forestry.

The trial is a randomised complete block design with four replications. Each plot contains 36 trees (6 x 6) with the inner 16 (4 x 4) being assessed. Spacing between the trees is 3m. Six imported seedlots are tested and unfortunately no seedlot of the local land race was included as a marker. Origin of the seedlots is described in Table 7.2.4.1.

Seedlot	Origin
9/77	Tres Piedras, Honduras
10/77	Finca El Chilero, Guatemala
18/77	Finca la Pineda, Matagalpa, Nicaragua
17/78	Rio Canas, Puerto Rica
30/78	Finca Rincon Alegre, Guatemala
33/78	Nueva Guineau, Nicaragua

Table 7.2.4.1 Origin of Seedlots

Table 7.2.4.2 gives the survival, mean dbh and mean height for each seedlot.

Seedlot	Dbh (cm)	Height (m)	% Survival
9/77	13.16	13.02	70
10/77	12.57	13.03	94
18/77	18.07	18.74	86
17/78	14.62	15.45	86
30/78	15.20	16.99	87
33/78	19.5	18.64	53

Table 7.2.4.2 Dbh, Height and Survival at 89 months

Figure 7.2.4.1 shows the performance in terms of height, dbh and survival compared to the trial mean at age 89 months. A seedlot with both above average growth and survival is 18/77. The dbh, height and survival of this seedlot was compared with

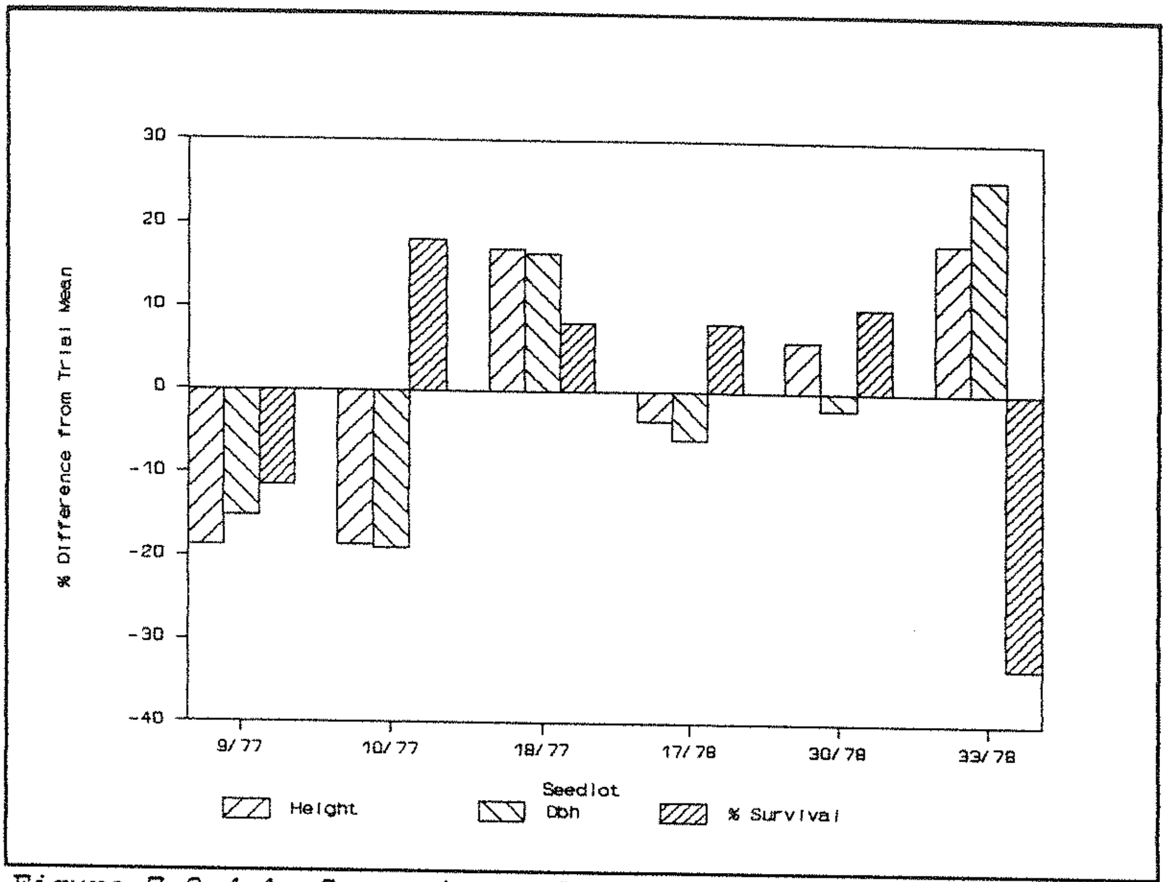


Figure 7.2.4.1 Comparison of Height, Dbh and Survival of seedlots with a trial mean

other seedlots to examine which were significantly different. Only 33/78 was better than this seedlot and although survival of this seedlot was poorer it was not significantly so.

It was unfortunate that a local seedlot was not included in this trial. It is not known whether any of the seedlots tested have performed better than the local land race. Furthermore, the seedlots tested were not included in any of the other *C. alliodora* provenance trials, which also makes it impossible to compare the growth with other exotic seedlots. Of the seedlots tested 18/77 from Finca La Pineda, Nicaragua and 33/78 from Nueva Guineau, Nicaragua would appear to be good performers being above average in both growth and survival. These seedlots should be considered, in addition to other promising ones in the other provenance trials.

7.3 Liquidambar styraciflua Provenance Trial

Liquidambar styraciflua is a timber tree, with a wide geographic range in Central and South America and is known to occur from altitudes as low as 650m up to 1600m. The wood can be used for saw timber, veneer, plywood and pulp. Tree form is good in natural conditions and in plantations.

The *Liquidambar styraciflua* trial (ST17/85 SON) was established to test five provenances in a randomised complete block design with four replicates. Origin of seedlots is shown in Table 7.3.1. Plots contain 36 trees (6 x 6) with the inner 16 (4 x 4) being measured. Spacing between trees was 2.5m. Heavy damage by cyclones has left the trial with large gaps and one provenance (48/83) has no survivors in the trial.

Seedlot	Origin
48/83	Yucul, Matagalpa, Nicaragua
3/84	San Esteban, Olancho, Honduras
2/84	Buenos Aires, Sierra del Omoa, Honduras
5/84	Finca las Victorias, Sierra de las Minas, Guatemala
84/83	Gomez Farias, Tamaulipas, Mexico

Table 7.3.1 Origin of seedlots

Due to missing plots in all blocks an Anovar was not possible. The data sheet for Block II was missing from the trial and so results are from three blocks only. The data from all blocks was clumped and means for dbh, height and survival calculated. For dbh and height 95% confidence limits were also calculated. Results from the most recent assessment (15 December 1992) at age 82 months are shown in Table 7.3.2.

Results from the trial at Vanafo would suggest that *L. styraciflua* is not well suited to the conditions on Santo. All seedlots failed completely on at least one block and one in all blocks. However, at Ipota on Erromango this species has grown well and shows good survival and little wind damage (Tolfts, pers. comm.). There is therefore too little information to dismiss this species completely.

Seedlot	Height (m)	95% CL Height	Dbh (cm)	95% CL Dbh	Survival (%)
3/84	14.9	0.8	14.6	0.9	58
84/83	12.4	0.8	13.5	1.1	58
48/83	--------	---------	--------	---------	0
2/84	14.5	1.5	15.8	1.7	31
5/84	13.4	7.6	16.5	1.3	25

Table 7.3.2 Height, Dbh and Survivals at Age 82 months

Examining the 95% confidence limits for the mean height and dbh of seedlots there is no obviously superior seedlot. Figure 7.3.1 shows means for dbh, height and survival expressed in % deviation from the trial mean.

The *L. styraciflua* trial at Vanafo has not allowed identification of a superior seedlot. The poor survival also indicates that this species may not be suited to conditions on Santo. Possibly the best *L. styraciflua* seedlot at Vanafo is 3/84 from San Estaban, Honduras. Height and survival was

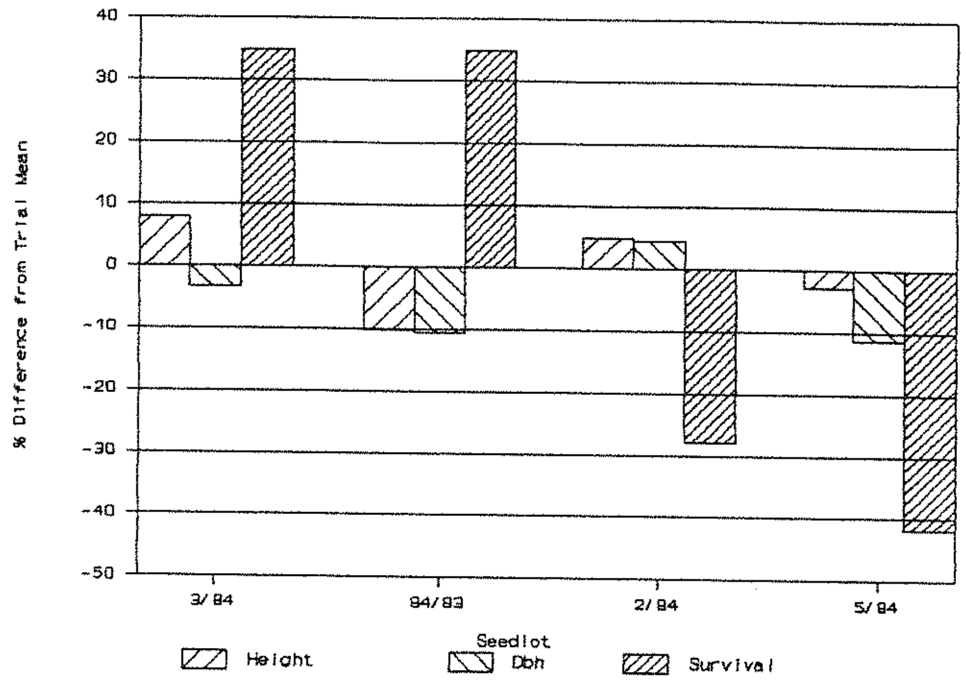


Figure 7.3.1 Height, Dbh and Survival Relative to the Trial Mean

better than the mean and dbh was only marginally inferior to the trial mean. Results from this trial should be compared with those from Ipota.

7.4 Cedrella odorata Provenance Trial

Cedrella odorata is a species with a wide distribution, from Mexico to Argentina and is found at altitudes up to 1200m. In natural forest and plantations it has the characteristics of a good timber tree with a straight clear stem and compact crown. The wood has been used as sawn timber, plywood, veneer and pulp. *C. angustifolia* is a close relative to *C. odorata*.

Seed for the trial was obtained from the Commonwealth Forestry Institute, now the Oxford Forestry Institute. The *C. odorata* provenance trial (ST3/86 SON) tests the growth and survival of three provenances of *C. odorata* and one of *C. angustifolia* (Table 7.4.1). The trial is a randomised complete block design with 4 replications. Plots are 6 x 5 trees, with the inner 3 x 4 trees being assessed. Spacing between trees was 3m. Age of the trees was 75 months at the last assessment (15 December 1992).

An Anovar was applied to the dbh and height data and no significant differences in dbh were found between seedlots. However there were statistically significant differences in height (@ 5%) between seedlots. There were also significant differences in dbh and height (@ 5%) between blocks. The dbh and survival of each seedlot is shown in Table 7.4.2.

Seedlot	Species	Origin
42/79	C. odorata	Chetalon, Guatemala
50/79	C. odorata	Copar, Honduras
53/79	C. odorata	Taulabe, Honduras
16/80	C. angustifolia	El Vigia, Equador

Table 7.4.1 Origin of seedlots

Growth and survival were good, although there was quite a high incidence of forking (23%) or broken tops (6%). Wind damage was slight compared with the nearby *Liquidambar styraciflua* (Roata, pers. comm.)

Seedlot	Dbh (cm)	Height (m)	Survival (%)
42/79	18.30	13.15	97.2
50/79	19.17	15.91	91.7
53/79	19.72	15.96	100
16/80	20.01	16.76	94.5

Table 7.4.2 Height, Dbh and Survival at 75 months

Growth and survival of both *Cedrella* species was good and is compared in Table 7.4.3 with *Cordia alliodora* and *Swietenia macrophylla*, two mainstays of planting programmes in Vanuatu. The *C. alliodora* data is the average of provenances at Sharks Bay and the *S. macrophylla* data is for a Vanuatu land race at the Santo IFP Provenance trial.

Species	Age (months)	Height (m)	Dbh (cm)
C. odorata	75	15.0	19.06
C. angustifolia	75	15.76	20.01
C. alliodora	77	----------	16.9
S. macrophylla	70	13.86	16.1

Table 7.4.3 Comparison with C. alliodora and S. macrophylla

Wind damage of the *Cedrella* species at Vanafo was much less that that in the neighbouring *Liquidambar syraciflua* provenance trial. However at Ipota, Erromango, *L. styraciflua* showed little damage after a cyclone, whilst *Cedrella* spp. were badly damaged. Many subsequently died possibly from infection by pathogens (Tolfts, pers. comm.). A further constraint to growing cedrella in plantations in Vanuatu maybe wood quality. Wood of cedrella grown in Fiji was found to be less dense and strong than expected (Tolfts, pers. comm).

The performance of the three *C. odorata* seedlots relative to a trial mean is shown in Figure 7.4.1. The seedlot with the best dbh, height and survival was seedlot 53/89 from Taulabe, Honduras.

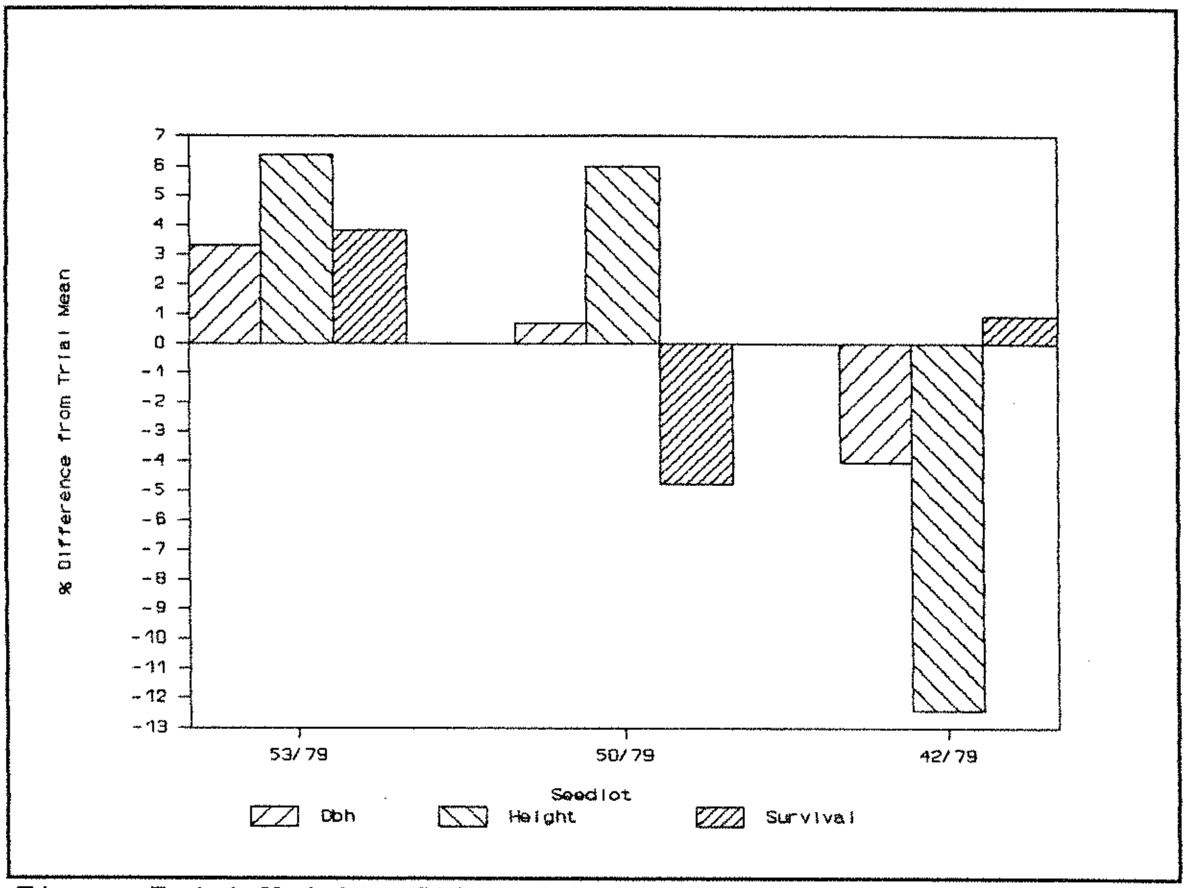


Figure 7.4.1 Height, Dbh and % Survival Relative to the Trial Mean

C. odorata and *C. angustifolia* are two species with potential for use in plantations in Vanuatu. However, some doubts remain of their resistance to wind damage and disease and also their wood quality. Further investigations are necessary and testing of Vanuatu grown timber would be worthwhile. Should *C. odorata* be planted on a limited scale for production plantations, the seedlot best suited to Santo conditions is Taulabe, Honduras.

7.5. Monbiftek Pinus carribaea Provenance Trial

A *P. carribaea* trial established in March 1972 was assessed at age 241 months. Six seedlots were tested in a randomised complete block design trial with four replications. Available information on origin of the seedlots is shown in Table 7.5.1.

Only dbh was assesssed as it is unlikely that P. carribaea will be widely planted on Santo. Species with much higher value timber grow equally or more quickly. An ANOVAR was conducted on the dbh data and no significant differences were found between seedlots or blocks. Results of dbh and survival are shown in Table 7.5.2.

Seedlot	Origin
10/73	Fiji, Sequoqa Plantation
R169B	Queensland, Select seed trees
R179R	Queensland, Good quality crop trees
28/71	Fiji, Drasa Plantation
R162P	Queensland, Progeny Trial No. 158
R172R	Queensland, Crop Trees

Table 7.5.1 Origin of Seedlots

Seedlot	% Survival	Dbh
10/73	49	27.7
R169B	28	26.2
R179R	33	31.6
28/71	41	27.2
R162P	44	29.4
R172R	29	25.0

Table 7.5.2 Results of Dbh and Survival

Should *P. carribaea* be planted again on Santo a reasonable choice in terms of growth and survival would be R162P, a seedlot from a Queensland Progeny Trial.

SECTION 9. Agroforestry Research

9.1. Mahogany with Crops C5. (092.1)

A trial was established comparing mahogany growth with five agroforestry treatments. The trees were planted in March and June 1991 at 5 x 5m spacing in silk sorghum pasture cover crop. The first crops were planted in November 1991. The 5 treatments were; Root crop rotation 1, root crop rotation 2, kava, Melanesian mixed food crop garden plot, silk sorghum control. These are described in table 9.1.1. The trial was designed as a randomised block design with 4 replications. Each plot contains 16 trees (4 x 4) at a square spacing of 5m. This was a collaborative trial and Agriculture was to monitor crop production.

Results of dbh and height growth at 110 weeks are shown in Figure 9.1.1. Statistical differences in dbh at 5% were found between the Kava with Silk and Food Crop I treatments and between the Silk Pasture and the Food Crop II treatment. Also, statistical differences in dbh at 1% were found between Food Crop I and Silk Pasture (Secker Walker, 1993d).

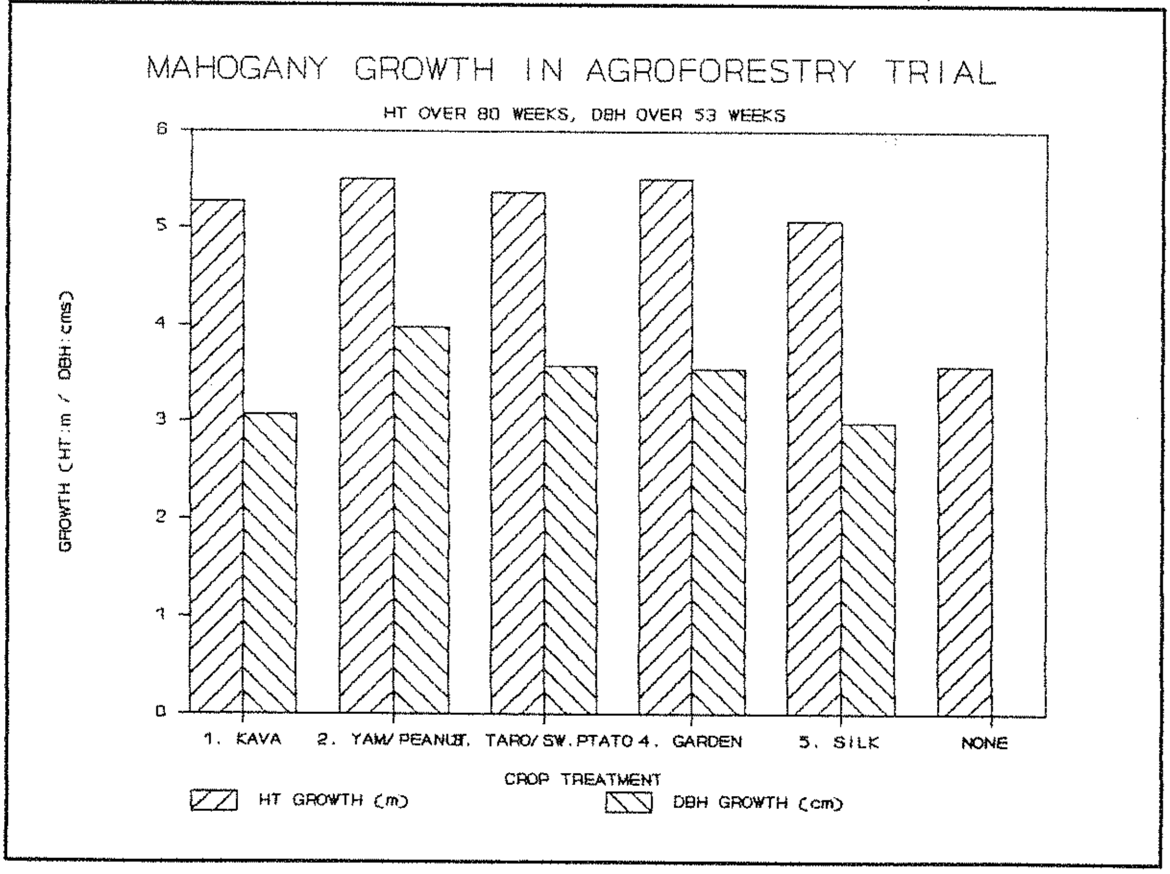


Figure 9.1.1. Results of Dbh and Height at 110 weeks

The better growth of the trees in the Food Crops treatments were probably due to the intensive weeding of these plots. The soil was kept completely free of weeds. In the silk plots an area of 1 m diameter was spot weeded and in the kava plots the ground was initially complete weeded, but later the weeding was similar to the silk plots.

Treatment	Species	Cultivar	Spacing (m)	No./ plot	% area covered	Plant date	Harvest date
Mahogany trees	*Swietenia macrophylla*	Efate, ex-Fiji	5 x 5	16	< 0.06	Mar, Apr, May 1991	2016-2021
1. Kava	*Piper methysticum* Forst.	Puariki Borugu Visul Melmel	2.5 x 2.5	33	6.5	Feb, May 1992	Nov 1994
2. Food Crops I	Yams Maize		1 x 1	220	55 16	Nov 91 Nov 91	Jul 92 Jun 92
	Island taro		0.8 x 0.7			Jul 92	Failed
	Peanuts					May 93	Sep 93
	Sweet potato					Sep 93	Jan 94
	Cassava					Jan 94	Nov 94
3. Food Crops II	Island taro		1 x 0.75	297	74	Nov, Dec 1991	Jul 92
	Sweet potato					Apr 93	Aug 93
	Fiji taro					Sep 93	Dec 93
4. Mixed Garden	Sweet potato Cassava Yams Pineapple Maize Dwarf bean Fiji taro Bananas		1 x 1 1 x 1 1.5 x 1.5 1 x 1 varies varies 1 x 1 varies	56 39 50 36 17 16 15 8 253	34 20 13 9 4 4 4 2 90	Dec 91, Jan 92	Depends on crop
	Spring onion, Island cabbage					Dec 92	
5. Silk pasture cover crop (control)	*Sorghum spp.*	hybrid silk	3kg/ ha	Plots were mainly *Sorghum spp.*, as legumes did not take well.		7-15 Oct 90 + 21 Nov 90	
	Desmodium intortum		2kg/ ha				
	Stylosanthes guianensis	Cook	1.5kg/ ha				

Table 9.1.1 Treatment Summary

Due to the early age of the trial a precise estimate of the improved financial returns of intercropping is not possible. A rough estimate was made by Secker Walker, (1993d). Assumptions on growth were conservative. It was assumed that the trees in both treatments would grow at the same rate in the future and that the only advantage would be the reduction in time for the trees in the Food Crop I treatment to reach harvestable size compared with the trees in the Silk treatment. The same was undertaken for the reduction in time for Food Crops II compared with Silk. Projecting the results at age 110 weeks the Food Crops I treatment added 1.05% to the value of the trees, and the Food Crops II added 0.8% to the value of the trees, compared with the Silk treatment. There is also the value of the crops themselves to consider.

A nearby management planting of mahogany was assessed to give data on growth in normal weed growth. This was poorer than for any of the agroforestry treatments. To check whether this was not simply due to the more intensive management associated with research trials a management planting of mahogany in silk pasture was also measured. Growth of mahogany in this was still better than in natural weed growth.

Other benefits of intercropping included more visits to the site and therefore more attention being given to the quality of the trees. For example, it would be easy to prune or single trees at the same time as tending crops. A farmer is likely to visit the site less frequently if only trees are being grown.

Marketable crop yields from the first year (Anon, 1993) of the experiment are shown in Table 9.1.2. crop values were not assessed.

Block	Taro	Cassava	Yam	Garden
1	221	532.5	171.4	48
2	278	495	280.3	48
3	22.5	417.8	113.2	135
4	2.3	536.5	130	134
Total	523.8	1981.8	694.9	365
T/ha	3.274	12.368	4.343	1.46

Table 9.1.2. Marketable Yields (kg/plot)

9.2 Coffee/ cocoa intercropping pilot study. (092.2)

A trial of coffee (*C. robusta* and *C. arabica*) intercropped with cordia and with mahogany was established in June 1993, when a small number of *C. robusta* seedlings were planted into an area of mahogany for the IFP Open Day. The Vanuatu Public Servant's Association Strike in November 1993 prevented further planting of coffee into the cordia and mahogany areas.

Proposed lay out of the trial was: 5 unreplicated plots approx 1 ha each:

(i) Mahogany (10 x 4m) with robusta coffee
(ii) Mahogany (10 x 2.5m) with arabica coffee
(iii) Mahogany (10 x 2.5 m) with cocoa
(iv) Cordia (5 x 5m) with arabica coffee
(v) Cordia (5 x 5m) with cocoa.

The trial was designed in collaboration with IRCC (CIRAD Coffee and Cocoa Research station). Cocoa would not be planted until the trees were providing sufficient shade.

No assessments were made of the area planted with coffee.

SECTION 8.. CYCLONE DAMAGE SURVEYS

Three damage surveys were made following Cyclone Betsy, which hit Santo in January 1993. At Pekoa Airfield at Luganville wind speeds of average 28 knots and maximum 48 knots were recorded.

8.1 IFP Mahogany Trial Cyclone Damage Survey

A survey was made in February 1992 of damage by Cyclone Betsy in the IFP mahogany provenance trial (ST1/88SON) and were described in Secker - Walker, (1993a). The trees were age 58 months. The data were reviewed and certain tests applied to examine the significance of differences of interest.

Only the data from the inner 9 trees of the 25 tree plot were used for analysis, boundary trees being excluded. Two provenances, 322 and P/4/87, which showed very poor survival of 6% and 25% respectively, and poor growth were also ommitted from any analyses. Details of origin of seedlot are shown in Section 7.

The summarised results of numbers of trees in each damage category are shown in Table 8.1.1. The categories used for the survey were as follows:

0 No Damage
1 Uprooted
2 Snapped stem < 6m high
3 Leaning
4 Broken Top > 6m high
5 Some crown damage

	Damage Category					
Seedlot	0	1	2	3	4	5
13/34/87	11	0	2	2	0	4
23/85/F	12	0	2	0	0	3
713	15	3	2	5	0	5
319	12	1	0	3	0	2
320	15	2	2	4	0	2
VAN8/85VLI	15	1	0	1	1	2

Table 8..1.1 Damage by Seedlot and Damage Category

There were insufficient numbers of trees surveyed to analyse differences in seedlots for the 5 types of damage recorded. Therefore, analysis was only of proportion of damaged and undamaged trees. These data were subjected to a X^2 and there were found to be significant differences (@ 5%) in the incidence of damage in different seedlots.

The most wind resistant provenances were Rio Piedras, Puerto Rico (319); Colo-i-Suva, Fiji (23/85F) and Tagabe, Vanuatu (VAN8/85VLI). Perhaps selection had taken place for resistance to wind damage in the Vanuatu and Fijian land races.

8.2 Survey of Damage to mahogany in Different Cover Crops

Damage, after Cyclone Betsy to mahogany varying in age from 35 to 41 weeks old was surveyed growing within 4 cover crops. Composition of the cover crops in kg/ha seed is shown in Table 8.2.1 and the different components below:

SS - Sorghum sp - Hybrid with Silk (Silk Sorghum)
Set - Setaria sphacelata var. sericea
GL - Desmodium intortum (Greenleaf Desmodium)
CS - Stylosanthes quianensis var. cook (Cook's Stylo)
DO - Desmodium ovalifolium
HAM - Panicum maximum var. Hamil

Cover Type	SS	Set	GL	CS	DO	HAM
Setaria	3.0	2.0	1.5	1.0		
Greenleaf			2.5	1.5	1.0	
Hamil	3.0		1.5	1.0		4.0
Silk	3.0		2.0	1.5		

Table 8.2.1 Components of Cover Crops

Cyclone damage in different cover crops is shown in Table 8.2.2. There was no relationship found between size (height or root collar diameter) and damage. There was however a relationship between cover type and damage (Secker - Walker, 1993a).

Cover Type	% Snapped Stem	% Leaning	% Missing foliage or no damage
Setaria	0	12.5	87.5
Greenleaf	6	0	94.0
Hamil	0	2.5	96.5
Silk	0	0	100

Table 8.2.2 Cyclone damage in Different Crops

Leaning trees were found in the Hamil and Setaria cover crops. These are dense grasses and it is thought the weight of the grass sward may have helped push the trees. However, it is also thought they may have supported tham preventing stem snap. Greenleaf is a shorter cover crop and may have left the trees unsupported and prone to wind snap (Secker - Walker, 1993a).

8.3 Survey of Cyclone Damage to mahogany with Different Agroforestry Practices

A damage assessment was made of mahogany planted with 5 different crop types. These were:

Silk - For composition see Table 8.2.2.
Silk / Kava - As above as Kava not yet planted
Garden - Mixed food crops laid out irregularly, comprising banana, pineapple, sweet potato, taro, cassava, beans, yams.
Yams - Planted between lines of trees with maize in remaining spaces.
Taro - Colocaria taro planted in rows between trees.

Cyclone damage in the different crops are shown in Table 8.3.1.

Crop	% Uprooted	% Leaning	% Missing foliage or no damage
Silk	0	4.8	95.2
Silk/ Kava	0	4.8	95.2
Garden	0	19.8	80.2
Yams	0	21.9	78.1
Taro	1.6	25.4	73.0

Table 8.3.1 Cyclone damage in Different Crops

It was thought that damage may be linked to the roughness of the crop canopy. A dense crop or bare ground made a relatively smooth surface which caused no damaging eddies to form. A rough surface however, caused eddies and more damage to the trees. The garden, yams and taro were by their lay out providing a rough surface which would encourage wind turbulence and eddies and therefore more damage (Secker Walker, 1993c).

8.4 Informal Assessments of Cyclone Damage

In addition to the formal assessments of damage, information collected for other purposes has shown the following species to be very susceptible to cyclone damage:

Acacia mangium - All trees within the PSP in Compartment 7 were snapped in January 1994 by gale force winds assoctiated with Cyclone Sara.

Acacia crassicarpa - Only 30% of this species were left standing in the PSP in Compartment 7. In the C7 species trial one seedlot (13682) was more resistant than the other (15646). See Section 6.3.2.

SECTION 10 SITE INVESTIGATIONS

10.1 Soil Survey of IFP Area

A soil survey was conducted in 1989 by ODNRI. Findings were published in Bennet, (1989). Transects were laid across the site and 106 auger samples were made at 400m interval along the transects. In addition 17 pits were dug and the samples taken for chemical analysis.

The soils were classified as Dystric Cambisols (FAO classification) and are derived from a layer of volcanic ash overlying a raised coral base. Laboratory analysis showed all the soils be clays with little colour variation. They have good physical structure, rapid water infiltration, good moisture retaining capacity, permeability and good aeration except where a water table occurs. there was no constraint to rooting above the coral.

Chemically all the soils showed great similarity. They were found to be more fertile than expected, and are beneficially affected by the release of calcium from the weathering of the coral below. This raises the pH, which varies from 7.1 to 7.5. The soils have a low cation exchange capacity, high phosphate retention and a high water retention of 15 bar. There are however areas, generally in the oldest parts, where soils are lime deficient and where aluminium toxicity may be present.

In conclusion the soils over most of the IFP area were considered suitable for plantation forestry, with the only major nutrient likely to become deficient being Potassium.

10.2 Investigation of Poor Growth in Compartment 4

A soil survey was conducted in Compartment 4 following poor growth of *Cordia alliodora* in an area where growth of the legume, lab lab was also poor. The area close to the road was found to have particularly good tree and legume growth. Six samples were taken from each area and bulked. These were sent to Fiji for analysis of N content. It was found that it was the same (9.9 mg/g) in the good growth and poor growth areas (Secker - Walker, 1992a).

Better growth of the trees and legume near to the road could be due to slope; those trees on flat areas where soil may be deeper were growing faster than those on the slope. Also, soil water conditions can be better for plant growth close to the road where run-off from the road surface is concentrated.

SECTION 11. PESTS & DISEASES

11.1. Brown Root Rot, Phellinus noxius (064)

Ivory, (1993) found that cordia was more susceptible to infection by *P. noxius* than mahogany. In the Carter Holt Harvey trials, cordia was also found to be about ten times more susceptible to P. noxius infection than the another five species; *Eucalyptus deglupta, E. urophylla, Acacia mangium, A, crassicarpa* and *Gmelina arborea*.

Innoculating young plants in field nurseries in Fiji and Vanuatu showed mahogany and cordia to be susceptible to attack by *P. noxius*, although later trials showed mahogany to be less so than cordia. Species such as Fijian and Vanuatu whitewood were highly resistant.

Several methods of reducing infection levels were discussed in Ivory, (1993):

(i) Spacing

Closer spacings, those of 3m x 3m or closer appear to be linked to the worst outbreaks of *P. noxius*. However even with slow spread of the pathogen losses could be considerable over a 30 year rotation period. planting in widely spaced lines would restrict spread between lines. This may account for the low incidences of attack in early line plantings of cordia in Vanuatu and mahogany in Fiji. The natural vegetation in the areas between the cut lines in Fiji may also have reduced infection.

(ii) Thinning

No evidence yet exists of *P. noxius* colonising stumps of thinned trees unlike Fomes Root Rot (*Heterobasidion annosum*).

(iii) Mixed Plantings

Ivory, (1993) suggests that interplanting susceptible species eg mahogany with resistant species eg whitewood could be an effective way of reducing infection. The effective distance between susceptible trees would be increased and also the resistant trees may act as a physical barrier preventing spread.

(iv) Blocking Plants

A couple of the species thought to be successful blocking plants were tested for anti-fungal chemicals. None were identified. Also it was found to be possible to innoculate the plants with *P. noxius*, which suggests that anti-fungal chemicals are not formed in response to attack.

11.2. Other Pathogens

Ivory, (1993) mentions three pathogens, other than *P. noxius* that he identified in Vanuatu.

(i) Poria Root Disease

Two cordia trees were killed at the Santo IFP Project by the fungus causing this disease, *Rigidoporus vinctus*. It is very similar to brown Root rot and it may be more common than supposed.

(ii) Pink Disease

A disease caused by *Phanerochaete salminicolor* which is quite common on cordia trees between 1 and 8 years old. It causes cankers to branches and /or the stem which can result in death of branches and occassionally the whole tree. On more resistant trees it can exist as a large canker on the stem. In Vanuatu it has also been recorded on the Santa Cruz provenance of kauri.

(iii) Eucalyptus leaf Blight

A leaf blight caused by *Cylindrocladium quinqueseptatum* which has attacked *Eucalyptus urophylla* and *E. grandis* on the Carter Holt Harvey plots at IFP. Young trees, at 6 and 15 months old were severely defoliated (up to 80%), although the attack declined markedly in the period between.

11.3. Whitewood Pests and Disease Surveys

Following observations of moth larvae (*Cyfura bifusciata* or *Urapteroides astueniata*) and fungus (*Phaeoseptoria* sp.) damaging whitewood, a survey was conducted in November 1993. Ten rows from Compartment 13 were sampled during the exercise and the combined results were:

Trees with fungus infection = 46.4%

Trees with fungus and moth attack = 1.6%

Trees with moth infestation = 0.5%

In March 1994 a further pest was found on whitewood planted at in cut lines near Hog Harbour by Melcoffee Sawmills. A weevil was found to be defoliating recently planted whitewood seedlings. They had previously been seen on the Merremia vine and thought that they may have transferred onto the seedlings. As the vine grew back the weevil damage decreased.

Observations at IFP in Compartment 13 during May and June 1994 show the moth to have become more serious with most trees having some older leaves skeletonised. Two types of moth larvae were responsible. Infection by the fungus was no longer obvious. It could be that in the wet season (October - April) conditions are better for the fungus, whereas during the dry season the conditions are better suited to the moth larvae.

An assessment in July 1994 comparison of damage to whitewood in cut lines (Compartment 18) and in the open (Compartment 13) showed that there was not greater damage by the moth larvae in the open areas than in the cut lines. However, comparing both the young whitewood areas (age 15 and 18 months respectively) and older whitewood (age 37 months), in Compartment 5 and Compartment 6 showed highly significant differences ($P < 0.1\%$) in the severity of attack. It would appear that damage is related to age of the crop rather than the site preparation (See Table 9.3.1).

	Open Young (C13)	Open Older (C5 & C6)	Cut Young (C18)
No infestation	24	2	28
Light Infestation	52	14	43
Moderate Infestation	22	43	25
Heavy Infestation	1	39	2

Table 11.3.1 Number of trees in each damage category

11.4 Mahogany Pests and Disease Survey

A survey was conducted in November 1993 to examine pests and diseases on mahogany in Compartment 2. The mahogany was then 39 months old. No insect pests were recorded and only one of the trees in the 963 trees recorded was infected by *Phellinus noxius*.

11.5 Natapoa Nursery Pests

In June 1994 caterpillars of one type of moth and butterfly were found eating the older leaves of *Terminalia cattapa* in the IFP Nursery. They had consumed most of the leaves, only leaving the mid rib. The larger green caterpillars with yellow markings and black stripes were identified as those of the skipper butterfly, *Badamia exclamationis*. This is not noted as having attacked *T. cattapa* before but is a common nursery defoliator of *T. calamansanai* and less often *T. brassii* in the Solomon Islands. The white, hairy moth caterpillars were identified as *Roeselia lignifera* which has been recorded defoliating *Terminalia* spp, including *T. cattapa* in the Solomon Islands.

11.6 Whitewood Seed Pests

Whitewood seed was found to have been damaged by a small insect. The larva ate the endosperm of the seed and the adult emerged from a small hole in the seed coat. A survey was undertaken of seed collected by the Santo IFP project (Mabon, 1992). It was found that between 28 and 72% (Mean of 48.8%)

of seed of different batches contained larvae or pupae of the seed wasp. A further 4 to 20% (Mean of 8.8%) contained little endosperm and had been recently vacated by the wasps. The wasp was later identified by Quarantine in Vila as *Syceurytoma* sp., family Eurytomidae.

11.7. Kauri Seed Pest Identification

A small moth, *Agathiphaga vitiensis* was found to have parasitised seed of kauri (*Agathis macrophylla*) and has been previously described from other islands in Vanuatu where kauri occurs naturally.

SECTION 12. PERMANENT SAMPLE PLOTS

12.1. Permanent sample Plots at IFP

Most plots in the permanent sample plot (PSP) programme were only established in 1993 and so only very early results are available. These are shown below in Table 10.1.1.

Compartment/ Species	Height (cm)	95% CL Height	Age (months)	% Survival
C13 Whitewood (Plot 1)	206.5	12.5	18	57
C13 Whitewood (Plot 2)	191.5	10.4	18	81
C14A Cordia Stick Rake	163.7	17.2	12	93
C14B Cordia Stick Rake	239.9	18.5	12	91
C14C Cordia Roller	231.3	27.0	12	87
C15A E. urophylla Stick/legume	410.4	26.6	12	89
C15B E. urophylla Stck/ legume	265.7	38.4	12	65
C15C E. urophylla Roller	359.3	56.4	12	72
C16 Octomelis	151.4	11.6	12	81
C16 Grevillea	245.6	16.0	12	100
C16 Nakatambol	46.0	10.0	12	14
C16 Black Bean	125.1	8.13	12	94
C16 Terminalia calamansanai	87.3	4.95	12	30
C18 Black Bean Cut Lines	173.4	27.6	15	75
C18 Whitewood Cut Lines	159.7	15.4	15	62
C18 Mahogany Cut Lines	211.4	24.9	15	84
C18 Octomelis Cut Lines	360	38.7	15	78
C18 Cordia Cut Lines	397.1	31.6	15	98
C19 Gmelina	172.6	22.1	12	94

Table 12.1.1 Growth in PSPs at less than 36 months

Ten older PSPs exist and the latest results are shown in Table 12.1.2.

Compartment/ Species	Height (m)	95% CL Height	Dbh (cm)	95% CL Dbh	% Survival
C12B E. deglupta	8.44	0.77	7.32	0.63	66
C12B E. urophylla	10.24	0.54	9.03	0.63	86

Table 12.1.2 Results of PSPs at Age 28 months

Compartment/ Species	Height (m)	95% CL Height	Dbh (cm)	95% CL Dbh	% Survival
C7 A. crassicarpa	10.29	2.43	11.65	1.24	30
C8 A. mangium	*	*	13.3	0.77	63
C8 E. deglupta	15.44	0.77	14.81	0.9	68
C8 E. urophylla	7.71	0.35	9.78	3.22	84

Table 12.1.3 Results of PSPs at Age 36 months
* all tops broken

Compartment/ Species	Height (m)	95% CL Height	Dbh (cm)	95% CL Dbh	% Survival
C1 Mahogany Cattle/ Manual (Plot 1)	10.96	1.25	15.98	1.74	70
C1 Mahogany Cattle/ Manual (Plot 2)	11.75	1.11	16.13	1.39	85

Table 12.1.4 Results of PSPs at Age 39 months

Compartment/ Species	Height (m)	95% CL Height	Dbh (cm)	95% CL Dbh	% Survival
C1 Cordia (Plot 1)	17.07	0.65	17.86	1.92	68
C1 Cordia (Plot 2)	16.71	0.90	18.07	1.15	80

Table 12.1.5 Results of PSPs at 48 months

12.2. Other Permanent Sample Plots

One other permanent sample plot was established outside the IFP leasehold by Carter Holt Harvey.

Results for the Solway PSP's at age 2 years are shown below in Table 12.2.1.

Species/ Plot No	Top Height (m)	Dbh (cm)	% Survival
E. deglupta 1	8.24	9.87	63
E. deglupta 2	5.61	8.02	62
E. urophylla 1	5.62	7.25	37
E. urophylla 2	4.63	6.55	33
A. mangium 1	5.82	8.69	62
A. mangium 2	4.30	7.37	51
A. crassicarpa 1	5.23	6.9	14
A. crassicarpa 2	4.52	5.16	14

Table 12.2.1 Results of the Solway PSPs.

12.3 PSPs Established in 1994

Eight PSPs were established in 1994 and are described in Table 12.3.1.

Species	Compartment
Alphitonia zizyphoides	22
Cordia alliodora	9
Endospermum medullosum	24
Samanea saman	7
Flueggia flexusosa	12
Sweitenia macrophylla	11
Sweitenia macrophylla	11
Sweitenia macrophylla	10

Table 12.3.1 PSPs established in 1994

CHAPTER 13 SOCIAL FORESTRY RESEARCH

13.1 Relevant Findings of the Local Supply Plantation Review

Certain findings from the survey for the Local Supply Plantations Review by Jenks, (1992) are relevant to the IFP's activities. Most men in the survey said they had planted trees. However, most women felt that they were not interested or were not allowed or did not have the tools.

The survey showed on Santo that there were no acute shortages of firewood, posts and sawn timber in the 4 villagers sampled (Hog Harbour, Vanafo, Beleraux and Navota Farm). However, for Navota it took between 30 and 60 mins to walk to collect enough fuelwood, for Hog Harbour and Vanafo, more than 60 minutes. People in Belleraux could find sufficient fuelwood in less than 30 minutes. There was money available in all villages to buy some sawn timber.

All villages sampled on Santo, were interested in planting plantations, except at Vanafo where there was no decision, whether they would plant or not. The survey found that although there is general concern over wood supplies in the future few people are doing anything about it (20% men, 29% women).

13.2 Farmer Tree Survey

A brief survey of 25 farmers was conducted by a former IFP Extension Officer, Hinge, (undated). Most farmers had planted trees and most of the trees planted were found to be citrus trees. Of the non-fruit trees the most popular was namaumau, it having been planted by 32% of the respondents. Table 14.2.1 shows the percentage of farmers planting each type of tree and their uses.

Species	% of Farmers	Purpose	Place Planted
Oranges	100	fruit for home use or market	Home and garden
Pamplemouse	100	fruit for home use or market	Home and garden
Namaumau	32	posts and poles	Garden
Avacado	4	fruit for home use or market	Home
Grevillea	4	ornamental	Home
Eucalyptus	4	experimental	Garden
Bredfrut	8	fruit for home use or market	Home and garden
Cocoa	8	cash crop	plantation

Table 13.2.1 Trees planted, their uses and planting sites

The survey also showed an intereest by farmers in planting nut trees, particularly nangai and natapoa.

Other issues included concern about logging and the resulting disappearance of some species, such as whitewood and blackbean from some areas. All the farmers interviewed felt they needed advice concerning logging. Of these 40% felt a the Department of Forestry should create a logging awareness programme.

CHAPTER 14. END USE RESEARCH

Most end use research conducted by IFP and the Department of Forestry was concentrated on uses of cordia. However, several surveys have also been conducted in Santo and other islands on traditional uses of different tree species and those results are summarised in 14.3.

14.1 Cordia Timber Properties Testing

A study was conducted for the Santo IFP Project by the Forestry Commission of New South Wales to assess the suitability of *C. alliodora* for veneer and plywood production. The results were published in Wade, Ksiazek and Chapman, (1992).

The peeling exercise showed that *C. alliodora* peeled well and produced a smooth, tight veneer of uniform thickness. it was considered to be comparable with other Pacific species, such as Luaan, Meranti and Ramin. Temperature was found to greatly affect the recovery of veneer from the logs. In the test the recovery was low due to the small size of the logs and the irregular cross section of the trunks. Also splitting was found to be a problem, although it is likely that these could be overcome in production.

An adhesive test was also performed and cordia was found to produce good "A" bonding with two very different glues. On a "B" and "C" bond test it was comparable to flooded gum and forest red gum; it can therefore be used in composites with those eucalypts. The veneer was found to have good handling properties during gluing and pressing.

Tests were also conducted on the panels. No warp was detected on panels weeks after pressing and they could be handled without operators having problems with splinters. The panels cut with smooth edges and were easily sanded to a smooth finish.

Samples of the five and seven ply plywood were distributed to three Sydney plywood distributors. Their reactions were favourable, the general opinion being that it was good enough for furniture and panelling. Price would be crucial as there is cheap plywood available from Malaysia and Fiji.

14.2 Post Graveyard Test

Between 1986 and 1987 a graveyard test of poles of whitewood, cordia, coconut, pine and terminalia was established at Monbiftek. This was assessed in June 1994 when most of the posts were approximately 8 years old, the whitewood being 6½ years old and the coconut being 7 years old. The cordia posts were divided into two types; tops and butts. The two types of cordia posts, the pine and the terminalia had three treatments applied:

(i) Pressure treated with copper chrome arsenate (CCA)
(ii) Sap replacement treatment with CCA

(iii) No treatment

All the whitewood poles were pressure treated and none of the coconut poles were treated. All the pressure treated posts of every species were still sound, with the cordia top posts showing most deterioration. Most treated with sap replacement showed considerable decay or had rotted to a stump at ground level. Of those treated by sap replacement, only three of the five pine posts were still reasonably sound, the other two were missing. Untreated posts of every species were either missing or had rotted, with a stump at ground level being the only remains. Although one of the coconut posts was still standing it showed heavy decay, three were rotted stumps and one was missing.

For durable posts of the species tested pressure treatment with CCA would appear to be the only viable treatment. Treatment of coconut poles still needs to be investigated.

14.3 Traditional Uses

A review of the Local Supply Plantation programme by Jenks, (1992) involved a questionnaire designed to identify forestry needs of villagers. This also involved examining the preferred tree species for various uses. Uses and preferred species are listed below in Table 14.3.1.

Use	Species
Construction	Navenwe, burao, nabanga, namaumau
Ground Posts	burao, natora, navenwe
Aerial members	navenwe, nabanga, namatal (more in the southern islands), namaumuau
Fuelwood	Navenwe, stinkwood, burao, namatal, cassis, nandao (No strong preferences expressed for those for cooking)
Tool Handles	casuarina, natora, namalu, comb tree, natora
Digging Sticks	namaumau, natongtong, nakatambol, cassis, casuarina
Canoes	Canoe tree, bredfrut and occassionally bluwota, burao
Tamtams	bredfrut, natora, bluwota
Carvings	nataroa, natora, black palm
Windbreaks	Nambanga, mango, burao, casuarina, nataroa
Live Fences	burao, bluwota, narara.
Fruits/ Nuts	navele, nakatambol, nangai, Nakavika, namambe, nandao.

Table 14.3.1 Uses and Preferred Species

SECTION 15 SUMMARY, CONCLUSIONS & RECOMMENDATIONS

15.1. Summary, Conclusions and Recommendations

Seed Handling Research

For most of the native species that produce quality timber appropriate seed pretreatments are known. However two species, *Alphitonia zizyphoides* and *Dysoxylon amooroides* require further work.

All seed of native species is sown as soon after collection as possible and further work needs to be conducted on methods of storage.

Nursery Research

More research needs to be undertaken on finding methods of successfully raising cuttings of kauri (*Agathis macrophylla*). Failure at the IFP trial was probably due to some basic mistakes, notably the low humidity, that the material may have been too old and possibly the wrong hormone or using water instead of alcohol to dilute the hormone. Successful techniques used by Neil, (1987) should be used and refined to make them suitable for large scale rather then research scale production. Using cuttings to produce stock of bluwota (*Pterocarpus indicus*) would seem to be straightforward.

Other nursery trials concentrated on nursery techniques for *Cordia alliodora*. Unfortunately this species is no longer planted at IFP and is unlikely to form a large part of any other forestry plantings in Vanuatu. In the container trial a relatively small container (151 cc) was found to be appropriate for raising cordia and this will give considerable savings over using the standard plastic pot (622 cc).

The combined growth medium/ fertiliser trial again using *C. alliodora* showed that for this species required additional nutrients to be added to the soil if a plantable seedling is to be raised in 3 to 4 months. Mixing sand with the soil was not found to improve growth. Fertiliser applications of about 17g NPK 1:1:1 (47) per 100 pots seems to be a reasonable treatment. There is conflicting evidence for best placement of the fertiliser. The TD2 treatment, where the fertiliser is placed $^1/_3$ down the pot gives a better growth: cost ratio in the pots but the normal top dressing gives a better growth: cost ratio in the trays. For convenience a normal top dressing would be preferred.

A collaborative trial between the IFP Project and ACIAR testing the effect of seven fertiliser treatments on the growth of whitewood seedlings yielded no significant differences between treatments. Application per unit soil was much less than in the cordia fertiliser/ growth media trial although application per tree was greater, except for P. Possibly the amount of fertiliser applied was too small or there may have been sufficient nutrients in the soil already.

Fertiliser Research

The two trials established to test the effect of fertilisers on growth of mahogany and whitewood in cut lines showed no significant differences between treatments. This may have been due to the effect of heavy weed competition. Weeding was not as rigorous as usual due to the civil servant's strike of 1993/ 1994.

In the small trial established with *C. alliodora* to test the effect of "Fertimel" slow release fertiliser tablets on growth the fertilised trees had a greater mean height. However, the differences were not significant between the height of trees with the fertiliser and those with no fertiliser.

Site Investigations

A soil survey of the IFP leasehold by ODNRI showed there to be no constraints to growth of *C. alliodora* except possibly deficiency of K.

Species Testing

Several species have been found that are well adapted to the conditions on Santo. These are *C. alliodora*, *S. macrophylla*, *G. arborea*, *P. carribaea* and several of the indigenous species, notably *E. medullosum*, *A. macrophylla*, *F. flexuosa*, *I. bijuga* and *C. australe*.

Several of the indigenous species would not be considered for commercial plantings. The slow growth of *I. bijuga* and *C. australe* make planting of these species unattractive compared with some other high quality timber trees, notably *S. macrophylla*. Early results indicate *D. vitiense* and *D. amooroides* are also slow growing. At present markets for *C. australe* are poor and due to pipe rot in the bole being common, recovery is often not good. *F. flexuosa* has a role in future plantings as it has a highly durable heartwood and for poles can be cut much earlier than trees raised for timber. Initial growth at IFP has been reasonably fast although the twenty year old trees at Navota Farm have grown slowly. It is one of the most popular species in the IFP extension programme. Kauri (*A. macrophylla*) is another species worth planting. Initial growth is slow but the size of the old trees at Navota Farm and Monbiftek suggests that reasonable growth can be expected over the rotation. Timber of this species is valuable. Possibly the most promising native species is *E. medullosum*. This produces a pale non-durable wood that is much in demand, prices having doubled in the past four years. The only commercial plantings of any scale, by Melcoffee Sawmill have been of this species. Some doubts remain of its cyclone resistance, but initial growth is good, being a bit slower than the exotic, *S. macrophylla*.

Unfortunately, it may be that the trials at IFP and elsewhere in Vanuatu have not shown the full potential of the indigenous species. Some have been evaluated on the basis of performance of trees from seed collections of a few trees only.

Of the exotic species that have been tested for over twenty years, *S. macrophylla* is a species that should be given priority for future plantations for high quality timber. There is much experience of this species in other parts of the Pacific prone to cyclones; it was recommended for high quality timber production in a review of species for Western Samoa (Wilcox, 1991) following major damage to plantations there by Cyclone Ofa. Experience in Fiji has shown it to be relatively resistant to cyclone damage and disease. The species favoured in the past in Vanuatu, *C. alliodora* has unfortunately been shown to retain dead knots, lowering timber quality; to have poor markets in the Asia-Pacific Region; to produce profuse, weedy natural regeneration and to be susceptible to *Phellinus noxius*. This species is no longer planted.

For utility timber *G. arborea* is a favoured species with fast growth. Quality of the material in Vanuatu needs to be improved and much of it has poor stem form. The fast growing eucalypt, *E. deglupta* should not be planted due to poor resistance to cyclone damage. In Western Samoa 78% of the stands were written off due to damage by Cyclone Ofa (Wilcox, 1991). For Western Samoa *E. pellita* was suggested by Wilcox,(1991) as a substitute. This species has grown slowly relative to other eucalypts at Matevulu Pico and at a trial in Compartment 7 at IFP.

For pulp *G. arborea* may also be considered, as the eucalypts and especially the acacias tested have been shown to be susceptible to cyclone damage. However, the gmelina tends to have poor stem form which would increase transport and processing costs. The eucalypt, *E. urophylla* shows a tendency to produce strong upright shoots when snapped and thus may be the best of the eucalypts tested. It is also a fast grower. Of the seedlots tested Mount Lewotibi, 14532 would be a good choice. Two other eucalypts may also be considered *E. deglupta*, which has shown good performance at a range of sites and Queensland *E. grandis*, which grew well at the Matevulu Pico Site and at IFP Compartment 7. An earlier introduction of *E. grandis* from Transvaal, South Africa did not perform well.

Of the other species tested over a reasonably long period, *P. carribaea* may be suitable for drier sites, such as the west of Santo, if planting for utility timber was ever started there. On the wetter sites this species grows slower than much higher value timbers such as *S. macrophylla* and there seems little point in planting it. Species which may have potential but need further testing include *C. odorata*, *C. angustifolia*, *L. styraciflua* and *T. ivorensis*. Growth rates of these species is reasonable but insufficient numbers have been planted to determine cyclone resistance.

Recently introduced species with potential include *Octomeles sumatrana* a fast growing species from the Solomon Islands. Growth data for Santo is only for one year, but in Western Samoa, older trees showed good growth and good resistance to cyclone damage (Wilcox, 1991). Others include *Grevillea* *robusta* which has grown over two and a half metres in the first year at IFP and *Schizolobium parahybum*, some of which are over four metres high two years after planting.

For windbreaks the indigenous, *C. equisetifolia* would seem to be a good choice as a windbreak and is used as such on a coffee plantation on the Vanafo road.

Nut trees with potential include nangai (*C. indicum*) and Natapoa (*T. cattapa*).

Provenance Testing

Unfortunately, provenance testing in the past concentrated on *C. alliodora*. This species is unlikely to be planted extensively in the future. Seedlots that performed well in the trials included Turrialba and San Carlos from Costa Rica and Finca La Pineda and Nueva Guineau from Nicaragua. No marker provenance was put in all the trials which makes comparison between some impossible.

The 1988 *S. macrophylla* provenance trial has given some preliminary results on those provenances most suited to Santo conditions. Two hybrid seedlots, did not perform particularly well and can be rejected. Of the others survival of the Fiji and Vanuatu land races was good and they may be well suited for extension. However, growth was not as good as some of the other seedlots. Two seedlots gave a good compromise between survival and growth, one from Lancetilla, Honduras and one from Rio Piedras Botanic Garden, Puerto Rico.

Results from a *L. styraciflua* provenance trial suggested that this species was not well suited to Santo conditions, one seedlot failing completely. However, at Ipota on Erromango this species has grown well and shown good survival. A seedlot with good survival and not significantly different from those with larger mean dbh and height was from San Estaban, Honduras. However, more work needs to be undertaken before planting of this species can be recommended.

A provenance trial of *C. odorata*, including one seedlot of *C. angustifolia* yielded statistical differences in height but not diameter between seedlots. Growth has been good and this species has some potential. At Ipota it was badly damaged at Ipota and more testing is needed before it can be recommended. Best height, dbh and survival was a seedlot form Taulabe, Honduras. The height of this seedlot was not tested statistically against the other seedlots. Should growth continue to be good and cyclone resistance be shown to be good further assessment and analysis would be worthwhile. The trial should be systematically thinned in the near future.

There were inconclusive results only from a *P. carribaea* provenence trial at Monbiftek. No statistical differences were found between seedlots for dbh. This species is unlikely to be widely planted on Santo as it grows no more quickly than species which yield more valuable timber.

Establishment Research

Growth in line plantings was compared with growth in the open through a survey of two areas. It was found to be similar and line planting is a considerably cheaper method. A replicated trial would be useful to isolate the effect of the different clearance methods and other factors such as site variation.

A survey was conducted to examine the growth of *S. macrophylla* trees in five cover crops and no cover crop. None of the cover crops gave significantly better tree growth than the no cover crop treatment. From this survey it would appear that the expense of a cover crop cannot be justified by growth of trees alone. Again, a replicated trial would be useful to test the treatments to examine differences due to site variation and due to the treatments.

A replicated trial examined examined the effectiveness of cover crops in suppressing weeds and increasing growth of *C. alliodora.* The glyphosate weedkiller was found to be cheaper and more effective at reducing weed competition and increasing tree growth. Also it was found that the legume cover crop reduced growth of the trees compared with the no cover crop treatment.

Direct sowing of 5 indigenous species was tried with very poor results. This cheap establishment technique cannot be recommended in Vanuatu conditions because of the fast grwoth of competing vegetation. Even if the seed germinated the small seedling is likely top be smothered by weeds.

A further simple and cheap establishment method is the use of directly planted cuttings. One trial using large staves of *P. indicus* was completely unsuccessful. However, this technique for this species is used successfully for live fencing and it should not be dismissed.

Cattle have been used as a way of assisting land clearance and also to reduce weed cover in areas already planted. Some success has been achieved with *C. alliodora.* Cattle, at a stocking intensity of 1.5 cattle were introduced to an area of 17 month old trees in February 1992. No damage was done to the trees. Two and a half months later the trees were assessed agian and no damage was noted except to leaves and lower branches of some trees. Stocking was then reduced to 1 cattle per ha. Two months later all cattle removed as they had been breaking out of the enclosure. Later introductions of cattle into other areas have been less successful.

A weeding survey was conducted to examine the time to weed trees in open. A visual assessment showed that weed growth was worse in the open area than in the cut lines. Although weeding trees in cut lines was faster the difference was not significant.

Data from an unreplicated spacing trial of *C. alliodora* was examined. Even at 30 months spacing appeared to have an effect on tree growth.

Agroforestry Research

A trial established with mahogany in which plots of different crops were tested showed that tree growth was better in the intercropped plots than in plots with the normal weeding practices. This was thought to be due to the more intensive weeding in the agroforestry plots. Unfortunately, the data collected on crop production, is not sufficient to give an indication of any increase in growth of any of the crops, compared with planting without trees.

One other trial has been established in collaboration with IRCC, to examine coffee and cocoa growth in mahogany and cordia. Only a small number of coffee have been planted and it is hoped to have all the coffee planted in 1995.

Cyclone Damage Surveys

In February 1992, a month after Cyclone Betsy, a damage survey in the mahogany provenance trial, planted in March 1988, showed three seedlots to be relatively resistant to cyclone damage. These were a Vanuatu landrace, a Fijian landrace and a seedlot from Rio Piedras Botanic Garden, Puerto Rico (Secker Walker, 1993b). It may be that there has been some selection for resistance to wind damage in the Vanuatu and Fiji land races.

A further damage assessment of younger mahogany, between 35 and 41 weeks old was made and a relationship between ground cover type and damage was found. No relationship between age and damage was found. All the trees with snapped stems were found in the greenleaf cover crop and it was thought that this shorter vegetation may not have provided the support to the trees' stems of the other taller cover crops. Leaning trees were found only in the setaria and hamil cover crops, which are dense grass swards and it may be that the weight of the sward contributed to pushing the trees over (Secker Walker, 1993a).

Cyclone damage to mahogany was also investigated in the agroforestry plots. A higher proportion of damaged trees was found in the garden, yams and taro plots than in the silk and silk/kava plots. It was thought that the greater damage in the garden, yams and taro plots may have been due to the layout of these plots promoting eddies and turbulence (Secker Walker, 1993c).

Informal assessments have shown the exotic acacias, *A. crassicarpa* and *A. mangium* to be highly susceptible to damage by cyclones. Planting these species in Vanuatu cannot be recommended.

Pests and Diseases

As part of an ODA funded Project investigations were made into the susceptibility of several species planted on Vanuatu to the Brown Root Rot, *Phellinus noxius*. Cordia was found to be more susceptible than mahogany and about ten times more susceptible than *E. deglupta, E. urophylla, A. mangium, A. crassicarpa* and *G. arborea* (Ivory, 1993). Three other pathogens were identified on trees in Vanuatu during the study.

Several surveys of pests and diseases on whitewood have been conducted. All the trees at IFP are still less than two years old and it is not known what pest and pathogen problems will occur on older trees in plantation. In the wet season, a leaf fungus (*Phaeseptoria* sp) can be a problem, through reducing leaf area, not killing the tree. In the "dry" season moth caterpillars (*Cyfura bifuscata* or *Urapteroides astueniata*) seem to do most damage. Damage was more pronounced in one compartment than the others and this may be due to the trees being 18 to 21 months older. In March 1994 a new pest, a weevil was found attacking newly planted trees at the Melcoffee Sawmill plantings near Hog Harbour.

Two caterpillar defoliators of *Terminalia cattapa* were identified as the moth, *Roeselia lignifera* and the butterfly *Badamia exclamationis*. They had stripped nursery stock of much of its leaves, the mid rib only being left.

Seed pests of two indigenous trees have been identified; a wasp, *Syceurytoma* sp. on whitewood and a moth, *Agathiphaga vitiense* on kauri.

Permanent Sample Plots

Most of the permanemt sample plots are less than two years old and so conclusions cannot be drawn from the results. It is hoped that they will provide data which will add to the information gained from the trials. A review of the programme is needed soon to examine whether there are enough plots to obtain a sufficiently precise estimate of growth of the species and the compartment.

Preliminary results confirm the findings of the trials, with species like *E. urophylla, O. sumatrana, G. robusta, G. arborea, C. alliodora* and *S. macrophylla* showing good growth and survival.

Social Forestry Research

Several surveys have been conducted on peoples' uses and preferences for trees for particular purposes. This is ongoing, with two botanists from the Department of Forestry continuing to examine people's use of trees. There is now a considerable amount of information collected.

End Use Research

Cordia logs were sent to the Forestry Commission of New South Wales to be tested for peeling, for veneer and plywood. In general it peeled well and adhesive tests showed it to be suitable for plywood and there were no problems foreseen in combining it in composites with eucalypts. The plywood panels produced had a good finish and were not prone to warp. Samples sent to plywood distributors met with a favourable response (Wade, Ksiazek and Chapman, 1992).

A graveyard test for poles was established at Monbiftek in 1986 and 1987 by the Department of Forestry. Results showed that pressure treating with CCA was essential for the species tested and that the sap replacement treatment was not sufficient. None of the coconut tested was treated in any way and it was shown to have very poor durability.

Information on preferered species for traditional uses was extracted from the LSP Review by Jenks, (1992).

15.2 Recommendations for Future Work

Recommendations for priority areas for research for Phase II of the Project have been discussed in a separate document (Leslie, 1994). Priority areas identified from a survey included:

(i) Seed handling, particularly for indigenous species. There have been problems with poor or delayed germination of some of the indigenous species, notably *A. zizyphoides*, *A. macrophylla* and *E. medullosum*. These are species with potential and further work is required.

(ii) Nursery research, particularly for several indigenous species. Unfortunately, most nursery work concentrated oin methods of raidsing *C. alliodora*. Simple trials for optimum pot size and nursery nutrition are needed for species such as *S. macrophylla*, *E. medullosum* and *S. flexuosa*.

(iii) Establishment methods, particularly spacing. Replicated spacing trials are needed for promising exotic species, such as *S. macrophylla* and indigenous species such as *E. urophylla*, *S. flexuosa* and *E. medullosum*. These should concentrate on the cut line method of establishment as it would appear to be most financially attractive for large scale plantation establishement. Trials in open areas should also be established for *S. macrophylla* and *S. flexuosa* as these species are popular with smallholders and could be included in gardens.

(iv) Tree improvement including further species and provenence trials. Provenance triels should concentrate on species such as *E. medullosum* (several Vanuatu seedlots and also some from the Solomon Islands), *S. macrophylla* (Concentrating on those seedlots that are readily available from suppliers) and *G. arborea*.

(v) Agroforestry Techniques. Much of the work undertaken by IFP has concentrated on examining the way that crops affect tree growth and information on how trees affect crop growth is at present lacking.

Data on growth rates, returns and costs are also important to interest investors in forestry and also to enable comparison of plantation forestry with other land uses.

Should IFP become a Research Centre for the Department of Forestry it will be necessary to move trials off the IFP site. Trials must be established on sites representative of areas where tree planting is likely to occur in the future. These would include the areas where coconut is now planted and also possibly pasture. VANRIS, a geographical information system for Vanuatu could be used to identify representative sites.

There is a need to find other ways of informing the public and Foresters of research findings. Most Foresters have never read a Research Report. This includes those involved in extension. Regular field days, radio programmes and short articles in Bislama on important research findings might help.

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APPENDIX 1. SEED INFORMATION

LOCAL TREES: SEED COLLECTION & SOWING

SPECIES	SEED RIPE[1]	NO. PER KILO[2]	PRE-SOWING TREATMENT[3]	GERMINATION RATE[4]	1ST GERM.[4]	SOWING TECHNIQUES[5]
Bean tree *Castanospermum australe*	May - July.	22 - 27. Fresh seed.	None.	91 % Fresh seed. 50% after 3 months stored at 25°C	32-36 days	1 seed per pot, in large pots. Bury seed in soil to depth of 5 - 7cm (ht of seed).
Bisa *Adenanthera pavonina*	Oct.	Fresh seed.	None.			Scatter seeds on soil in tray. Cover with thin layer of fine soil. Transplant when 2 leaves.
Kauri *Agathis macrophylla*	Feb Mar Jun	4,900. Fresh seed[6].	None. Sow as soon as possible after collection.	45 - 50 % up to 1 - 2 weeks after collecting. Germin. falls rapidly after that.	8 - 10 days.	Sow in tray or ground. Stand seeds upright in soil. Just cover seeds with sand. Transplant when 2 leaves grown.
Milktree *Antiaris toxicaria*	Jun July Aug[7]	170-260. Fresh fruit. (1 seed/ fruit).	Soak in water for 1 day and one night.			1 seed per pot, in small pots. Stand seed on thin end and push 3 - 4 cm into soil. Transplant when 2 leaves.
Nakatambol *Dracontomelon vitiense*	Apr - Aug	500-806. (Av=599) Fresh pips[8].	Soak pips[8] overnight in 1:2 vinegar + water. Or soak overnight in water only.	38% vinegar soak. 18% water soak 15% no soak.	33 days[8]	Trays / open bed. Lay seeds (pips[8]) flat on soil and push $^1/_2$ cm into soil. Transplant when 2 leaves,
Namalaus *Garuga floribunda*	Jan Feb Mar	1,300 Fresh fruit	None			Sow in trays. Transplant when 2 leaves appear.

LOCAL TREES: SEED COLLECTION & SOWING

SPECIES	SEED RIPE[1]	No./KG[2]	PRE-SOW TREATMT[3]	GERMIN. RATE[4]	1st GERM.[4]	SOWING TECHNIQUES[5]
Namamau *Securinega flexuosa*	end Apr, May July	2,800 - 8,000 (Av= 5,100). Fresh fruit. c. 4 seeds per fruit	None		5 weeks	Rub berries together in hands and scatter seeds and crushed berries onto soil in tray or open bed. Shake thin layer of fine soil over seeds. Transplant when 2 leaves appear
Namarui *Acacia spirorbis*	Aug-Nov		None.			Scatter seeds onto 1:1 sand[9]+soil mix in tray. Shake thin layer sand[9] over seeds. Transplant when 2 leaves appear.
Nanara (Bluwota) *Pterocarpus indicus*	Jan - Mar	1,500-3,000 (Av=2,300). Air dry fruits. (c. 50% fruits contain 1 healthy seed)	None.			Sow in open bed or seed trays. Lay fruits flat or standing and push into soil by c. 1 $^1/_2$cm. Cover with thin layer of soil. Transplant when 2 leaves.
Nandau *Pommetia pinnata*	Apr July[1] o		None			Bury seed in soil to depth of c. 7cm (ht of seed). Transplant when 2 leaves.
Nangai *Canarium indicum*	Jul Aug Sep	35-100 (Av=50). Fresh fruit. (1 seed per fruit)	Crack seed coat with hammer			1 seed per large pot. Push seed into soil 3$^1/_2$ - 4cm deep. Transplant when 2 leaves. Shed leaves naturally in Jun/July.

LOCAL TREES: SEED COLLECTION & SOWING

SPECIES	SEED RIPE[1]	NO. PER KILO[2]	PRE-SOWING TREATMENT	GERMIN. RATE[4]	1ST GERMN[4]	SOWING TECHNIQUES[5]
Natapoa - wild *Terminalia sepicana*	Jul	180 Fresh fruit. (1 seed per fruit). 450 dry seeds/kg	None	35 - 40%	5 weeks	Sow in small pots, I per pot. Lie seed flat on soil and push 1 - 2 cm into soil.
Natapoa - edible *Terminalia catappa*	May Jun Jul	20 - 30 fresh fruit/kg. (1 seed per fruit)	Germin. was 9 days earlier when seed coat craked with hammer. Germ. rate not affected.	60 %	34 days with no pre-treat-ment	Sow in large pots, 1 seed per pot, under about 4 cm of soil.
Natora *Intsia bijuga*	May Jun	360 seed/kg				Sow in small pots. Stand seed upright on thin end and push down till under 2 - 3 cm soil.
Navasvas *Alphitonia zizphoides*	Aug - Sept	8,900 dry fruit/kg (c. 2 seeds per fruit)	Soak in water for at least 12 hours: improves germ. rate of old seeds (> 10 months old)		16 days (seed > 10 months old)	Sow in tray, cover with thin layer of fine soil. Transplant when 2 leaves appear.
Raintree[11] *Samanea saman*	Aug	193 dry fruit/kg (c. 1700 seeds in 1 kg of pods)				

SPECIES	SEED RIPE[1]	NO. PER KILO[2]	PRE-SOWING TREATMENT	GERMIN. RATE[4]	1ST GERMN[4]	SOWING TECHNIQUES[5]
Sandalwood *Santalum austro-caledonicum*	Nov Dec Jan May[11]	Average = 3900 (3300-4500). Dry seed.	1. Remove fruit flesh immediately after collection. 2. Air dry seed (10 days). 3. Chip seed coat off pointed end of seed using a sharp knife. 4. Soak overnight: - seeds just covered with 0.25 gm/l Gibberellic acid. 5. Wash in fungicide (eg Benlate) for 3 mins).			Sow in trays of sterilised well washed coarse coral or river sand. Press seeds into sand - half buried. Prepare pots with 50:50 mixture of sand with soil or peat. Plant cuttings or seeds of a host plant ([12]) into pot about 2 weeks before transplanting sandalwood seedling. Transplant sandalwood as soon as roots appear into the pot with the host plant.
Sea oak *Casuarina equeseti-folia*	Jan - Mar[13].		None			Sow in tray in mixture of soil and sand[9]. Cover thin layer of sand. Transplant when 2 leaves appear.
Stinkwood *Dysoxylum amooroides*	July - Oct	1400. Fresh seed.	None			
Whitewood *Endospermum medullosum*	Mar Apr May Jun Jul	9000 - 9600 Av=9100 Fresh fruit.	None	up to 35 % when fresh.[14]	4 - 6 weeks	Scatter seeds onto soil in tray or open bed. Shake a thin layer of soil over seeds.[15] Transplant when 2 leaves appear.

APPENDIX I. LOCAL TREES SEED COLLECTION & SOWING. NOTES

1. Seed ripening times are based on seed collections made in 1992-3 in Santo. Seeds of the same species may ripen at different times in different areas and on different islands. Even within the same area, weather (cyclones, drought) may affect seed ripening times in different years.

2. This gives the range of seeds, or fruit, per kilo found in a small sample of trees in Santo (up to around 15 trees or stands of trees for each species). The average, given in brackets, is the weighted average for the seed collection as a whole from these trees. For many species there is wide variation in the seed size between different trees of the same species, and even on the same tree.

3. Pre-sowing treatment. These are treatments such as soaking in water, or breaking the seed coat. Many of the treatments described are based on preliminary trials at the Santo IFP using small numbers (50 - 200) of seeds. "None" indicates that seeds can germinate without treatment and though treatments may have been tried, none has been found to improve germination rate.

4. Germination rates / 1st Germ ("1st Germ" is time from sowing to first seed germinating) : These figures are based on tests of a very small sample of seed (50 - 200 seeds) of each species (usually from 1 or 2 trees only). They are therefore very preliminary 'ball park' figures.

5. Sowing techniques: These are methods used at the Santo IFP nursery, but are not hard and fast rules.

6. Kauri seed is collected just before the cones open. Once the cones open, the seeds fly everywhere and are hard to find. Kauri seeds in Santo, Erromango and Aneityum are attacked by the parasite *Agathis vitiensis*, and will not grow. A good seed is hard when pressed between thumb and forefinger, whereas the larvae-affected seed is soft. Kauri planted in Efate are so far free from this pest, though planted trees at Monbiftek in Santo are parasitised.

7. Milktree probably fruits several times a year or all year round. It may be that some trees can be found fruiting at any time of year.

8. The hard dark brown 'seed' is the stone (pip) in the nakatambol fruit). 5 seeds are encased in each pip, though only 2 or 3 look large enough to grow. First germination at 21 days was in fresh untreated pips.

9. Well-washed beach sand or river sand.

10. April - July is the peak fruiting period for nandau, though it fruits throughout the year.

11. Sandalwood ripened in November and December in Dillon's Bay and Ipota, Erromango, and in January in Efate, and in May in Santo in 1992/3.

12. Host plants for Sandalwood. Sandalwood is a parasite and needs to grow attached to another plant (a 'host'). Most of the plants found to act as hosts are legumes - plants which put nitrogen into the soil. When sandalwood is young, it uses soft plants as hosts like *Alternathera* or *Desmodium spp*. Greenleaf desmodium (*Desmodium intortum*) and *Alternathera* are being tried at the IFP. Later, when planted out in the field, pigeon pea (*Cajanus cajan*) makes a good intermediate host, though the *Alternathera* or *Desmodium* will also act as host if planted out in the field. Finally, sandalwood needs a woody host - the most common one being namariu (*Acacia spirorbis*). More details on sandalwood production are given in 'Production of Sandalwood Trees in New Caledonia' by Jean-Paul Chauvin, Port Laguerre Forestry Seeding Section, New Caledonia (Revue Bois et Forets des Tropiques, N° 218, 4e trimestre 1988, p33-41.

13. Sea oak fruits are collected while still closed, ideally just before the cones open. The cones are kept inside and when they open it is easy to shake out the seed and collect it.

14. Depends partly on levels of infestation by a parasitic wasp found in all seed recorded from Santo. The wasp is *Syceurytoma spp.* Family : Eurytomidae. (Hymenopteran), described in 'The Insect Pests of Forest Plantation Trees in the Solomon Islands', by M. Bigger (1988) ODNRI, Central Ave, Chatham Maritime, Kent ME4 4TB, UK. Eggs must be laid in the young seed, and the larvae eats the seed as it grows. Many of the seeds contain only a wasp larvae inside, but they look the same as the seeds which will grow. Some seeds have a hole in them. These are empty and will not grow, because the young wasp has bored a hole in the seed coat and climbed out.

15. Whitewood seed was also sown directly on damp tissue paper with no covering and kept moist. None of these 200 seeds germinated.

APPENDIX 2 : ACIAR NUTRIENT RECIPES

Salt	mgsalt / kg soil	mg nutrient / kg soil		Total mg nutrient/ kg soil
Complete.				
KH_2PO_4	100	P 22.7	K 28.7	N 100
$NH_4\ NO_3$	280	N 100		P 22.7
K_2SO_4	140	K 62.9	S 25.8	K 91.6
$CaCl_2.2H_2O$	100	Ca 27.3	Cl 48.3	S 42.0
$MgSO_4.7H_2O$	80	Mg 8.0	S 10.4	Ca 27.3
$MnSO_4.7H_20$	15	Mn 3.7	S 2.1	Mg 8.0
$Zn\ SO_4.7H_20$	20	Zn 4.6	S 2.2	Mn 3.7
$Cu\ SO_4.5H_2O$	10	Cu 2.6	S 1.4	Zn 4.6
$H_3\ BO_3$	7	B 1.2		Cu 2.6
$Co\ SO_4.6H_2O$	0.5	Co 0.11	S 0.06	B 1.2
$Na_2\ Mo\ O_4.2H_2O$	0.4	Mo 0.16	Na 0.08	Co 0.11
Fe Na EDTA	20	Fe 3.0	Na 1.2	Mo 0.16
				Fe 3.0
				Changes
Complete minus N				N 0
delete $NH_4\ NO_3$				
Complete minus P				
delete $KH_2\ PO_4$				P 0
add KCl	55	K 28.8	Cl 25.8	K 28.8
				Cl 25.8
Complete minus K				
delete $KH_2\ PO_4$				
$K_2\ SO_4$				
add $Ca\ (H_2\ PO_4)2.2H_2O$*				K 0
	100	P 24.6	Ca 15.9	P 24.6
reduce $Ca\ Cl_2.2H_2O$	40	Ca 10.9		Ca 26.8
*added as powder				
Complete minus Ca				Ca 0
delete $Ca\ Cl_2.2H_2O$				
Complete minus S				
delete $K_2\ SO_4$				
$Mg\ SO_4$				S 0
add KCl	120	K 62.8		K 91.5
$Mg\ Cl_2.6\ H_2O$	70	Mg 8.4		Mg 8.4

Complete minus Mg		
delete $MgSO_4$		Mg 0
add Ca $SO_4.2H_2O$ 56	S 10.4 Ca 13	S 40.1
reduce Ca $Cl_2.2H_2O$ 50	Ca 13.7	Ca 26.7
Complete minus Zn		
delete Zn SO_4. 7H2O		Zn 0
Complete minus B		
delete H_3BO_3		B 0

Notes on Costs of Site Preparation and Weeding Table:

All prices 1991-3, Santo.
mds= mandays.
Skilled labour for cutting lines and clearing bush (using chainsaws) rated at 800vt/manday.
Weedkiller application rated at 1000 vt/manday.
Weeding labour rated at 540 vt/manday including supervisor costs.

Weeding costs per ha are usually not with the full stocking of trees, as there are always losses. In the early months, before beating up, losses will usually be greater.
Weeding for the first year was by daily rated labour in C1, C2, C5 and C10, and by labour on targets or contracts in C14, 15, and 18.

Cattle-Manual : Clearing first by grazing with cattle (100 head in 25 ha) to open up the area. Then manual cutting of all vegetation except large trees using bushknives, chainsaws and axes.

Bulldozer : D7 Caterpillar, costs about 10,000 vatu/hr, 1991-3 in Santo. Windrowing : the vegetation is pushed into lines by the buldozer, leaving exposed soil. Root rake: this is a large rake attached to be back of the bulldozer. After pushing vegetation away, the rake is dropped down and pulled through the soil forming a good tilth needed for successful legume germination and growth.

Roller Crusher: (Marden roller) - a bulldozer pushes over all vegetation except standing trees and pulls behind it a double drum roller which crushes the vegetation forming a mat of crushed branches and leaves which help to hold down weed regrowth. Compartment 14.3 was first logged, so that all the merchantable large trees were removed.

Cut lines: Lines are cut through the bush, 2m wide and at 10m spacing. Line cutting is done by hand (chainsaws, bushknives, axes) and the price partly depends on how many small trees are sited in the lines. The large trees are left standing. Contract labour was used in C18, but though this greatly reduced costs (to 3000 vt/ha), the quality was poor. Subsequently the lines had to be opened up again as the vegetation closed in where the lines had not been cut wide enough in the first place. This additional work was done by daily rated labour and had added 4.1 mds/ha 5 - 6 months after the original line cutting.

.... *continued overpage*

Mixed legume = cover crop as follows :	C5 & C10	C14.1 & 14.2
Greenleaf desmodium, *Desmodium intortum*	2.0 kg/ha	2.0 kg/ha
Desmodium ovalofolium	0.5 kg/ha	-
Cook Stylo, *Stylosanthes guianensis* cv. Cook	0.5 kg/ha	0.5 kg/ha
Verano Stylo, *Stylosanthes hamata* cv. Verano	0.5 kg/ha	-

Price of mixed legumes in C14.1 & 14.2 will be rather less than the 7,500 vt/ha in C5 & C10 as less legumes used per ha.

Glyphosate 360. (Roundup). Applied @ 2 litre of glyphosate per ha, though applied mixed with water (80ml glyphosate : 10 l water)

Ht growth rate : Height growth rate of mahogany (in C2 and C5) is the mean from randomly-located sample plots in unreplicated blocks. The variance in growth rate in the legume block was very large, so that some of the trees grew much more quickly than this, and some grew much more slowly.
Height growth rate of cordia in C10 with legumes compared to C10 with glyphosate treatment, are averages from a replicated trial.
Height growth rate from cordia in the cut lines in C10, is the mean from randomly-lcoated samples plots in an unreplicated block.

Tree planting in subcompartment 3 (C14.3 and 15.3) happened one month later than in subcompartments 1 & 2 (C14.1, 15.1, 14.2, 15.2)

Compartment 1: Daily rated labour, 1990.

APPENDIX 3

Santo IFP : Costs of Site Preparation and Subsequent Weeding

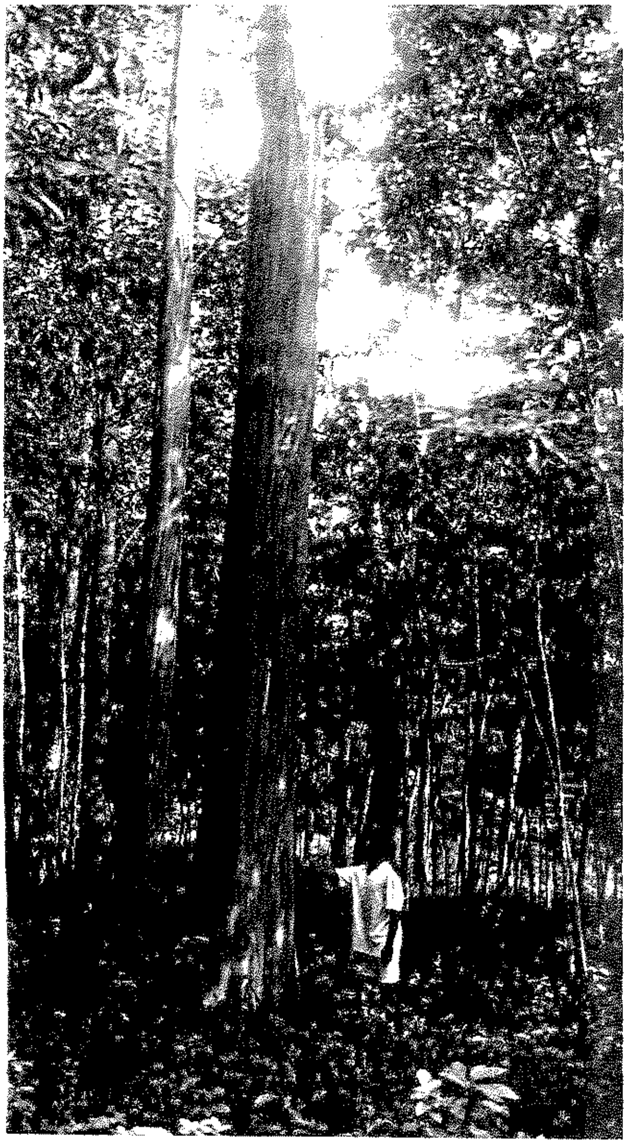
Land clearing Method	Cost/ha machine hrs, mds, vt	Site capture Method	Total Cost vt/ha	Tree species. Spacing	Weeding labour mds/ha/month. Age of weeding	Ht Growth Rate m/week. Age measured
C2 : Cattle-manual. Daily rated labour	3-6 mds 2400-4800 vt Excl. cattle	None	-	mahogany 5 x 5 m		3.02 m/wk (average) Age: 0-87wks
C1 : Cattle-manual. Daily rated labour	3-6 mds 2400-4800 vt Excl. cattle	None	-	cordia 5 x 5 m	1.48 mds, 0-8 mths. 1.03 mds, 8-12 mth	
C5 : Bulldozer, remove all trees, windrow.	9.2 hrs/ha 92,000 vt	Mixed legumes	7,500	mahogany 5 x 5 m	Info. not collected	2.97 m/wk av Age:0-85 wks
C10 Bulldozer + root rake, trees left standing.	3-4 hrs/ha 30-40,000 vt/ha	Mixed legumes	7,500	cordia 5 x 5 m	0.70 mds, Age:0-8 mth. 0.52 mds, Age:8-12 mth.	5.68 m/wk Age: 7-12 months
C10 Trial Bulldozer + root rake	3-4 hrs/ha 30-40,000 vt	Glyphosate weedkiller.	4,900	cordia 5 x 5 m	No weeding: 0-8 months.	8.00 m/wk 7-12 months
C14.1: Bulldozer + root rake, trees left.	3-4 hrs/ha 30-40,000 vt	Mixed legumes	rather less than 7,500	cordia 5 x 5 m	0.67 mds, 0-4.75 months	
C14.2: Bulldozer + root rake, trees left.	3-4 hrs/ha 30-40,000 vt	Mixed legumes	rather less than 7,500	cordia 5 x 5 m	1.71 mds, 0-4.75 months	
C14.3 : Roller crusher after logging.	2.2 hrs/ha 22,233 vt	None	0	cordia 5 x 5 m	1.76 mds, 0-4.75 months	
C18 Cut lines. Contract	7200 vt/ha	None	0	mixed 10 x 2 m	1.73 mds, 0-4.75 months	
C10 Cut lines. Daily rated	11.4 mds/ha 9120 vt/ha	None	0	cordia 10 x 2 m	Not available separately	

Appendix 4

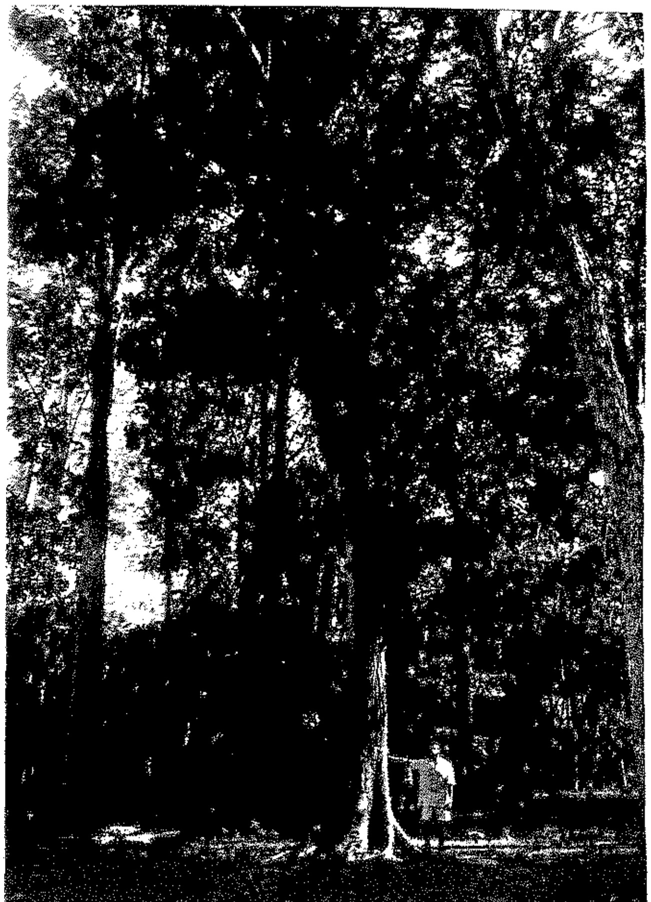
Bislama and Scientific Tree Names used in the Text.

Bisa	*Adenanthera pavonina*
Blackbean	*Castaneospermum australe*
Black palm	Not recorded
Bluwota	*Pterocarpus indicus*
Bredfrut	*Artocarpus atilis*
Burao	*Hibiscus tiliaceus*
Candlenut	*Aleurites mollucana*
Canoe tree	*Gyrocarpus americanus*
Cassis	*Leucanea leucocephala*
Combtree	*Pouteria linggensis*
Cordia	*Cordia alliodora*
Kauri	*Agathis macrophylla*
Milktree	*Antiaris toxicara*
Nabanga	Not recorded
Nakatambol	*Dracontomelon vitiense*
Namalu	Not recorded
Namambae	*Inocarpus fagiferus*
Namariu	*Acacia spirorbis*
Namatal	*Klienhovia hospita*
Namaumau	*Securinega flexuosa* (Syn. *Flueggia flexuosa*)
Nandao	*Pommetia pinnata*
Nandau	*Pommetia pinnata*
Nangai	*Canarium indicum*
Nakavika	*Syzygium malaccense*
Natapoa (kakae)	*Terminalia cattapa*
Natapoa	*Terminalia sepicana*
Natongtong	*Ceriops tagal, Avicennia marina, Rhizophera spp., Sonneratia spp.*
Natora	*Intsia bijuga*
Navasvas	*Alphitonia zizyphoides*
Navele	*Barringtonia edulis*
Navenwe	*Macaranga dioica*
Raintree	*Samanea saman*
Sandalwood	*Santalum austro-caledonicum*
Sea Oak	*Casuarina equisetifolia*
Stinkwood	*Dysoxylon amooroides*
Whitewood	*Endospermum medullosum*

Terminalia calamansanai (left) and Blackbean (right), both 21 years old at Monbiftek



Eucalyptus deglupta, 22 years old at Monbiftek



Mahogany, 23 years old at Navota Farm

Octomeles sumatrana, 1 year old at IFP.

Grevillea robusta, age 1 year at IFP.

Gmelina arborea, age 22 years at Monbiflek

Securinega flexuosa, age 23 years at Navota Farm. Slow growing but very durable