

Testing and Genetically- Improving Forest Trees for the Northern Territory

A report for the RIRDC/Land & Water Australia/FWPRDC
Joint Venture Agroforestry Program

RIRDC Project DNT27A



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ISBN 0 642 (RIRDC to assign)
ISSN 1440-6845

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Foreword

This project was initiated to provide an opportunity to develop farm forestry in the Northern Territory. The research undertaken is seen as an essential step in gathering information on the adaptability and potential growth rates of existing high quality forestry genotypes to a range of sites in the region. It has also enabled the selection of superior individuals for further breeding work and the establishment of genetic improvement facilities.

For this project, a logical staged approach for the rapid development of high-yielding forest tree varieties has been adopted.

This project was funded by the R&D Corporations RIRDC. This Corporation is funded principally by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Peter Core

Managing Director

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Acknowledgments

We owe thanks to Barry and Donna Keitel on whose property the initial taxa trial was established, for their support of the trial work. As well, we acknowledge funding from the RIRDC Joint Venture Agroforestry Program. We owe thanks to our collaborators at QFRI who contributed to the project with advice, supply of genetic material and trial design. The contributors with QRFI who deserve special thanks, include Dr D. Garth Nikles for his tireless efforts and mentoring, Mr Ken Robson for his assistance with initial concept and on-going support with design and collection of data in the field and Mr Nick Kelly for his contribution to trial lay-out and planting.

Thanks also goes to Dr David Lee for his design and layout of the African mahogany (*Khaya*) Clonal Seed Orchard and Seed Bank and supply of the Corymbia complex seed for the second taxa trial at Howard Springs.

Also thanks to NT DBIRD Farm staff for plant allocation and delivery, Dr Mark Hearnden, Biometrician for assistance with analysis, Yaruga nursery for supply of clonal material and thanks to Mr Bob Moore of Parks and Wildlife Commission of the NT for his contributions to the site at Howard Springs. Mr Jim Stuart and Ms Meghan Whitbread deserve thanks for the contributions they made at planting of the trials and subsequent measurements.

Abbreviations

AFFS	Agency for Food and Fibre Sciences
ATSC	Australian Tree Seed Centre
CQ	Central Coast
CSIRO	Commonwealth Scientific Industrial Research Organisation
DBHOB	Diameter at Breast Height Over Bank
GANT	Greening Australia – Northern Territory
MAR	Mean Annual Rainfall
MASL	Mean height Above Sea Level
NNW	North north West
NQ	North Queensland
NT	Northern Territory
NWQ	North West Queensland
OP	Open Pollinated
PNG	Papua New Guinea
QFRI	Queensland Forestry Research Institute
RCB	Randomised Complete Block
SO	Seed Orchard
SPA	Seed Production Area
SSO	Seedling Seed Orchard

Contents

FOREWORD	2
ACKNOWLEDGMENTS	3
ABBREVIATIONS	3
EXECUTIVE SUMMARY	6
1. INTRODUCTION	10
2. CHAPTER TWO - TAXA TRIAL PLANTED NEAR BERRY SPRINGS, NT	13
2.1 INTRODUCTION	13
2.2 OBJECTIVES	13
2.3 METHODOLOGY	13
2.4 RESULTS.....	20
2.6 IMPLICATIONS	28
2.7 RECOMMENDATIONS FOR FUTURE MANAGEMENT	28
3. CHAPTER THREE - THE <i>E. PELLITA</i> SEED PRODUCTION AREA PLANTED AT HOWARD SPRINGS IN DECEMBER, 2000	29
3.1 INTRODUCTION	29
3.2 OBJECTIVES	30
3.3 METHODOLOGY	30
3.4 RESULTS.....	34
3.5 DISCUSSION OF RESULTS.....	36
3.6 IMPLICATIONS	36
3.7 RECOMMENDATIONS FOR FUTURE MANAGEMENT	37
4. CHAPTER FOUR - THE CLONAL SEED ORCHARD AND CLONE CONSERVATION BANK OF <i>KHAYA SENEGALENSIS</i> PLANTED AT HOWARD SPRINGS AND BERRIMAH RESPECTIVELY IN DECEMBER 2001	38
4.1 INTRODUCTION	38
4.2 OBJECTIVES	39
4.3 METHODOLOGY	39
4.5 DISCUSSION OF RESULTS.....	46
4.6 IMPLICATIONS	46
4.7 RECOMMENDATIONS FOR FUTURE MANAGEMENT	46
5. CHAPTER FIVE - TAXA TRIAL PLANTED AT HOWARD SPRINGS IN 2002/2003	48
5.1 INTRODUCTION	48
5.2 OBJECTIVES	48
5.3 METHODOLOGY	48
5.4 RESULTS.....	57
5.6 IMPLICATIONS	57
5.7 RECOMMENDATIONS FOR FUTURE MANAGEMENT	58
6. APPENDICES	59
APPENDICES – CHAPTER TWO	59
APPENDIX 2.1	59
APPENDIX 2.2	61
APPENDIX 2.3	62
APPENDICES – CHAPTER THREE	63
APPENDIX 3.1	63
APPENDIX 3.2	64
APPENDIX 3.3	65
APPENDIX 3.4	66
APPENDIX 3.5	67
APPENDIX 3.6	68

APPENDICES – CHAPTER FOUR	69
APPENDIX 4.1	69
APPENDIX 4.2	70
APPENDIX 4.3	72
APPENDIX 4.4	73
APPENDICES – CHAPTER FIVE	74
APPENDIX 5.1	74
APPENDIX 5.2	74
APPENDIX 5.3	75
APPENDIX 5.4	76
APPENDIX 5.5	77
7. REFERENCES	78

Executive Summary

In the Northern Territory climatic factors and soil deficiencies have generally prescribed a low level of natural productivity associated with vegetation. Native forest is made up of tropical Eucalypts and Acacias that have low productivity and therefore precluded any major timber industry development. The only significant harvesting of the natural resource were during times of peak demand posed by historical events such as the early development of Palmerston, later named Darwin, the overland telegraph line and defence infrastructure from 1942- 45 (Bateman, 1955).

Much of northern Australia's agricultural environment is comprised of pastures in woodland ecosystems, ie: savannas. This is markedly different to the situation in southern Australia where much of the agricultural landscape has been cleared of trees (Turvey and Larson, 2001).

The climate of the Top End of the NT has a dry monsoon climate. The average annual rainfall is highest at Melville Island where up to 1800mm occurs. This figure decreases by about 240 mm for each 100 km in a south-easterly direction (Lacey, 1979). Rainfall is markedly seasonal, with 95% being within the period November to April. The greater part of the rainfall results from storm activity, but heavy falls may also be associated with widespread tropical depressions. The mean monthly maximum temperature is within the range 30°C (dry season) to 34°C (wet season) and the corresponding variation in mean monthly minimum is greater (19-25°C). Mean monthly relative humidity changes from moderately high (62%) to high (80%) from the dry season to the wet.

Identification and genetic development of commercial species and provenances for agroforestry in northern Australia is a key priority for the Joint Venture Agroforestry program. A recent analysis identified that there is considerable potential for agroforestry in the NT (Applegate, 1997). This analysis also indicated that genetic development and testing of key species to be a major research priority to support the development of farm forestry in the region.

This project has undertaken to test the suitability of important genotypes of Acacias, Eucalypts and other potentially useful hardwood species and intends to continue their genetic development by establishing testing facilities on a range of sites in the NT and by further development of improvement facilities in north Queensland. The species and provenances that have been selected are most likely to perform well on suitable sites in the NT as obtained from previous work undertaken by QFRI in collaboration with the Australian Tree Seed Centre and the NT Conservation Commission.

For this project, a logical staged approach for the rapid development of high-yielding forest tree varieties has been adopted. The stages comprise: parallel testing of "best bet" taxa (species, provenances and hybrids); development of commercial varieties matched to sites, from the superior taxa; infusion of new genetic material including various locally-produced hybrids; and on-going breeding for refinement of superior varieties.

The main components of the strategy for the initial stage of the project are:

- A series of trials spread across key regions established in the 1800 mm MAR zone in the Darwin region of the NT. These replicated trials compared imported eucalypt hybrids and best bet local species as well as dry zone exotic hardwoods.
- Superior hybrid trees identified in trials will be propagated clonally for further testing.
- Establishment of Seed Production Areas and Clonal Seed Orchards of the most genetically superior material currently available for use in the Northern Territory that aims to develop sources of seed and vegetative material suited to the particular environment.

The Queensland Forest Research Institute (QFRI) has undertaken a hybrid eucalypt development program to increase knowledge on suitable fast growing, marketable dryland species to extend forestry into marginal sites including the Northern Territory. Ongoing observation and assessment of seedlings planted in these series of trials for survival, stress tolerance, vigour, and marketability will enable QFRI to increase its taxa-site data base providing for the establishment of commercial forestry over large areas, previously non viable, including the Northern Territory. The testing of pure species taxa is important for comparing their growth and survival to that of the performances of the hybrid species. This will also provide growth performance data for the provenances of tested dryland species.

This paper presents:

- 3-year results for the 'Dryland taxa trial in the Northern Territory',
- the 'Eucalyptus pellita Provenance Seedling Seed Orchard (PSSO),'
- two years of results for the 'Khaya senegalensis (African mahogany) Clonal Seed Orchard' establishment
- The first year's results for the second dryland taxa trial established at Howard Springs in the 2002-03 wet season.

The major components of the project were the establishment of species/provenance (taxa) evaluation trials and the genetic improvement facilities for *E. pellita* and *K. senegalensis*. The first of the taxa trials was established on private property approximately 45 kms southwest of Darwin in the 2000-01 wet season. Within this trial were 32 entry numbers allocated to 8 treatments or taxa groups in a randomised complete block design with 4 replications. The trial was planted and fertilised in December 2000 and measures have been taken in April of each year subsequent to planting. The most recent results of April 2003 indicate large variation in the data especially with regard to height measures and is not abnormal with the variety of species tested. Although it is early in the life of the trial and judgement of the best performing species and provenances would be premature at this early stage, it is possible to make some assessment on the growth performance and survival of individual entries. The poorer performing entries are most notable (although few) as their persistency was very low or non-existent after only 28 months and susceptibility to insect damage was evident. The best performing species were of no surprise, with the fast growing tropical Acacias, the *E. camaldulensis* from a Thailand seed orchard and fast growing exotic, *P. macrocarpus* performing the best. An interesting aspect is the relatively good performance of the *E. grandis x camaldulensis* hybrid clones (although they have been attacked by insects) and the *E. urophylla x pellita* hybrids especially when compared to the *E. urophylla x grandis* hybrids that have also suffered from insect damage and have not persisted well.

In the same wet season, the *E. pellita* Seedling Production Area was established on crown land at Howard Springs, 20 km south east of Darwin. The species does not naturally occur in the NT but has performed well in trials planted on Melville Island (NT) in 1992 and in CSIRO research plantings of Papua New Guinea (PNG) provenances also on Melville Island in 1989, (Harwood, 1998). As there are uncertainties about the long-term maintenance of the Melville Island plantings and those in north Queensland, there was a perceived need to develop a land race adapted to the Top End of the NT. It was regarded as important to establish a similar facility on the NT mainland of this very promising species.

The composition of the *E. pellita* SPA was made up of 3 provenances from natural stands in PNG and open pollinated bulked seed from phenotypically-superior trees selected in the Melville Island provenance-progeny trial (Harwood et al. 1997a). As the number of seedlots was small, a randomised complete block (RCB) was used. Each of the 36 replicates comprised 6 rows x 16 trees, 2 rows each for the Kiriwo and Goe provenances and 1 row each for Serisa and Melville Island provenances, randomly allocated within each block.

Survival and growth have been best for the Melville Island provenance as could be expected on the basis it is less likely to exhibit a degree of neighbourhood in-breeding than the natural provenances due to the mixture of provenances in the Melville Island SSO and because the seed parents were selected for phenotypic superiority and overall adaptability to the monsoonal tropics of Melville Island. (Nikles, 2000).

It is anticipated that after the final culling of the poorer performing trees and the final thinning down to the recommended 200 trees per hectare, the SPA can be expected to fulfil its planned function successfully.

In the 2001-02 wet season the clonal seed orchard (CSO) and clonal conservation bank (CCB) of *Khaya senegalensis* were established at Howard Springs and Berrimah Farm respectively. This is the first time that genetic improvement facilities have been established for this very promising species in northern Australia. The source of genetic material for the facility was from the Gunn Point provenance trials that were established some 30 years ago by CSIRO, beginning in the 1970-71 wet season and continuing for 3 years. Two other evaluations of this species were also planted on Melville Island but were not screened for this project. Within the 3 provenance trials that were screened for selection of superior trees, there was 20 provenances (18 from African countries and 2 from New Caledonia, ex Ivory Coast) included in the CSO. Two additional trees with outstanding characteristics, but of unknown origin were chosen from Berrimah Farm to be included. The design for the CSO and CCB was a non-blocked, permuted neighbourhood design for 96 clones was used for both facilities.

The computer based design is aimed to maximise opportunity for crossing between clones. Originally the method of further propagating the select trees from the provenance screening was to be from seed collected off the superior trees. This was not possible for a number of reasons, including the fact that; many of the select trees were not seeding when visits were made to the site, seed that was collected gave zero germination, the seed that was set tended to occur near the tops of the trees and the provenance trials had not been thinned so poorer inferior trees still potentially had input to the seed set. For these reasons the CSO approach was preferred to a Seedling Seed Orchard (SSO) and would be expected to flower earlier than a SSO.

Collection of suitable scion material began in July of 2001 with the aim of selecting four trees per provenance and then to obtain 6 ramets per ortet that would provide 4 of each clone for the CSO and 2 of each for the clonal seed bank. Grafting of this species was also a first for this project and a variety of techniques were tried initially until it was decided that the 'top cleft' method was chosen as the best and also the quickest to employ. In all, 850 grafts were made with an overall success rate of 85%. The sites were planted out with the clones from the 10 –13th December 2001. Losses were very few and where they occurred, the vacant position was replanted either with a ramet of the same clone or the best clone of the same provenance from the left over grafts that were kept in reserve. The establishment of both the CSO and CCB has been very successful and it is highly likely that the objectives of the work will be achieved. As a result of the successful establishment, when the trees begin to set seed, farm forestry and industry stakeholders in the NT (and possibly other regions in northern Australia) can expect the availability of CSO seed that will be suitable for local plantings. In addition there is a sound base from which to undertake a genetic improvement program. This could include: recurrent selection for general combining ability, initially using open-pollinated progeny trials from seed of the orchard clones; and clonal testing from forward selections in progeny trials with deployment via clonal forestry. Therefore the availability of genetically-improved seed in the near future as a result of this sub-project could have a significant impact on forestry industry development in the NT and possibly other parts of northern Australia.

The second of the taxa trials was established over two days, on 31/12/02 and 2/1/03 on government land at the Howard Springs site adjacent to the *E. pellita* SPA. The trials design consisted of 8 treatments with 4 replications. An individual tree application (ITA) of 200g of NPK fertiliser 6:14:14.2 was applied on 6/1/03. Superimposed on top of this in replications 1 and 3 was an application of agricultural lime at a rate of 3858 kg/ha applied into the deep ripped lines before planting. This rate was calculated so as to bring the soil optimum calcium level to 600ppm.

Overall the survival at the April measurement (age 4 months) was good except for *E. argophloia* (17%) and the Corimbia hybrid complex (67%). The two outstanding species for height growth were *A. crassicarpa* (mean ht 148.5cm) from the Fiji seed orchard, and *Pterocarpus indicus* (mean 150cm). Since the April measure there has been some losses to *Mastotermes darwinensis* (Giant termite) and a baiting program has commenced. The *E. pellita* SPA had similar termite problems, but appears to have been over come after a concentrated baiting program.

As a result of the successful work undertaken within this project and the on-going maintenance and development of the breeding/improvement facilities established at Howard Springs, Berrimah Farm and private property at Darwin River, the Northern Territory is in a good position to become self sufficient in producing plantation tree species and provenances suited to the environment of the Top End.

1. Introduction

Timber harvesting by Europeans has been carried out in the NT since the mid 19th century. In general, native species suitable for timber production were scarce, the timber hard, heavy and difficult to work, and the trees often with high defect due to termites. As termites less frequently attacked native cypress pine (*Callitris intratropica*), this species was accepted for a number of applications. Small timber felling and processing operations with this species commenced in the 1870's (Bateman, 1955). By 1953, the eight sawmills in the NT were cutting in total less than 3,500m³ per annum. This low cut was due to the scattered nature of the stands, the long haulage distance, difficulties of access and lack of suitable labour (Lacey, 1979).

In the NT climatic factors (long dry season, periodic cyclones), frequent wild fires and soil textural and nutrient deficiencies have generally prescribed a low level of productivity of the native forests (Galvin, 1973). A small population base and great distances from most markets have also been responsible for a lack of intensive agricultural pursuits (with the exception of cattle raising) and limited development of forest industries. The Northern Territory accounts for 17.5% of the national land area but less than 1% of the population. Of that land area, more than half is granted aboriginal land (Lacey 1979).

Despite the difficulties mentioned above, and in view of the generally high cost of importing timber, some potential for plantation production in the region was seen. Thus, from 1950 site suitability surveys and testing on a wide range of tree species for plantation potential was undertaken. Testing to find the best species to grow in any commercial plantations in the region started in 1960 and by 1976 over 300 species had been tried (Cracium, 1978). A number of the more promising species had further work done to refine the nursery and establishment techniques; as well, provenance and/or progeny testing were undertaken with several species. Due to a lack of resources or to deliberately allow expression of genetic potential, many of the plots remain unthinned and results from them do not indicate species potential under good silviculture. With the value of hindsight, and from the results of more recent trials that were better managed, there is no doubt that, for many species, tree growth and stem quality of retained trees could now be significantly improved through better nutrition and appropriate silvicultural management (Haines, 1986).

The two main species that were established at industrial-plantation level were the native Cypress pine and the exotic Honduras Caribbean Pine (*Pinus caribaea* var. *hondurensis*) both species almost wholly on Melville Is.

Nutritional studies with Caribbean Pine showed benefits from the addition of nitrogen, phosphorus and sulfur on the soils most likely to be used for plantation development. The most suitable sites were found to be on Melville Island. (Haines, 1986). A Commonwealth-funded planting program during the 1960's and 70's resulted in establishment of about 4,200 ha of Cypress and Honduras Caribbean pines of reasonable quality, although Cypress was very slow growing. An additional 1,200 ha of these species was established on the mainland. (Haines 1986)

From the mid-1980's to 1995 there was a lack of interest in production forestry in the NT by local and federal management agencies. Recently there has been greater interest from local authorities and funds from the Federal Farm Forestry Program were used to employ a farm forestry development officer and to undertake a feasibility study of farm forestry (Applegate 1997). There has also been an increasing level of interest and activity in the region from the private sector. The feasibility study identified four areas on the mainland of the Top End with suitable soils and climate for farm forestry. Possible markets for farm forestry products included construction grade plywood and sawn timber for local and export markets and woodchips for export. The Applegate feasibility study revealed that research requirements for the successful development of farm forestry included further species trials for species-site matching and tree improvement activities with a range of species, processing and utilisation research and land capability assessments.

Following on from the feasibility study, indicating potential for farm forestry activities in the four specific agricultural regions of the Top End of the Northern Territory, funding was provided through the Natural Heritage Trust for the Top End Regional Tropical hardwood Forestry Project. The project aim was to encourage incorporation of farm forestry on cleared agricultural land in the Top End region to promote wood and non-wood production and to integrate it with other farming activities. The means to achieve this was to establish 24 x 1 hectare sites on a range of soil types across the four main agricultural sub-regions of the Top End of the NT. The objective was to identify species suitability to soil types and conditions, and/or eliminate species with low compatibility to certain soil types or conditions. As a result of the 3-year project and subsequent analysis, four 'best bet' species/provenances were identified for further evaluation in partnership with industry to establish a large scale commercial farm forestry planting. This further evaluation is designed to facilitate fine tuning of species / provenance performance and silvicultural requirements for optimum production. Of the four identified species from the trial work, two have been identified for breeding and improvement work in this RIRDC project. The two are African mahogany (*Khaya senegalensis*) and Red mahogany (*Eucalyptus pellita*) that have been established in a clonal seed orchard and seed production area respectively. They are reported on in chapters 3 and 4 of this report.

The Department of Primary Industry and Fisheries, NT, (now Dept of Business Industry and Resource Development, DBIRD) in association with Queensland Forestry Research Institute entered into a collaborative research project funded by RIRDC in 1999. This project is titled "Species testing and genetic improvement of forest trees for the Northern Territory". The project proponents took note of:

- a) the ongoing promise of *Khaya senegalensis* in the NT, the unique collection of germ plasm of this species at Gunn Point and elsewhere in the NT that was at risk, and the potential for genetic improvement of the species;
- b) work QFRI (in collaboration with the Australian Tree Seed Centre of CSIRO and the NT Conservation Commission) had been undertaking in the early 1990s on genetic conservation and improvement of a range of *Acacia* and a few *Eucalyptus* species, by establishing joint project facilities in north Queensland and Melville Island in the NT. These facilities (seedling and clonal seed orchards, clonal testing and some hybridising facilities) have been based on seed collections from difficult to collect places in northern Australia, PNG, Irian Jaya and other islands in the Indonesian archipelago (Harwood et al. 1994). Many of these genotypes have out performed local north Queensland provenances in trial plantings in north Queensland and overseas. These genotypes are therefore likely to perform well on suitable sites in the NT and they are likely to be the most genetically superior material currently available for trial. (Nikles, 2000) This project provided for the testing of these improved genotypes of a number of key species and other potentially useful hardwood species on a range of sites in the region. This has also allowed staff working on farm forestry in the region to take advantage of the fruits of the work of the cooperative relationship between QFRI and CSIRO.

Many species of eucalypts have been tested in the NT and most suffered from drought and insect attack. Among a few exceptional species, *Eucalyptus pellita* has shown promise, especially in tests planted on Melville Is in 1992, of adaptability and good growth to 3.2 yr (Harwood et al., 1997a). The species has also shown good growth and form in the NHT Farm Forestry plantings under taken in the three planting seasons between 1999 and 2001 across the Top End of the NT (Clark, 2003 - Draft Final Report) referred to above.

It is well known that forest tree species such as *E. pellita*, with demonstrated genetic variation at the levels of provenance and family-within-provenance (Harwood et al. 1997a) and much phenotypic variation within families, can be improved for yield, tree quality, wood properties and other economic traits by means of tree breeding practices (Eldridge et al. 1993). Thus, genetically-improved planting stock can contribute to the profitability of plantation enterprises. Therefore, it is important to develop secure seed sources and initiate tree improvement with *E. pellita* in the NT.

There are a number of prospective growers in the NT and interstate who are keen to plant *K. senegalensis*, especially if genetically-improved planting stock is developed. The increasing interest in the species from commercial entities and farm foresters across the tropical north of Australia, and the clear need (pointed out by Dr D Garth Nikles in July, 2000 during a project establishment visit) to conserve and improve the unique genetic resource held in the NT, prompted the then NT DPIF Forestry Section to follow Dr Nikles' advice and establish a gene conservation bank and a clonal seed orchard on more secure sites closer to Darwin.

The project aimed to identify gaps in past and other current work, and advance progress towards the achievement of viable farm forestry in the Top End of the NT. Consequently, it was considered that the following further work was needed under an RIRDC project:

- a) Ch 2; The taxa trial planted near Berry Springs, Darwin River in December, 2000
- b) Ch 3; The *E. pellita* seed production area planted at Howard springs in December 2000
- c) Ch 4; The clonal seed orchard and clone conservation bank of *Khaya senegalensis* planted at Howard Springs and Berrimah respectively in December, 2001
- d) Ch 5, The taxa trial planted at Howard Springs in 2002/2003.

2. Chapter Two - Taxa Trial planted near Berry Springs, NT

2.1 Introduction

In the Northern Territory interest in establishing hardwood plantation has increased as there are predicted increasing demands for hardwood timbers, and supply from native forests is diminishing. Further, the land available for establishing hardwood plantations in the tropics is the subcoastal belt with 1000-1800 MAR where the potential for growing millions of hectares of hardwood species is available. However, there are very few trials evaluating the potential of taxa and matching taxa to specific sites in tropical northern Australia. Overseas, large viable plantation estates have been developed on similar marginal lands using hardy, high yielding eucalypt hybrids (Eldridge *et al.* 1993). Applegate (1997) also highlights that the lack of improved germplasm is one of the impediments to farm forestry in the Northern Territory. This project will capitalise on the 13 years of genetic improvement work collaboratively undertaken by the NT Conservation Commission, AFFS Forestry Research (formerly the Queensland Forestry Research Institute) and the CSIRO's Australian Tree Seed Centre. This collaborative improvement program focussed on improving tropical *Acacia* and *Eucalypt* species, by establishing joint project in facilities in north Queensland and on Melville Island, NT. These facilities (seedling and clonal seed orchards, clonal testing and some hybridising facilities) have been based on seed collections from difficult to collect places in northern Australia, Papua New Guinea, West Irian and other islands in the Indonesian archipelago (Harwood *et al.* 1994). Many of these genotypes have outperformed local north Queensland provenances in trial plantings in north Queensland and overseas. These genotypes are therefore likely to perform well on suitable sites in the Northern Territory and they are likely to be the most genetically superior material currently available for trials. This study aims to compare the site suitability of a range of eucalypt and *Acacia* species, provenances and hybrids in the 1000-1800 mm MAR zone of tropical north Australia. This will enable staff working on farm forestry in the Northern Territory to take advantage of the achievements of the cooperative relationship between AFFS FR and CSIRO.

2.2 Objectives

- To assess and compare the growth of a number of 'best bet' dryland varieties.
- To observe and assess the growth and variation of inter-specific eucalypt hybrids.
- To compare the growth of hybrid seedlings with pure species eucalypt seedlings and a range of "best bet" dryland species.

2.3 Methodology

The methodology used for this project is a logical, staged approach for the rapid development of high yielding forest tree varieties. The stages comprise: parallel testing of 'best bet' taxa (species, provenances and hybrids); development of commercial varieties matched to sites, from the superior taxa; infusion of new genetic material including various locally produced hybrids; and on-going breeding for refinement of superior varieties.

Specifically this project targets the first component testing of above, testing ‘best bet’ taxa. This has several elements:

- A replicated trial was established to compare imported eucalypt hybrids and best bet local species and several previously untested dry zone exotic hardwoods. This trial was established on land supplied by our partners as their in kind contribution to the project.
- This experiment had excellent silviculture with maintenance of weed free conditions in the first year.
- In the first year trees were measured (by AFFS FR and NT research staff) at six and 12 month. Subsequent measures are planned yearly intervals for four years. Data was entered directly into Husky Hunter hand held field computers, and analysed using appropriate statistical packages.
- Superior hybrid trees identified in trials will be propagated clonally for further testing.

Research findings will be published in scientific journals and transferred to the local communities through field days and newspapers articles.

Location

Berry Springs, private property of Mr Barry Keitel, trading as “Synden Park”, approximately 45 kms south west of Darwin.

Original Vegetation

The site was originally cleared in 1990 of native open woodland including *E. tetradonta*, *E. polycarpa* and *E. miniata*. Main grasses on the site, *Imperata cylindrica*, *Sorghum intrans* and *Chrysopogan fallax* and the introduced *Pennisetum polystachion* and *P. pedicellatum*. A large number of introduced species have volunteered in the paddock since clearing including; *Aeschynomene americana*, *Hyptis suaveolens*, *sida acuta* and *Cassia rotundifolia*.

Soil

Red, Kandosol (Isbell 1996) Gravelly massive earths, shallow to moderately deep. See appendices A and B for a comprehensive description of the soil and results of chemical analyses of samples.

Aspect

Flat with little or no undulation

Elevation

Approximately 50 m.a.s.l

AMG COORDINATES	8582750 N	Latitude 12° 43" S
	721750 E	Longitude 131° 02" E

Climate Data for 2000 and 2001

Table 2.1 Rainfall for Synden Park and temperatures for Darwin Airport (45kms NNW) What about average data as a comparison?

2000	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Max (C ⁰)	33.4	34.0	33.0	33.3	33.3	32.8	32.4	35.3	35.9	35.8	35.4	33.5
Min (C ⁰)	22.2	22.4	21.8	22.5	15.9	12.5	15.7	16.9	19.8	19.0	22.8	24.0
Rain (mm)	295	432	460	224	30	3	0.0	0.0	0.0	126	158	332
Average Rainfall 1996-2001	461.8	418.2	365.2	124.4	7	0.8	0.0	5.4	3.6	143.2	163	410.4
2001	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec
Max (C ⁰)	33.5	34.1	32.8	34.6	34.0	33.6	33.2	33.5	36.6	35.7	35.9	34.5
Min (C ⁰)	22.4	22.5	22.5	21.7	17.1	18.4	15.6	15.3	19.2	22.1	22.0	22.8
Rainfall	349	453	389	79	0.0	0.0	4.0	0.0	0.0	89	239	171

Site Preparation

The entire site was slashed in October and November 2000 and six large trees were removed by front-end loader to facilitate trial design. Cultivation consisted of deep ripping lines and mounding at 4.0 metre intervals was done on 5/12/00. Marking out of the planting sites was undertaken during December 2000. No herbicide was applied prior to planting as the site had become too wet for machinery. Follow up weed control etc can be seen in the 'Performance table' attachment.

Genetic Material

Eight taxa treatments were established in the replicated trial. These treatments are based on taxa that were thought to have potential for the low rainfall zone around Darwin. Specifically these taxa treatments comprise:

Eucalyptus pellita

This species was established on Melville Is. in 1989, 1992 and recent plantings, and in the Darwin region in farm forestry planting, over the last few years. It is possibly the most promising eucalypt species, with fast growth, good form, fungal resistance and some drought tolerance. Planted provenances:

- Melville Island seed orchard bulk (19718)¹
- Natural stand PNG (18199)
- QLD SSO (5203)

Acacia crassicarpa

This acacia has been planted in several trials both on Melville Is (since 1992) and the mainland since 1996. It has shown good growth and wind firmness. On some sites it is comparable to *A. mangium*, but most plantings show better growth and resistance to butt sweep. Timber quality is similar to *A. mangium* and although suited as a pulping species can be used for heavy grade furniture, flooring etc. Planted provenances:

- Fiji Seed orchard bulk (20003)
- Natural stand PNG (19731)

¹Numbers in brackets refer to seedlots obtained from the Queensland DPI Forestry Tree Seed Centre

Acacia mangium

Planted in trials in the 1980s-1990s and now in large-scale plantations on Melville Island, this acacia can, surprisingly, tolerate the long dry season and still maintain good yearly growth increment. Wood is predominantly used for pulp but can be utilised for other uses. Planted provenances:

- PNG ex QLD SSO (10204)

E. camaldulensis

This species has the widest geographical range of any eucalypt. It is tolerant to drought and high temperatures. It naturally occurs on a range of soil types. Timber is construction grade but can be used for poles and furniture. Planted provenances:

- Katherine (10537)
- Thailand S.O (20383)

Other potential eucalypts

E. cloeziana

This species is a very desirable timber tree and is widely planted in wetter areas in southern Queensland (> 1000mm). However there are several provenances that occur in low rainfall (<700 mm) regions. It will grow well in poor shallow soils of moderate to low fertility. Planted provenances:

- Herberton , NQ (137)
- Koorboora (West of Petford, NQ) (10682)

C. citriodora subsp. Citriodora

Occurs in drier regions of north eastern and western Queensland on a variety of soils but commonly on poor gravelly soils. Has good timber qualities and is used for construction, framing, flooring and casing. Planted provenances:

- Hughenden, NWQ (11148)
- Glenden, CQ (10895)

E. tetradonta

Is found only in north Queensland, northern NT and in the Kimberley region of WA. Found on a range of soil type, but prefers well-drained sandy soils. Timber is moderately durable and used for poles and general construction. Seed in store is limited. Planted provenances:

- Local collection – Darwin region

C. nesophila

Is found only in far north Queensland, northern NT and in the Kimberley region of WA. It was planted in significant areas around Darwin pre-1970. It has grown very well with outstanding form. It appears to be resistant to, or can grow through, insect attack to leaves and growing tips. Found on a range of soil type, but prefers well-drained sandy soils. Timber is moderately durable and used for poles and general construction. Planted Provenances:

- Local collection –

North Queensland

Eucalypt hybrid clones

The camaldulensis x grandis (C x G) – selected clones (Kleinig) have performed well in several trials in NQ (Robson pers. comm... 2000). The clones available were:

- Clone 4
- Clone 10
- Clone 11
- Clone 12
- Clone 13
- Clone 20

Eucalypt hybrid seedlings

There are several inter-specific eucalypt hybrids that are suited to dry regions. These parental species are crossed so that the best traits of individual species complement each other. Several field trials established in North Qld during 1998 and 1999 have indicated that some hybrids have potential. Hybrids that we are testing here are:

- E. urophylla x E. pellita (M1677 x 1ep6-034) QFRI controlled crosses
- E. urophylla x E. pellita (M1677 x 1ep7-015) QFRI controlled crosses
- E. urophylla x E. pellita (M1684 x 1ep7-002) QFRI controlled crosses
- E. urophylla x E. pellita (M1684 x 1ep7-015) QFRI controlled crosses
- E. urophylla x E. grandis (B5993) ex CSIR South Africa
- E. urophylla x E. grandis (B10509) ex CSIR South Africa

Exotic dryland hardwoods

Khaya senegalensis

This species is an exotic cabinet quality timber tree. It is of the family Meliaceae and therefore susceptible to *Hypsipyla* spp. moth attack, which may affect bole lengths, as yet the moth has not been reported in the Northern Territory. This species has shown great potential in trial planting in low rainfall regions of NT. Planted provenance:

- Local collection Darwin region

Khaya anthotheca

This species is very similar to *Khaya senegalensis* but usually has a much better form and grows into a larger tree. However it requires more moisture and it may not be suited to the harsh dry season. Planted provenance:

- Local collection Darwin region.

Pterocarpus macrocarpus

Padauk is an exotic cabinet timber tree. Highly suitable for decorative veneers, high-class furniture, cabinet work, panelling and other types of high-grade interior finish. Planted provenance:

- Source of seed ATSC 19052 or 19853

Pterocarpus dalbergioides

This species has only been recorded from the Andaman Islands and like Padauk is from the Family Leguminosae. The two species are very similar in colour and uses. Planted provenance:

- Myanmar, Yangon provenance ATSC 20253

Swietenia humilis

Pacific Mahogany is one of the true Mahoganys (*Swietenia* species) but unlike its close relatives, grows in an area having a similar climate (dry season) to the Top End of the NT. The uses of Mahogany are well known in the furniture industry. Planted provenance:

- Honduras No seedlot details available

Chukrasia tabularis

Chickrassy is a most attractive timber found in various forest regions of India, Burma, Thailand and the Andaman Islands. Uses include good class furniture, carving and panelling in solid and veneered forms. Planted provenance:

- Vietnam, Thanh Hoa provenance ATSC 20035

Plants

All seedling stock was raised at the NT DPIF Forestry Nursery, Berrimah farm, whereas the *E. camaldulensis* x *E. grandis* hybrid clones were produced by Yuruga nursery in north Queensland. The seed was sown during two periods depending on how quickly the seedling would be ready for planting in the field. All seedlings were transferred from 60% shade to direct sun approximately 6 weeks after germination.

- The *E. pellita* and the Eucalypt hybrid seed was direct sown into Hyco Trays (40 cells) during the 25th to 29th September 2000. The other Eucalypt species and Acacia species were sown at the same time into flat trays and pricked out into Hyco trays. Individual plastic inserts were used in each cell of the Hyco trays, to facilitate sorting for height and vigour. Germination commenced within 12-14 days of sowing. The potting mix consisted of 10% clean coarse sand, 50% Coco Peat and 40% mixture of Vermiculite and Perlite (50-50). A slow release fertiliser (Osmocote 9-12 months) was added to the potting mix at a rate of 6 kg/m³.
- The seed of all the other species was sown between the 21st to 25th of August 2000, into flat trays, and pricked out into Lannen Side Slot Trays (35 cells, 270 cubic centimetres). Germination commenced after 10 days for the *Pterocarpus macrocarpus* and 20 days for the *Khaya* species.

The overall quality of the seedlings was good and height ranged from 5cms-30cms. The smaller stock was mainly *E. cloeziana*, *E. tetradonta* and *C. nesophila*. All stock was tagged for field entry identification purposes prior to planting.

Design and Layout

The design is a randomised complete block with 4 replications. Plot size was 48 trees, 6 rows x 8 trees. Spacing is 4 metres between rows and 2 metres between trees. This realises a stocking of 1250 stems / hectare. The net area required is 1.22 ha for the net plots.

For those treatments with more than one provenance, each row within each plot consists of a different provenance. These provenances are randomised within each plot.

- For example:
- Treatment 1 (*E. pellita*) has only 3 provenances, therefore 2 rows within the plot were randomly allocated to each provenance.
- Treatment 2 (*A. crassicarpa*) has 2 provenances, therefore 3 rows within the plot were randomly allocated to one provenance and 3 rows are randomly allocated to the other provenance.
- Treatment 3 (*A. mangium*), has only 1 seedlot, therefore no within plot randomisation was required.
- Treatment 4 (*E. camaldulensis*) has 2 provenances, therefore 3 rows within the plot were randomly allocated to one provenance and 3 rows randomly allocated to the other provenance.
- Treatment 5 (other Eucalypts), there is 6 seedlots within this treatment; therefore each seedlot was randomly allocated a single row within each plot.
- Treatment 6 (Hybrid clones), there are 6 different clones, so allocation will be as for Treatment 5.
- Treatment 7 (hybrid seedlings), there are 6 hybrids in this treatment, four are *E. urophylla* x *E. pellita* hybrids (U x P) and two are *E. urophylla* x *E. grandis* (U x G) hybrids. The U x P hybrid – M1677x1Ep6-034 (entry No. 21) was randomly allocated two rows in each plot. The other U x P hybrids were randomly allocated one row each per plot and the two U x G hybrids (entry Nos. 25 & 26) each shared a row in each plot. This allocation was because of the low germination of the two U x G hybrids and the good germination of entry No. 21.
- Treatment 8 (exotic hardwoods), as per treatment 5.

Planting and Initial Weed Control

The trial was planted between the 15th and 19th of December 2000. Planting positions along the ripped and mounded lines were marked out at 2.0 metre intervals. Planting holes were made using tree planting sticks and seedlings planted immediately to avoid drying out. A pre-planting herbicide application was not permissible due to very wet conditions. Simazine herbicide was applied on 27/12/00 at 4-6 litres per hectare over the planted seedlings using a 1 metre wide boom with no apparent harm done to the seedlings. The aim of this simazine application was to obtain some residual weed control for subsequent weeds emerging after planting, however it was ineffective, as weeds remained a problem during the first few months of establishment. This may have been due to the very wet conditions at planting. On-going weed control was maintained with applications of Glyphosate (10ml/litre) with hand sprayers and slashing the inter-rows.

Fertilising

An application of NPK Fertiliser (12:12:14:4) at 50Kg P /ha as an Individual Tree Application (ITA) of 346 grams on 22/12/00. The fertiliser was applied in a circle around each tree about 20cm from the stem.

Refilling

A survival count was undertaken three weeks after planting. The initial survival was 87 percent. All dead seedling were subsequently refilled.

Tending

Weeds and grasses were kept to a minimum with regular slashing of inter-rows and spraying with herbicide within the rows during the wet season when weeds are actively growing.

Thinning

No thinning has been undertaken as at May 2003 (trees aged 28 months) as the third annual measure of performance has just been undertaken. It is anticipated that thinning will be required in the dry season of 2003 as the faster growing species are beginning to reach canopy closure at the high stocking rate of 1250 stems/ha.

2.4 Results

The results of species performance in the taxa trial are presented in Table 1. A wide variation in growth was observed, especially with regard to the height growth. This is to be expected with the large range of varieties under test. Currently the trials are too young to predict the best tree varieties for this site in the Northern Territory, as the trees were only 28 months old at the latest measure. It is of greater value and relevance to compare similar species and tree types to ascertain their performance in a given set of conditions, ie the Northern Territory environment. Comparison of similar taxa such as individuals within the G x C hybrid clone group allows for greater selection within that group. It may then be possible to compare the best performing individuals from each treatment group with the best from other groups. This grouping together of similar species has been accommodated for with trial design allocating treatments 1 to 8 comprising the 32 taxa.

Table 1. Comparative growth and survival in the taxa trial planted at Berry Springs at ages 16 and 28 months

Taxa trial Species	April 2002			April 2003			
	mean ht (mm)	max ht (mm)	survival %	Mean ht (mm)	Max ht (mm)	Survival %	Twelve month growth increment
<i>E. pellita</i> Melville	231.9	430.00	78%	398.3	660.0	73%	166.4
<i>E. pellita</i> Serisa	236.3	450.00	67%	408.5	720.0	64%	177.2
<i>E. pellita</i> SSO	200.1	380.00	64%	371.1	620.0	56%	171.0
<i>A. crassicarpa</i> PNG	321.1	530.00	69%	460.0	720.0	67%	138.9
<i>A. crassicarpa</i> Fiji	298.2	460.00	61%	425.5	640.0	59%	127.3
<i>A. mangium</i>	419.6	580.00	82%	608.8	840.0	76%	189.2
<i>E. camaldulensis</i> Kath	291.2	490.00	92%	462.6	700.0	92%	171.4
<i>E. camaldulensis</i> Thai	334.6	505.00	88%	504.3	720.0	86%	169.7
<i>E. cloeziana</i> Herb	60.0	60.00	3%	0.0	0.	0.0	0.0
<i>E. cloeziana</i> Koor	152.2	230.00	6%	310.0	310.0	3.0%	157.8
<i>E. citriodora</i> subsp. <i>citriodora</i> Hugh	185.3	340.00	53%	359.0	550.0	31%	173.7
<i>C. citriodora</i> subsp. <i>citriodora</i> Glend	158.2	290.00	56%	292.2	360.0	28%	134.0
<i>E. tetradonta</i> local	64.7	180.00	59%	158.3	260.0	25%	93.6
<i>C. nesophila</i> local	46.9	65.00	50%	75.0	110.0	13%	28.1
G x C hybrid clone 4	246.6	340.00	91%	327.9	490.0	91%	81.3
G x C hybrid clone 10	265.2	410.00	97%	371.0	520.0	97%	105.8
G x C hybrid clone 11	252.6	370.00	91%	349.6	460.0	84%	97.0
G x C hybrid clone 12	274.2	440.00	94%	401.4	580.0	88%	127.2
G x C hybrid clone 13	220.8	330.00	94%	300.0	430.0	78%	79.2
G x C hybrid clone 20	237.1	355.00	75%	320.5	450.0	59%	83.4
UxP (77x34)	271.5	430.00	73%	410.0	660.0	73%	138.5
UxP (77x15)	234.4	380.00	84%	407.6	650.0	84%	173.2
UxP (84x2)	285.0	410.00	88%	462.7	670.0	84%	177.7
UxP (84x15)	240.6	390.00	81%	471.0	690.0	65%	230.4
UxG (5993)	265.0	290.00	13%	420.0	460.0	8.0%	155.0
UxG (10509)	195.0	330.00	50%	328.3	560.0	17%	133.3
<i>K. senegalensis</i>	197.9	340.00	81%	398.4	540.0	78%	200.5
<i>K. anthotheca</i>	75.0	130.00	34%	137.8	230.0	28%	62.8
<i>Swietenia humilis</i>	123.1	285.00	69%	289.0	540.0	59%	165.9
<i>P. dalbergioides</i>	114.4	200.00	28%	196.7	350.0	19%	82.3
<i>P. macrocarpus</i>	343.7	560.00	97%	533.6	700.0	97%	189.9
<i>Chukrasia tabularis</i>	184.2	300.00	75%	287.0	420.0	72%	102.8

The primary objective when growing these species in the NT is for the production of saw logs to produce high value timber. The anticipated rotation length for many of the species evaluated will be between 18 and 30 years. Therefore, the results obtained to date with respect to adaptation and growth need to be regarded as very preliminary.

Survival across the thirty-two taxa at age 28 months planted at Berry Springs ranged from 0% for *E. cloeziana* – *Herberton* up to 97% for *Pterocarpus macrocarpus*, closely followed by G x C hybrid clone number 10 at 97% (Table 1). Survival varied considerably between species and interspecific hybrids with *E. cloeziana* and *C. citriodora* subsp. *citriodora* generally having lower survival, as did *E. tetradonta* and *C. nesophila*, 25% and 13% respectively. There was a range of 0% to 3% for the two *E. cloeziana* provenances and 28% to 31% for the two *C. citriodora* subsp. *citriodora* provenances. Survival of the G x C clones, 4, 10, 11, 12 and 13 range between 78% and 97%, with clone 20 dropping to 59% survival, yet the U x P hybrids ranged from 65% to 84% and the combinations of G x U and U x G had 8% and 17% survival respectively. The exotic hardwood group including the two species of *Pterocarpus spp* had the greatest variation for survival between species in a treatment group, ranging from 19% for *P. dalbergioides* up to 99% for *P. macrocarpus*.

The mean height of *A. mangium* was by far the best at over 6.1 m at 28 months (Figure 1.). At the same age, the best of the Eucalypts was *E. camaldulensis* – Thai Seed Orchard at 5.0 m while the best of the interspecific hybrids was *E. urophylla* x *E. pellita* (entry 24) that averaged 4.7m. The best growth of the *E. grandis* x *E. camaldulensis* clones was from clone number 12 that attained a mean height of 4.0 m.

Growth varied quite considerably between clones and interspecific hybrids and there was considerable variation in growth within treatments indicating that factors other than phenotype were influencing growth and performance. This can be easily seen with the large differences between the mean and maximum heights recorded.

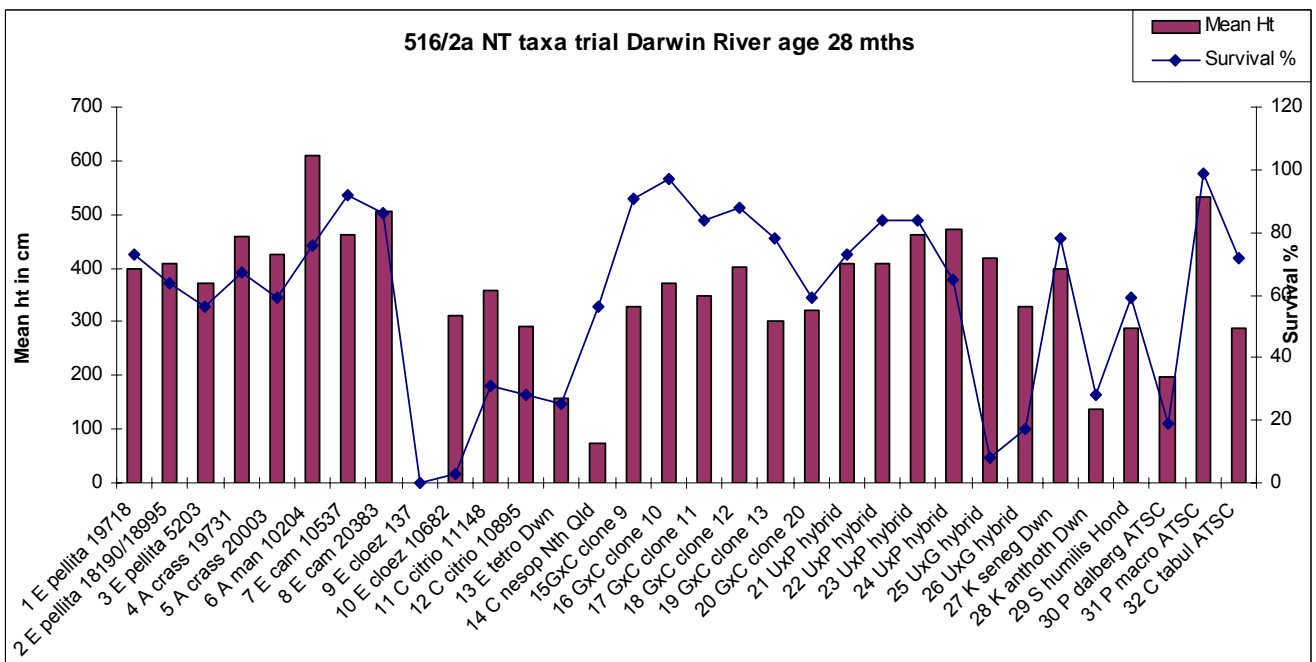


Figure 1. Mean height and survival % of species in at the Berry Springs taxa trial at 28 months.

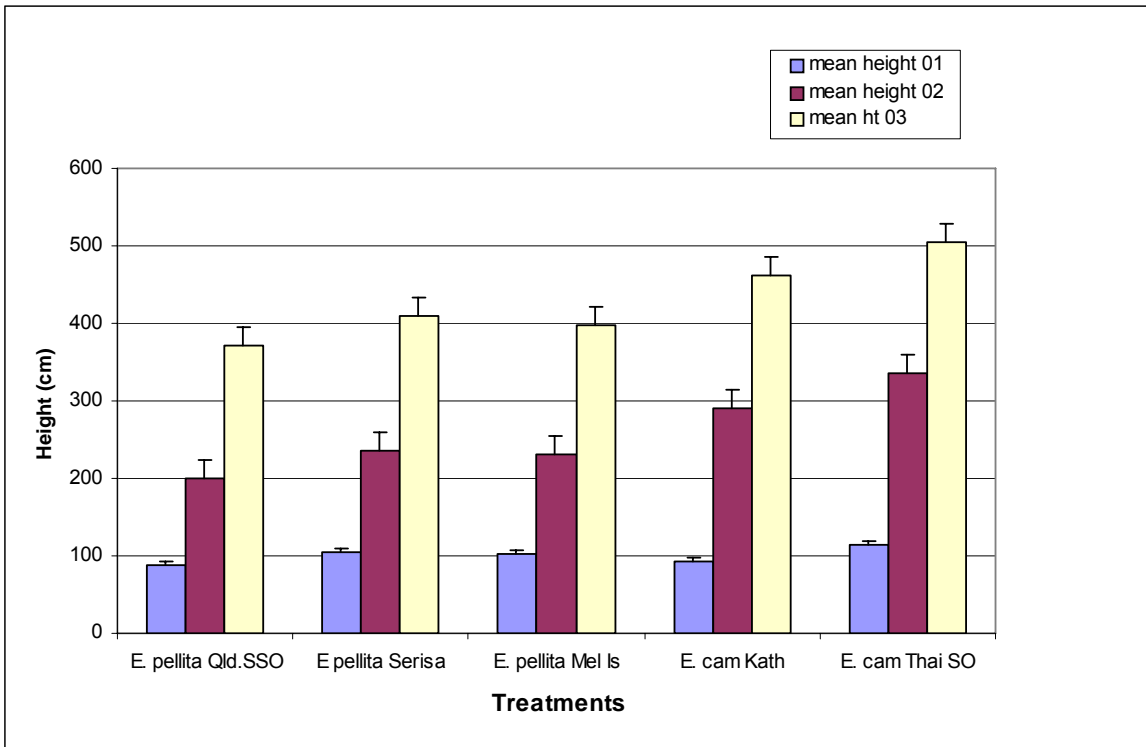


Figure 2. Mean height of *E. pellita* and *E. camaldulensis* at the Berry Springs taxa trial at 4 & 16 and 28 months. * Error bars indicate standard error

Figure 2 demonstrates the performance of the *E. pellita* provenances and the *E. camaldulensis* provenances planted in the taxa trial. The growth of the *E. camaldulensis* provenances exceeds that of all the *E. pellita*. There is also significant difference between the *E. pellita* provenances, with the Queensland SSO provenance significantly smaller than both the Serisa ($P = 0.034$) and Melville Island ($P = 0.012$) provenances at 16 months. There was no significant difference between the latter two provenances at 16 months after planting. At 28 months after planting there were no longer significant differences between *E. pellita* provenances.

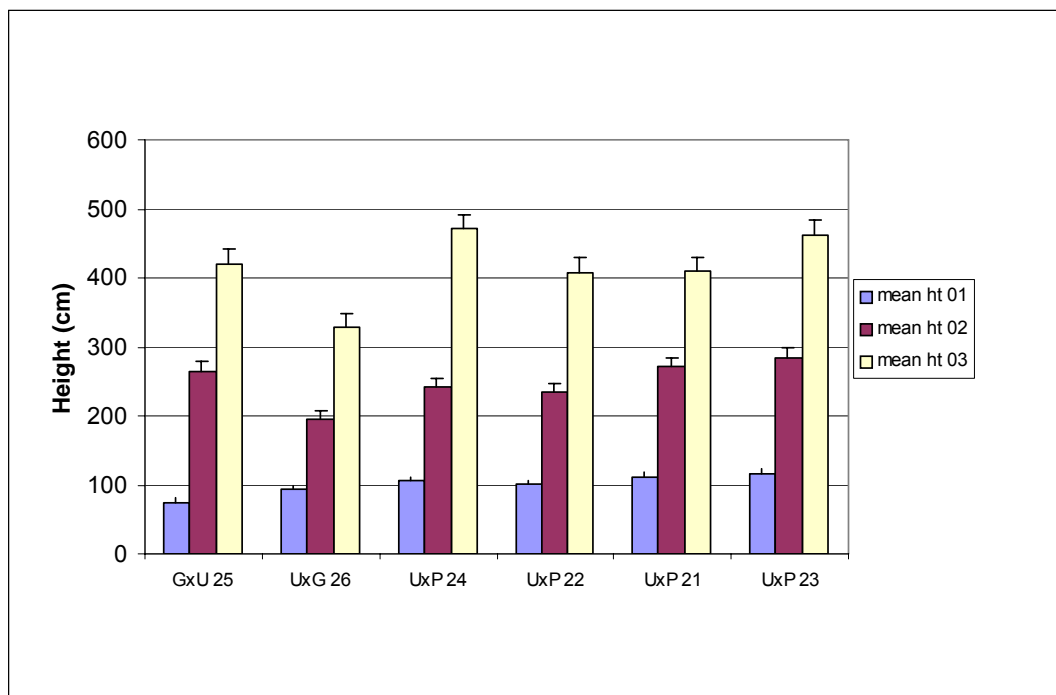


Figure 3. Mean height of U x P and G x U hybrids in at the Berry Springs taxa trial at age 4 and 16 and 28 months.

Treatments 25 & 26 share a single row in a plot, treatment 21 occupies 2 rows in a plot, others have 1 row each. * Error bars indicate standard error.

In the Northern Territory species and provenance evaluations have comprised the major proportion of work to determine the most potentially promising taxa for further commercial development. It is necessary to study provenance variation because of the likelihood of important genetic variation, as many of the species have extensive natural distributions. The advent of improved cloning and hybrid technologies have refined the selection process and increased the rate of improvement expected, therefore making available more genetic material that warrants testing in conjunction with traditional provenance testing. The first of this material to be planted in the NT taxa are the Eucalypt hybrids thought to be most suited to the tropical dry savannah regions of the NT, that have indicated potential in field trials established in north Queensland during 1998 and 1999. Treatment 7 of the taxa trial has within it 6 combinations of hybrids made up of *E. urophylla* x *E. pellita* (4 entries) and 2 entries of *E. urophylla* x *E. grandis*. (See Table 1). The 4 entries of U x P hybrids all performed better the U x G hybrids ($P < 0.05$) at age 16 months.

The second group of Eucalypt hybrid clones consisted of 6 of the best performing *E. camaldulensis* x *E. grandis* selected clones from the Kleinig collection that have performed well in several trials in north Queensland. (Nikles *et al*, 2000) These clones were in treatment group number 6 in the NT taxa trial and each occupied one row of eight plants in each treatment block replicated four times. Figure 6 shows the performance of each clone relative to the others at 4 16 and 28 months. It should be noted that, although the treatment consists of clones, there were large variations observed within each clone, (error bars indicate + 1 standard error). An analysis of the data at 28 months after planting indicates that clones 13 and 20 were significantly smaller than clones 10, 11 and 12 ($P < 0.05$) but not clone 4. Clones 10 and 12 were significantly taller than clones 20 and 13 ($P < 0.01$), while clone 11 was only significantly taller than clone 20 ($P < 0.05$)

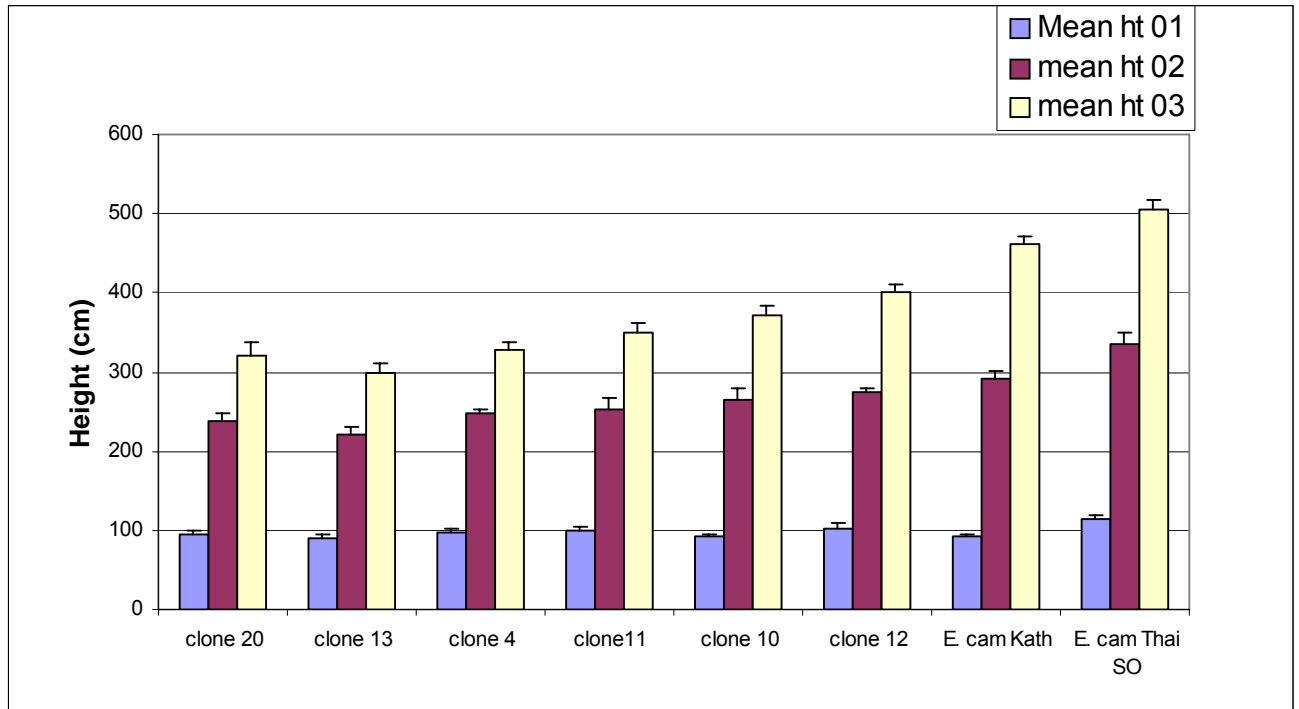


Figure 4. Mean height of C x G clones and two *E. camaldulensis* provenances in at the Berry Springs Taxa trial at 4, 16 and 28 months. * Error bars indicate standard error.

The opportunity also exists to compare these interspecific hybrid clones with pure species, ie *E. camaldulensis* to gain insight into their potential in relation to unimproved wild collections (Katherine) and that from seed orchards (Thailand). In this case it was apparent that the pure species of *E. camaldulensis* (both provenances) out performed the clonal material with the *E. camaldulensis* from Thailand SO was significantly taller than all the hybrids clones (Entries 4, 10, 11, 12, 13 and 20 ($P < 0.05$). The Katherine provenance of *E. camaldulensis* was also significantly taller than the clones 4, 11, 13 and 20 ($P < 0.05$) at 16 months.

Figure 5. Mean height of the exotic hardwood species in NT taxa trial at 4, 16 months and 28 months. Error bars indicate standard error.

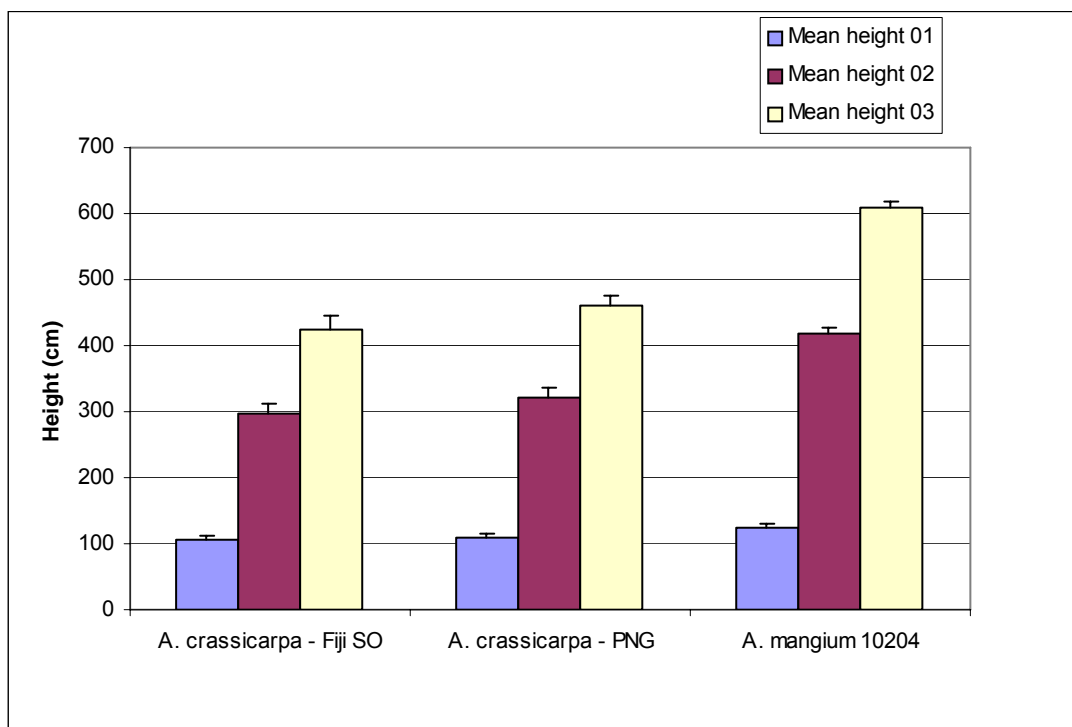
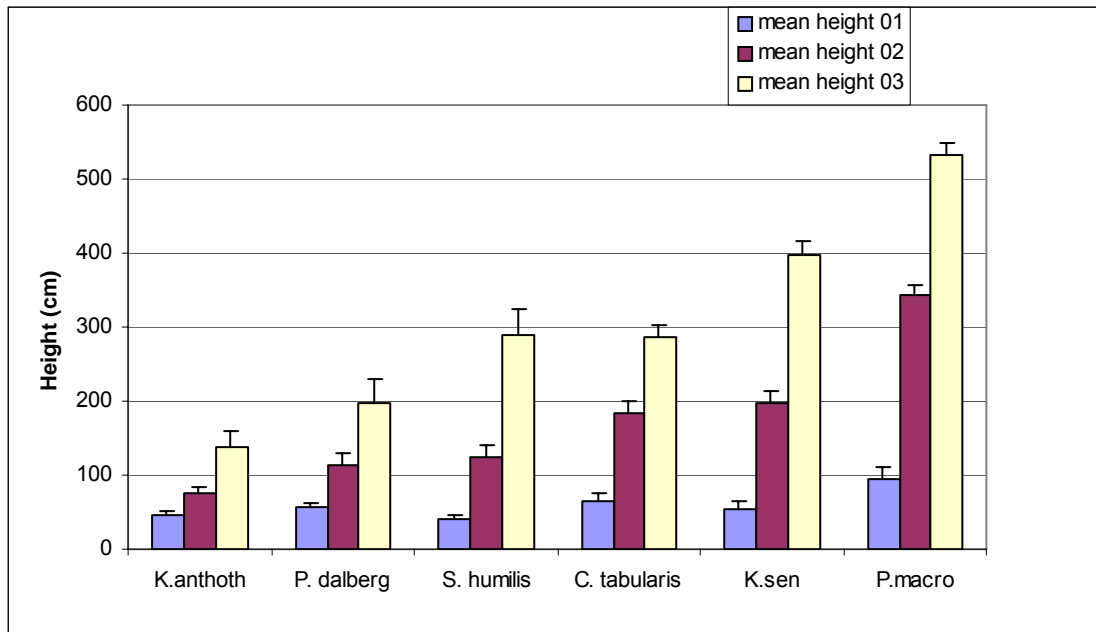


Figure 6. Mean height of Acacia species in the at the Berry Springs taxa trial at 4, 16 and 28 months. * Error bars indicate standard error.

Discussion

In the trial at Berry Springs the two best performing taxa at 16 months in terms of height are the *A. mangium* and *E. camaldulensis* from the Thailand SO. Both species are known “sprinters”, in that they make rapid early growth (Beau Robertson, DBIRD, pers. comm. April 2001) and their growth rates will probably reduce as they grow older. The best growth rates achieved at 28 months was still *A. mangium*, but the *P. macrocarpus* has overtaken the *E. camaldulensis* as the second best performing species. It is interesting to note that growth of the interspecific hybrids and clones has not been that spectacular in comparison to local pure species such as *E. camaldulensis* – Katherine (entry 7). This entry is made up of collections from wild populations, where as considerable work has gone into the selection and improvement applied to the hybrids and clones. The hybrids of G x U also exhibit damage from insect attack that may account for early poor performance. Despite that, entries 23 and 24 of the eucalyptus hybrids U x P both contain individuals that have reached heights of 6.7 and 6.9 metres respectively in 28 months. The hybrid clones G x C have also shown severe damage to leaves from insect attack. Despite the insect damage, most clones in this treatment display reasonable growth and survival. The early results also indicate the genetic material (both pure species provenances and interspecific hybrids) that can be discounted at this early stage based on poor growth and survival rates. Although it is very early to make presumptions, the provenances of *E. cloeziana*, *C. citriodora* subsp. *citriodora* and the interspecific hybrids of *E. urophylla* x *E. grandis* don't appear very productive in the NT taxa trial.

The promising early rapid growth of some of the exotic hardwoods in the trial is encouraging especially the *Pterocarpus macrocarpus* and to some extent, *Khaya senegalensis* that have achieved mean height of 5.33 metres and 3.98 metres respectively. The anticipated longer rotation lengths of these species compared to some of the Eucalypts and Acacias (that are being planted commercially at present for pulpwood and/or solid wood products) makes comparisons between the various taxa very difficult to interpret. It is also very early in the life of the trials in the NT and therefore difficult to predict the best species and provenances. (Nikles et al, 2000).

Productivity scores have not been calculated for any of the taxa to this stage as diameter at breast height (dbh) has not been measured and is a critical component of the calculation.

Fire damage was incurred in the dry season of 2001 in the first week of August. Plots adversely affected were on the southern and south-western side of the experiment. The plots affected were; 1, 2, 5, 6, 11, 20 and 21. An assessment was undertaken in the 25/9/01 where plots were graded into four categories on the severity of damage and these were;

- All or most of the stem above ground was killed
- Leader lost in fire and severe damage to crown but tree still alive
- Leader OK, but some damage to laterals
- Very little damage or no damage

Within these damaged plots, plot No. 1 (*Acacia crassicaarpa*) was the worst affected where all trees were killed and is reflected in the low survival percentage for that treatment across all plots (59% for the Fiji Seed orchard and 67% for the Oriomo PNG provenance). Plot No. 2 (exotics) was the next worst affected where *C. tabularis* and *S. humilis* were all killed and the low number of survivors of *K. anthotheca* and *P. dalbergioides* were also killed. All species within this plot were damaged by the fire, but treatments 27- *Khaya senegalensis* and 31- *Pterocarpus macrocarpus* incurred category 2 or 3 damage (above) but all these survived. The treatments in plot No. 5 were the next worst affected. The species within this treatment already had low survival from the initial assessment on 18/4/01 and suffered further deaths as a result of the fire. Plot No.6 (*E. pellita*) suffered similar damage to plot No. 5 where trees

received minor damage but most survived. In plot 11 (*A. crassicarpa*) the outside row received damage but no deaths were recorded. Plots 20 (G x C hybrid clones) and plot 21 (*A. mangium*) incurred similar damage and only the external row was affected.

Very little termite damage has been incurred on this site.

Weed growth has been difficult to suppress despite all the efforts of staff and the landowner to maintain a weed free status. The main weed problem has been the introduced legume, *Aeschynomene americana*, (Glenn joint vetch) and the tall grass *Imperata cylindrica*, (blady grass) that grew vigorously after the application of fertiliser at planting.



Figure 7. Example of weed problem in a U x G hybrids at 16 months at the Berry Springs taxa trial.



Figure 8. A G x C hybrid clone exhibiting severe insect damage in May 2003 at the Berry Springs taxa trial.



Figure 9. *K. senegalensis* on the left and *P. macrocarpus* on the right showing promising growth at 29 months at the Berry Springs taxa trial.

Overall, survival after the April 2003 measure has been disappointing due to fire incidence, insect damage, weed problems and the lack of compatibility of some species with the prolonged dry season experienced in the Top End of the Northern Territory. However some species have performed well in terms of growth increments. Some of the better performing individuals have obtained heights of more than 7 metres in 28 months. The best performing species ranked on growth increments from April 2002 to April 2003 were entry number 24, U x P hybrid clone (2.3 metres), entry number 27, *K. senegalensis* (2.05 metres), entry number 31, *P. macrocarpus* (1.89 metres) and entry number 6, *A. mangium* (1.89 metres). All of the U x P hybrids are showing promise with good growth and very little insect damage to leaves compared to other hybrid clones tested at this site. These results indicate that they are worthy of further investigation in the Top End on similar sites.

2.6 Implications

The taxa trial at Berry Springs is the first of two taxa evaluations undertaken within this project. The aim of comparing growth of interspecific Eucalypt hybrids with 'best bet' dryland species with pure eucalypt species and exotic hardwoods has been achieved. This experiment should be viewed as a valuable resource for the on-going evaluation of the better performing species in this trial for the Top End of the Northern Territory. Based on the preliminary results, there may be incentive for commercial interests to pursue plantation establishment of some of these species in the future. A commercial plantation company presently operating in the Northern Territory is already trialing eucalypt hybrids as part of its Research and Development program to evaluate fast growing Acacias and Eucalypts for its fibre project.

2.7 Recommendations for future management

The next stage of this project will be to commence thinning where necessary to allow the remaining trees to express their full growth potential. (Haines, 1986) It is intended that this work will be undertaken in the dry season of 2003 or 2004. All future assessments will include diameter measures so a productivity index score can be calculated to gain more information on volume production and economic potential.

3. Chapter Three - The *E. pellita* seed production area planted at Howard Springs in December, 2000

3.1 Introduction

In the Northern Territory, the primary source of timber has been the native forests of hardwood species and cypress pine. Past logging activities together with termites, cyclones and the increasing incidence of fires have diminished the resource while at the same time there is increasing local and global demands for timber. To meet the increasing demand for hardwoods, it will be necessary to establish plantations with species that are fast growing, stress and pest tolerant and produce marketable timber.

Many species of eucalypts have been tested in the NT and most suffered from drought and insect attack. Among a few exceptional species, *Eucalyptus pellita* has shown promise, especially in tests planted on Melville Is in 1992, of adaptability and good growth to 3.2 yr (Harwood et al., 1997a). As well, Papua New Guinea (PNG) provenances of this species have shown potential in earlier CSIRO research plantings (1989 - Harwood 1998) on Melville Is., and in the NHT Farm Forestry plantings under taken in the three planting seasons between 1999 and 2001 across the Top End of the NT (Clark, 2003 - Draft Final Report). Furthermore, by the time the present project was being planned in July, 2000, the 1989 planting had largest trees of 35 cm DBHOB with heights over 22 m and good stem form, and the 1992 planting had largest trees of 27 cm DBHOB with estimated top heights of 19 m, also with good form (records of DPIF and authors' data or observations in July, 2000). These stands also had good survival. Such results are especially encouraging because these stands did not receive good silvicultural management in recent years. The PNG (and West Papua) provenances are promising also in the similar, seasonally-dry tropics of north Queensland (Harwood et al. 1997b). *E. pellita* wood has a range of uses (Harwood et al. 1997a, Harwood 1998), potentially including high value applications such as furniture in which its rich red colour could be prized (W. Leggate, QFRI, pers. comm., 2001). It is highly likely, therefore, that *E. pellita* seed will be in demand to provide planting stock for some of the plantations that will be established in the NT in the future.

It is well known that forest tree species such as *E. pellita*, with demonstrated genetic variation at the levels of provenance and family-within-provenance (Harwood et al. 1997a) and much phenotypic variation within families, can be improved for yield, tree quality, wood properties and other economic traits by means of tree breeding practices (Eldridge et al. 1993). Thus, genetically-improved planting stock can contribute to the profitability of plantation enterprises. Therefore, it is important to develop secure seed sources and initiate tree improvement with *E. pellita* in the NT.

Although a seedling seed orchard of *E. pellita* was developed on Melville Is. by early thinning of the provenance-progeny trial planted in 1992, no further management has been applied. (In fact, the tree stumps coppiced after thinning, and it would be very expensive to redevelop the area as a seed orchard now). There may be at least one other planting of the species on Melville Is. (a 1998 planting by a private company, Sylvatech) a portion of which could possibly be converted into a seed production area if agreed by the owners. Other seed orchards exist in north Queensland (Harwood et al. 1997a, b), though only one is being managed actively. Uncertainties about the long-term maintenance of the Melville Is. and Queensland orchards, and the desirability of developing a land race adapted to the Top End mainland, make it important to establish a similar facility there with this very promising species. This is despite the fact that initial survival of *E. pellita* may be less on the mainland than on Melville Is., where rainfall patterns are more favourable and losses due to termites can be expected to be lower.

3.2 Objectives

- Establish a seedling seed production area of PNG *E. pellita* provenances in the N.T.
- Evaluate several *E. pellita* provenances.
- Manage the stand to produce improved seed best suited for planting in the Darwin region.

3.3 Methodology

Background

A SSO of a tree species is a stand of trees comprising an adequate number of identified families, preferably of known superior provenance/s, planted at a relatively high stocking (say, 1250 trees per hectare) to enable heavy, staged culling to retain just the best, say, 125 trees per hectare for seed collections and their use in establishing new plantings. The use of a high initial stocking of many, good families of superior provenances, and the heavy culling of inferior trees, leads to genetic improvement of the initial population, provided the tree traits selected for in the orchard are heritable. This approach has been demonstrated to deliver significant genetic gains in a number of eucalypt species (Eldridge et al. 1993). When, for simplicity, the identities of the seedlings from different seed parents are not retained in the field, ie a bulked seedlot or seedlots are used instead of individual families, the ensuing facility is called a seed production area (SPA) and it can deliver significant genetic gains also (*loc. cit.*, Shelbourne, 1969).

The approach of establishing a SPA was adopted under this project for the initial, mainland facility in the NT in part because of the need for ease of establishment and management. Although it was anticipated that progeny from the Melville Is. SSO would be acceptably adapted to mainland conditions, this could not be presumed; as well, the number of family seedlots available from selected trees in the SSO (30) was considered an inadequate base for a new facility. Therefore, a larger base was secured by including bulked seedlots from natural stands in PNG via the resources of the CSIRO's Tree Seed Centre (see below for details). This approach also provided the option to compare the Melville Is. and the natural-stand seed sources.

Location

The Howard Springs Forestry reserve was chosen for SPA establishment. This provided security of land tenure (it is Territory land) and a location relatively close to the base of Project staff (Berrimah). The SPA site is some 30 km southeast of Darwin and approximately 15 km from the Berrimah Administration office.

Original Vegetation

This comprised open, mixed eucalypt forest the predominant species being *Eucalyptus tetradonta* and some *E. miniata*. This was cleared in the 1960s for evaluations and experiments on a range of hardwood and softwood species. The area selected required the removal of natural bush regeneration and exotic invaders from a site of previous trials.

Soil

Gravelly massive earths, shallow to moderately deep. See Appendices 3.1 and 3.2 for a comprehensive description of the soil and results of chemical analyses of samples of it.

Aspect

Slight slope of about 1:100 from the NW to SE . Planting lines are across the slope.

Elevation

Approximately 40 m.a.s.l.

AMG COORDINATES. 8620500N

Latitude 12° 28" 17/18' S

721500E .

Longitude 131° 02' 15' E

Climate Data

Climate data for 2000 and 2001 - rainfalls for Howard Springs Nature Park and temperatures for Darwin airport 20 km to the north are given in Table 3.1 below for the critical establishment period in 2000-2001. Additional data and the long-term averages for Darwin airport are given in Appendix 3.3.

Table 3.1. Temperatures for Darwin airport (20 km NW of Howard Springs) and rainfalls for Howard Springs Nature Park (2 km from the SPA site) for 2000 and 2001.

2000	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Max C°	33.4	34.0	33.0	33.3	33.3	32.8	32.4	35.3	35.9	35.8	35.4	33.5	34.0
Min (C°)	22.2	22.4	21.8	22.5	15.9	12.5	15.7	16.9	19.8	19.0	22.8	24.0	19.6
Rainfall (mm)	505.9	816.9	382.4	339.0	17.6	0.4	0.0	0.0	0.4	76.6	122.4	229.3	2490

2001	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
Max C°	33.5	34.1	32.8	34.6	34.0	33.6	33.2	33.5	36.6	35.7	35.9	34.5	34.3
Min (C°)	22.4	22.5	22.5	21.7	17.1	18.4	15.6	15.3	19.2	22.1	22.0	22.8	20.1
Rainfall (mm)	684	419	320	58	18	0	12	0	1.4	77	216	156	1964

Site Preparation

Preparation for trial establishment for this project began in mid 2000 with clearing of native re-growth and weeds at the site to enable conventional site preparation. Pushed up material was windrowed and burnt in June 2000. The site was ripped and mounded in the one operation in October, 2000 with a 'mounding plough' fitted with a ripper. The implement available enabled penetration of the ripping tyne to a depth varying around 300 mm. Despite this depth limitation and its variation, the plough produced adequate mounds in which to plant the seedlings (Figure 3. 1).

Ploughing of the Howard Springs site was followed by an application of Glyphosate at 1 litre per hectare along the rows (only) when weeds emerged following the first substantial rains.



Figure 3.1. *Eucalyptus pellita* (Melville Is. provenance) in the Howard Springs seedling seed orchard in April 2001, 4 months after planting. Note the mounded rip line with low weed incidence.

Genetic Material

This comprised open-pollinated (OP), bulked seed from phenotypically-superior trees selected in the Melville Is. provenance-progeny trial (Harwood et al. 1997a), and OP seed from average or better seed-bearing trees in natural stands as follows:

- Bulked, second-generation seed from 30 selected trees in a Melville Island provenance trial of PNG provenances that was converted to a SSO by selective thinning (Seedlot 19718)
- Bulked, first-generation seed of Kiriwo provenance from PNG (Seedlot 19206) – 71 seed parents
- Bulked, first-generation seed of Goe provenance from PNG (Seedlot 19207) – 59 seed parents
- Bulked first-generation seed of Serisa provenance from PNG (Seedlot 18199) – 12 seed parents pooled with first-generation seed of Serisa provenance from PNG (Seedlot 18955) – 24 families.

Totalling the number of seed parents involved in the original seed collections (196), but realising that not all of them would be represented in the seed samples secured for this project, it can be seen that, even if only 70% of the seed parents were sampled for the seed sown, the genetic base of the seed obtained would have been desirably broad and large. Examination of the records (Harwood 1998) of the PNG seedlots used in the 1992 planting on Melville Is., and those of Kiriwo and Goe used in the Howard Springs SPA (Serisa seed sources were not available for the 1992 planting), show there is only a very low probability that progeny of some of the same first-generation trees may be represented in the Kiriwo plus Goe and Melville Is. blocks in the Howard Springs SPA. So there is little danger of inbreeding in the SPA on this account.

Plants

Seed was obtained from CSIRO's Tree Seed Centre. All plants were raised at the NT DPIF Forestry Nursery, Berrimah farm. Seed was direct sown into Hyco Trays (40 cells) during 25-29 September, 2000. Germination commenced after 12-14 days. The potting mix used in the trays was made up of 10% clean course Mary River sand, 50% Coco Peat and a 40% mixture of Vermiculite and Perlite (50-50). A slow release fertiliser (Osmocote 9-12 months) was added to the potting mix at a rate of 6 kg/m³. Each cell of the Hyco Trays was fitted with a plastic insert. This insert helped tremendously when trying to sort each tray of seedlings to a uniform size. Individual seedlings could be moved from tray to tray within each provenance, so that small plants could be separated from large seedlings. All seedlings were transferred from 60% shade to direct sun light 6 weeks after germination. Seedlings stock ranged from good (35cms) to poor (5cms). Spray drift from Starane used to control weeds in the nursery caused damage and some deaths to seedlings and reduced the number of planting stock available. Stock was tagged for field entry identification purposes before planting.

Design and Layout

As the number of seedlots was small, a randomised complete block (RCB) was used. Each of the 36 replicates comprised 6 rows x 16 trees, 2 rows each for the Kiriwo and Goe provenances, and 1 row each for Serisa and Melville Island provenances, randomly allocated within each block. This allotment of rows reflects the numbers of parents within each seedlot. Espacement was 4.0 metres between rows and 2.0 metres along the rows, realising a stocking of 1250 stems / hectare. No guard nor surround rows were planted, the latter due to shortage of stock. The SPA occupies almost 2.8 ha. The detailed layout of the SPA is given in Appendix 3.4.

Termite Protection Measures

Termites (*Mastotermes darwiniensis*) seem to be more active after the wet season, and deaths of plants occur throughout the following dry season. Therefore an ongoing baiting program was put in place in conjunction with the Entomology section of DPIF, new baits are being tested regularly. One such product was tested in the dry season of 2002 with good results; however it is not registered for use in forestry at the present time.

Planting and Initial Weed Control

The SPA was planted on 14 -15 December, 2000, two weeks after the first substantial rain of the season. Planting positions along the ripped and mounded lines were predetermined by measuring and marking at 2.0m intervals. Holes were made using tree planting 'pogo' sticks, and seedlings planted immediately to avoid drying out. Simazine weedicide was applied post planting on 28 December, 2000 at a rate of 4-6 litres per hectare over the planted seedlings with no apparent harm done to the seedlings. This simazine application was to obtain some residual weed control for subsequent weeds emerging after planting.

Fertilising

NPK Fertiliser (12: 12: 14: 4) at 50 kg/ha was applied as an individual tree application (ITA) of 346 grams on 28-29 December 2000.

Refilling

To determine refilling requirements, survival counts were undertaken in late December 2000. The initial survival was only 57% due to very dry conditions post planting and high incidence of insect damage. Due to the high requirement of refills and the inadequate supply of excess plants, it was decided to completely refill only 7 of the 36 blocks, to permit longer-term evaluation of the four provenances. Those blocks completely refilled were numbers 7, 8, 11, 12, 18, 20 and 24. The remaining blocks were considered viable for SPA purposes.

Tending

Weed and grasses were kept to a minimum with regular slashing of interrows and spraying with herbicide within the rows during the wet season when weeds are actively growing.

Fencing

Fencing of the entire site was undertaken to ensure security of the site as it is on accessible public land. The cost was shared between the custodians of land (Northern Territory Forestry and Timber Products Network), DPIF, GANT and the RIRDC.

Thinning

No thinning has been undertaken as at May, 2003 (trees aged 28 months, all provenance mean heights less than 5 m), primarily because of the need to retain the stocking of the seven blocks being used to compare provenances, and the relatively low stockings and tree heights in the other blocks as explained above. Thinning is anticipated in the 2004 dry season.

3.4 Results

Plant survival at 27 months (April, 2003) in the 7 refilled blocks averaged 64.5%, ranging from 54% to 76% among provenances (Table 3.1), and 44% to 80% among blocks (Appendix 3.5) It was highest for the Melville Is. (76%) and Serisa (69%) provenances, and considerably less for the Kiriwo (59%) and Goe (54%) provenances. Analyses of the RCB design, with 7 replications, using two appropriate statistical methods showed significant differences between provenances ($p=0.0191$ using arcsine-transformed proportion surviving data in an ANOVA; and $p=0.0042$ using logit-transformed binomial response data in an ANODEV). Melville Is. provenance was significantly superior to Goe (the poorest in survival), but similar to Kiriwo and Serisa, while Goe, Kiriwo and Serisa were not significantly different from each other (M. Hearnden, pers. comm., 2003). Survivals across all plots, as well as provenance and block means and the numbers of plots per provenance with 28-month survival less than 50% are shown in Appendix 3.6. These data, too, suggest superiority of Melville Is. versus Goe provenance with the other two intermediate (survival percentages of 58.4, 46.0, 39.4 and 35.8 for Melville Is., Serisa, Kiriwo and Goe provenances respectively). Some non-refilled plots had very low survivals (even zero) by April, 2003.

Height measurements were undertaken annually in April. Summaries of results are presented in Table 3.2 and Figure 3.2 in the form of provenance means and, in the graph, the standard error + 1 is shown also by the vertical bars. Views of trees of two of the provenances are shown in Figure 3. 2.

Statistical analyses have not been undertaken because experience shows such would be virtually meaningless when applied to data from trees only 27 months old at the maximum, and with provenance average heights all less than 5 m Table 3.1).

Table 3.2. Mean heights of *E. pellita* provenances in Howard Springs seed production area at ages 4, 15 and 27 months, 15-27 months height increases and survivals (and ranks) based on seven refilled blocks per provenance.

Provenance	Height at 4 months (cm) (and rank)	Height at 15 months (cm) (and rank)	Height at 27 months (cm) (and rank)	Height increase 15-27 months (cm) (and rank)	Survival (%) (and rank)
Melville Is.	75.36 (1)	271.21 (1)	484.40 (1)	213.2 (1)	76 (1)
Serisa	57.61 (2)	180.19 (3)	349.10 (4)	168.9 (4)	69 (2)
Kiriwo	49.87 (4)	152.58 (4)	362.10 (3)	209.5 (3)	59 (3)
Goe	54.46 (3)	183.54 (2)	394.80 (2)	211.3 (2)	54 (4)

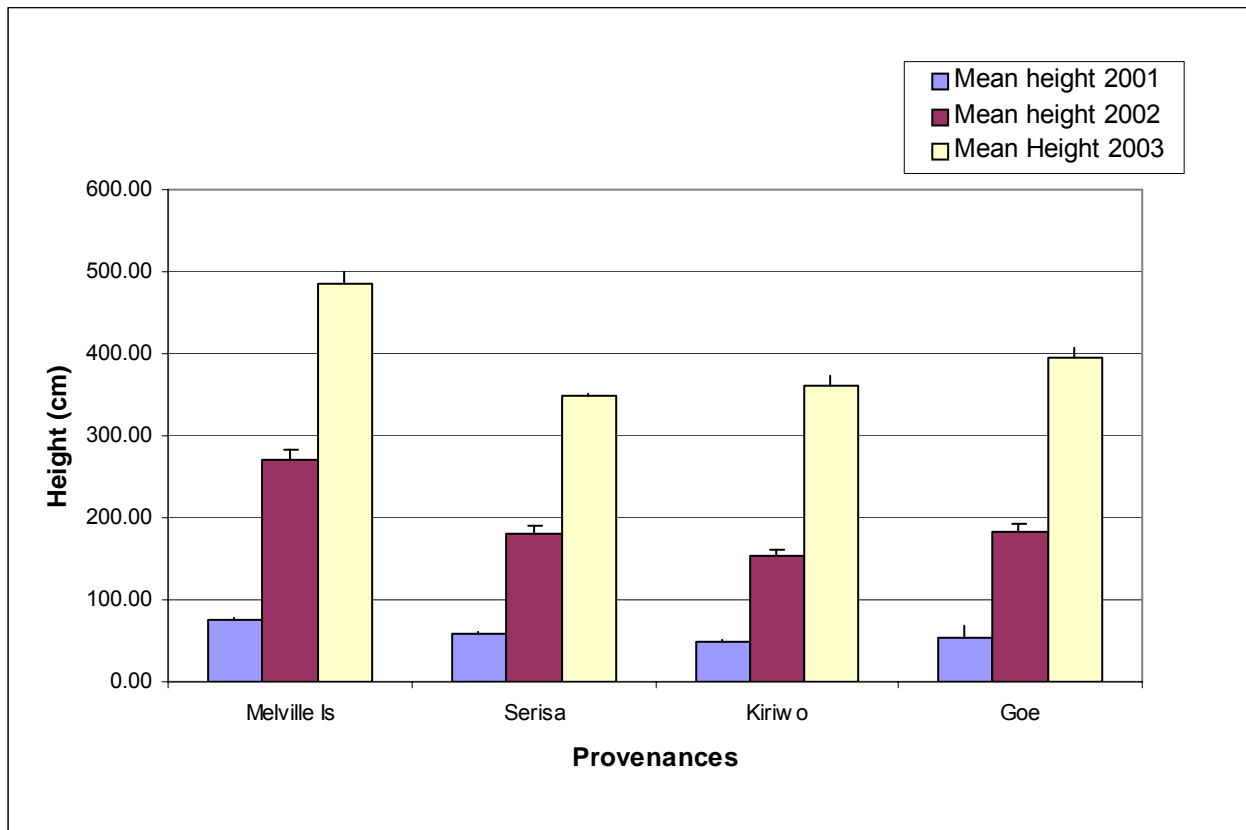


Figure 3.2. Relative height growth of *E. pellita* provenances in 2001, 2002 and 2003 at 4, 15 and 27 months respectively from planting in the Howard Springs seed production area (means of 7 blocks). Error bars indicate standard error.



Figure 3.3. Trees within the *E. pellita* seed production area at Howard Springs after its second measurement in April, 2002 (age 16 months). Melville Is. provenance 19718 (second generation ex PNG provenances) on left. Trees of this provenance were tallest on average. Serisa provenance 18199/18955 (first generation ex PNG) on right. This provenance had the least tallest trees.

3.5 Discussion of Results

Overall, survival after the December, 2000 planting has been disappointing, due to the cumulative, negative effects of: the relatively dry January, 2001 (118.6 mm less rainfall than the long-term median for that month – Table 3.1); termite attacks; and water stress in the dry seasons. This was despite the termite-protection measures taken, and the fact that planting was undertaken in December 2000 when soil moisture was considered adequate for the survival of the seedlings on the expectation of normal January rains. Such early planting is preferred over later planting in the Top End of the NT (and north Queensland) as, based on experience, it normally provides maximum opportunity for seedlings to establish themselves well prior to the end of the rains in the first season

Although the significant difference between provenances in survival at 27 months was only due to Melville Is. versus Goe, it should be noted that the Melville Is. provenance had higher and more consistently higher survival than any other provenance (Table 3.2, Appendices 3.5, 3.6). As well, this provenance had by far the smallest number of plots with < 50% survival (8 vs 18, 23 and 26 - Appendix 3.6). (Choice of a threshold of 50% survival as a means to compare provenances relates to recommendations on thinning outlined in Recommendations below).

Examination of the relative periodic heights and ranks for the provenances given in Table 3.2 show that the second-generation Melville Is. provenance has maintained its leading position at all ages, and its increase in height between 15 and 27 months was marginally greater than the increases attained by Goe and Kiriwo provenances, both first generation stock. Also, there is still a substantial margin in current heights between the Melville Is. and Goe and Kiriwo provenances (89.6 cm and 122.3 cm respectively). Note, too, that the Melville Is. provenance had the tallest individual trees at each measure (Figure 3.2).

Thus, the Melville Is. provenance seems the most promising for growth and survival at this stage. Both these differences could be expected on the grounds that the Melville Is. provenance is likely to exhibit a lower level of neighbourhood inbreeding than the natural provenances due to the mixture of five PNG, one West Papuan and several Queensland provenances in the Melville Is. SSO, and because the seed parents were selected for phenotypic superiority and overall adaptability in the monsoonal tropics of Melville Is. The Serisa provenance seems the least promising for growth as its relative height fell to rank 4 by 27 months of age, and its 15-27 month increase in height was substantially lower than that of all other provenances.

Nevertheless, experience suggests that large, within-provenance variation in growth and other economic traits, almost always found in such a diverse stand as this SPA comprises, will result, after final culling, in retention of considerable diversity (Harwood et al. 1996) and a low level of neighbourhood inbreeding in the SPA. When final thinning to the recommended 200 trees/ha (see section 3.7) has been completed in the SPA, some 560 good trees are expected to remain across its nearly 2.8 ha. Thus, the SPA can be expected to perform its planned function successfully, although a much better overall survival would have been preferred, as this would have enabled more intensive selection for growth and form at the times of thinning.

3.6 Implications

Experience to date with the establishment of this SPA shows there can be considerable difficulty in getting a SPA of *E. pellita* established in terms of a high initial and 27-month survival in areas such as Howard Springs. However, it is considered the SPA must continue to be maintained because of the greater convenience of future seed collection there, and the uncertainty that the only other *E. pellita* seed source in the NT (Melville Is) will be maintained and survive.

Based on the performance of the species in the recently established NHT Tropical Hardwood Trials, and in the taxa evaluations of this project, there should be increasing demand for improved seed suited to the conditions of the Top End of the NT. However, growth and survival on the mainland of the NT are not as promising as the initial growth shown on Melville Island due to rainfall distribution and the occurrence of the giant termite *Mastotermes darwinensis*.

The promising early survival and development of the Melville Is. population in the SPA indicates that, pending seed production on superior trees of the Howard Springs SPA, the Melville Is. SSO (1992) would be a satisfactory seed source for Top End plantings.

Finally, the results to date discussed above imply that all the objectives of the SPA project appear achievable, including the initiation of tree improvement with *E. pellita*. This could begin via mass selection within the SPA in the year after completion of final thinning, and in other suitable stands in the Top End.

3.7 Recommendations for future management

The schedule for managing the SPA will be a compromise because of somewhat conflicting objectives and necessities, and unknown future losses from termites and other causes. The need to thin in stages from an early age (to provide extra crown space for the better trees as they develop, and to eliminate the inferior trees) conflicts with a need to maintain trees long enough for a sound judgement of their genetic and seed producing potentials. There is also a need to maintain relatively high and equal stockings in the blocks allocated for measures and assessments in order to compare the provenances with reasonable precision. As well, account must be taken of the close, original espacement of trees within rows (2 m), and the great inequality of survivals in the blocks that are not measured (Appendix 3.6).

It is considered that the blocks nominated for measures could be reduced selectively to 50% stocking (to 16 and 8 trees in the 32- and 16- tree plots respectively) in the 2003 or 2004 dry seasons (at ages around 33 or 45 months). This strategy will depend on development over the remainder of the 2003 dry season. The seven plots with less than 50% stocking would not be thinned. All the other 29 plots could be selectively thinned to 50% stocking as soon as convenient in 2003, and then to 16% of full stocking, ie to 200 trees per ha, in two stages before the end of the 2005 dry season. A final stocking of 200 trees/ha seems appropriate in view of experience, (of some of the present authors) of crown development in *E. pellita* seed sources established in north Queensland, and a need to ensure against too low a residual stocking in the event of some loss of trees due to cyclones, a threat in the Top End.

Retention of the best performing trees for future seed production purposes should be the basis for thinning trees from the orchard. A proviso suggested is that no more than three trees be maintained at 2 m, within-row spacings in order to avoid excessive crown suppression. This, and the recommended final stocking of 200 trees/ha, could result in the ultimate retention of some 560, good trees over the nearly 2.8 ha of SPA by October, 2005. By that time, mature seed capsules would be expected to be available. If the final thinning is undertaken late in 2005, then the genetic quality of the seed crop of 2006 will reflect this, as all the pollen and seed parents of the flowering of early 2006 will have been select trees. If the demand for seed at seed collection in 2006 is less than whole-orchard production, the genetic quality of the collected seed can be upgraded further by restricting seed collection to only the number of very best trees needed to provide the amount of seed required at the time.

It is also recommended that the custodians of the Melville Is. *E. pellita* SSO be encouraged to manage (if possible) and protect it as an interim seed source.

4. Chapter Four - The clonal seed orchard and clone conservation bank of *Khaya senegalensis* planted at Howard Springs and Berrimah respectively in December 2001

4.1 Introduction

The Top End of the NT has a very small market for forest products locally, and it is far from other Australian and most overseas markets. As well, it has a monsoonal climate, is subject to occasional, severe cyclones and has generally poor soils available for forest tree plantations. It is often considered that farm forestry especially, as well as a plantation industry, in such a harsh environment would need to use one or more hardy, high-value species, though industry could be in a position to use commodity species such as acacias as well.

Research evaluating introduced species that might have potential for commercial forestry in the Top End began in 1959. This early work was undertaken by the (Commonwealth) Forest Research Institute, later becoming CSIRO, and sporadic plantings were made through to the early 1970s.

Khaya senegalensis (dry zone mahogany) was one of the species identified in the early trials in the 1960s as having promise for this region. In its native habitats in Africa (from Senegal on the west coast to Sudan and Uganda in the east of the continent) it is a large semi-deciduous tree to 35 metres in height and over 1 metre in diameter. Being in the family Meliaceae, its timber is of very high quality and its uses include furniture making, plywood, counter tops, joinery, turnery and carving. *K. senegalensis* is adapted to a wide range of soil types and will tolerate seasonal waterlogging. During the first year of growth, the tree develops a strong, deep taproot, which makes it the most drought hardy of all the *Khaya* species, hence the common name, "dry zone mahogany". Although the species is susceptible to shoot borer (*Hypsipyla* sp.) in Africa, there were no indications of attack on plantings of *K. senegalensis* in the NT. These features made the species attractive for further investigation in the NT.

Consequently, beginning in the 1970/71 wet season, CSIRO established a series of provenance trials at Gunn Point, 60 km north east of Darwin, and on Melville Island. The trials usually comprised 3 or 4 replications of 36-tree/49-tree, multi-row plots. Across these trials, planted during 1971-1973, a total of 24, introduced provenances (21 from natural stands in 11 African countries and three from stands in New Caledonia) were established (Table 4.1 – see the section GENETIC MATERIAL below) The Melville Island plantings had low survival and the Gunn Point trials were not thinned. However, the stocking at Gunn Point has been slightly reduced, as some of the better trees were utilised for timber by the Prison Farm, established in the area.

In more recent studies, *Khaya senegalensis* has also performed well in terms of survival and early growth over a range of different sites and soil types (Clark 2003). Furthermore, observations in these plantings (1999 to 2001) confirm those in the older plantings, viz. that the species is not attacked by shoot borers in the NT.

Prolific natural regeneration of *K. senegalensis* is clearly evident within and especially immediately adjacent to the edges of the stands planted at Gunn Point in the early 1970s. Significantly, however, such regeneration does not extend more than a few metres beyond the edge rows of the parent trees. Similar observations have been made at other localities in the NT where the species has been planted long enough for natural regeneration to occur, eg Darwin, Howard Springs, Melville Is. etc. There are a number of other factors that reduce the risk of *K. senegalensis* becoming a weed. These include: lack of a rampant vector for seed dispersal (such is evident with Neem trees in northern Australia where native birds

carry the seed long distances from the source); little chance of fruit setting prior to harvest age (approximately 25 years) which is later than the anticipated rotation age for commercial plantings; the seed is not winged to aid dispersal; the large seed pods fall to the ground mostly under the parent tree (with their seeds); and the timber is extremely valuable so that self sown seedlings (wildlings) would probably be managed to some degree, ie thinning. However, potential for weediness should be monitored. As with any exotic introduction, weed management plans can be requested with the submission of business and management plans, as has occurred with *Acacia mangium* and Neem in the Darwin region.

A weed risk assessment has been undertaken for *K. senegalensis* in the Northern Territory by Don Reilly and Arthur Cameron (DBIRD) in accordance with a prescription developed by Dr Paul Pheloung (ex-WA Dept of Agriculture). This assessment indicates that the species is “acceptable” and should not be regarded as a threat of weediness in the Top End of the Northern Territory.

The species was also planted on several occasions since the 1960s in the monsoonal tropics of western Cape York, Queensland, especially at Weipa. There, too, it has shown promise (G. Dickinson, pers. comm., 2003). It is also being tested in the Mareeba region of north Queensland (K. Robson, pers. comm., 2003).

The provenance trials in the NT comprise the broadest-based, extant collections of the species in Australia, if not the world. However, uncertainty exists as to the future security of these valuable plantings at Gunn Point due to wildfires, possible land tenure changes and development proposals in the area.

There are a number of prospective growers in the NT and interstate who are keen to plant *K. senegalensis*, especially if genetically improved planting stock is developed. This increasing interest in the species from commercial entities and farm foresters across the tropical north of Australia, and the clear need to conserve and improve the unique genetic resource held in the NT, prompted the project team to establish a gene conservation bank and a clonal seed orchard on more secure sites closer to Darwin.

4.2 Objectives

- Conserve a broad sample of the genetic resources of *K. senegalensis* from the unique, existing plantings in the NT in secure facilities located conveniently for maintenance, so as to capture the germ plasm and secure it against loss.
- Establish and manage a clonal seed orchard (CSO) in a secure location to serve as an improving seed source for anticipated plantings in the NT at least
- Establish a back up, gene conservation bank at a second, secure location

4.3 Methodology

Background

No seed orchards/seed sources of *K. senegalensis* have been established in the NT nor in Queensland. In reality, a CSO would be appropriate for seed production and conservation of the species, regardless of its pollination system, provided the vector/s required for pollination were present in the CSO site. The fact that viable seed is produced by *K. senegalensis* in the NT, evidenced by the common presence of natural regeneration under and beside old trees, confirms the appropriateness of adopting conventional seed producing facilities for this species.

Establishment of a CSO with a large number of clones (around 100) from trees selected within the Gunn Point provenance trials and a few other local sources will enable both gene conservation and a staged, genetic improvement of the population, eg via culling of the CSO as information on the relative breeding value potentials of the clones becomes available. As well, such a large number of clones should ensure adequate cross pollination (assuming this is the pollination system in the species) among any subsetting of the species caused by different provenances flowering at different times throughout the year.

The CSO approach was preferred to the potential alternative of a seedling seed orchard (SSO) for several reasons:

1. The provenance trials in the Northern Territory were un-thinned and seed would only have been available from the edge trees, thus limiting the number of trees available to the program.
2. Seed collections in these provenance trials often resulted in little or no viable seed being obtained (possibly due to premature collection through inexperience with seedpod collection of this species).
3. The trees in the provenance trials generally had poor form, so establishing the best of them in an area isolated from the pollen of inferior trees would maximise the initial genetic gain from sexual reproduction.
4. A CSO of *K. senegalensis* should flower much earlier than a SSO as the scions collected to establish the CSO will be from physiologically aged sections of the selected trees, and will therefore be predisposed to flowering.

As well, it is desirable to “conserve” the genes of the selected trees in a second, secure location, known as a clonal conservation bank (CCB), as insurance against loss of clones in the CSO.

Genetic Material

A list of the provenances in the various, replicated trials that were screened to select trees for the project is given in Table 4.1. In all approximately 10 ha of stands were screened, mainly at Gunn Point, NE of Darwin.

Although these old (around 30-yr), unthinned stands (examples shown in Figure 4.1) were not ideal for screening (edge effects and uneven survival led to inequality of growing space per tree), they represent a remarkably broad base of provenances and a rather large number of trees. As well, the trees selected for the CSO will have known adaptation to the local environment.



Figure 4.1. A view in July, 2000 of *K. senegalensis* trials EP 420 and EP388 at Gunn Point. Selected tree number 4 (D500 - Ghana), dbhob 41.7 cm and bole length of 11.0m), is on the left, and number 19 (D487 - New Caledonia ex Ivory Coast), dbhob 41.2 cm and bole length of 9.0 m, is on the right.

Table 4.1. *Khaya senegalensis* provenance trials screened for superior trees in trials at Gunn Point in the Northern Territory²

Seedlot number	Provenance	EP 388 Gunn Point	EP 363b Gunn Point	EP 420 Gunn Point
D407	Uganda (West Nile)		x	
D408	Uganda (West Nile)		x	
S9620	Uganda (West Nile)	x	x	
S10053	Uganda (West Nile)			x
D415	Upper Volta	x	x	
D416	Upper Volta	x	x	
D477	New Caledonia	x		
D487	New Caledonia (ex Ivory Coast)	x		
D522	New Caledonia (Noumea)			x
S10050	Ivory Coast	x		
D480	Jos Nigeria	x		
D486	Yola Nigeria	x		
D417	Senegal	x	x	
S9392	Senegal		x	
S10066	Senegal			x
D391	Central African	x	x	

² Other provenances were available at Melville Island, however these trials were not screened. In two fertiliser trials at Howard Springs (not detailed here) addition selections of some of the above provenances were also made.

Seedlot number	Provenance	EP 388 Gunn Point	EP 363b Gunn Point	EP 420 Gunn Point
	Republic			
S9368	Sudan		x	
S9687	Sudan	x	x	
D500	Ghana	x		x
D411	Togo		x	

Phenotypic Selection of Superior Trees

Starting in April, 2001 superior trees were selected in the provenance trials in the Gunn Point Forest reserve, and in fertiliser trials at Howard Springs, aiming to select at least four trees per provenance. Selection of trees was relative to neighbours growing with similar, inter-tree competition. Criteria used were: diameter, height, straightness of trunk, length of bole clear of branches, branching habit, crown cover and health. Co-ordinates of each selected tree were recorded and the trees marked so they could be relocated quickly in the future. More than 10 selects were rather outstanding, combining good relative growth, high proportions of clear bole and good straightness.



Figure 4.2. Left pictures - side veneer grafts (left and centre), top cleft (right); right picture – base of a well-established graft 5 months after planting, the finger indicating the position of the graft union.

An inventory of the 123 trees selected (119 at Gunn Point, 2 at Howard Springs and 2 at Berrimah) is presented in Appendix 4.1. Only three provenances had less than four trees selected.

Collection and Grafting of Scions

Scions comprised tips of vigorous shoots as high in the canopy as could be reached safely with climbing ladders where a high pruning saw was used to sever peripheral branches carrying several potential scions (Figure 4.1). Collection began on 25 July, 2001. Testing at the Berrimah nursery of different grafting techniques, applied to wildling plants collected in April-May, 2001 and potted into 4 inch pots or “forestry” tubes (65 mm x 65 mm), began a little earlier using the ‘bud’, ‘side veneer’ and ‘top cleft’ methods. Figure 4.2 (left pictures) shows examples of some such grafts in the nursery at Berrimah.

Initially, ‘side veneer’ grafting gave the best result (20 – 40%) until the humidity began to rise dramatically in late August or early September. During this period survival increased to 80 – 90% and the top cleft method was by far the best and also the quickest to employ. The root stocks were growing actively during this period which probably contributed, along with increasing skill in grafting, to the higher survival rates. Attempts were made to obtain at least 6 ramets per ortet (to provide 4 of each clone for the CSO, and 2 of each clone for the CCB). Regrafting as required was undertaken using more scions from the selected trees. Records

show that some 850 grafts were made in all for an overall success rate of approximately 85%.

All the grafted stock were kept in the shade house (70% shade) with a plastic bag over the scion until vigorous shoot growth appeared, when the plastic bags were removed. The grafts were grown on under shade for a further 2 weeks and then put out under partial shade for another 3 weeks. After this period the grafts were placed into full sun, fertilised with a slow release fertiliser, and watered regularly until planted in the field. Any shoots appearing below the graft union were pruned off at regular intervals.

Reproductive biology of *K. senegalensis*

The breeding system of *K senegalensis* is unknown. However, Dr David Boshier, of the Oxford Forestry Institute, UK (pers comm., 2002), an expert on reproductive biology of rainforest tree species, has advised that some species of *Meliaceae* e.g. *Swietenia humulis*, are highly outcrossed and highly self-incompatible. This is based on evidence from both controlled selfing and isozyme and microsatellite marker work. He also thought, that this would be similar for *K. senegalensis*.

Locations of the CSO and CCB

Howard Springs was chosen as the location for the CSO – it is Territory owned land and only approximately 15 km from the DPIF office at Berrimah. It was previously the former Forest Bureau's reserve for evaluations and experiments on a range of hardwood and softwood species. There are other current trials in the area and it is under active management, including fire control. Any *K. senegalensis* trees likely to shed undesired pollen into the CSO can be removed when the orchard begins to flower adequately, thus avoiding contamination. A site in the Berrimah Agricultural Research Centre grounds was chosen for the CCB. Prior to the tree-trial planting which began in 1995, this area carried a stand of Pangola grass that had been under grazing for some 40 years.

Soils

At Howard Springs, the soil comprises a gravelly massive earth, shallow to moderately deep. The detailed descriptions and chemical analyses for this site are the same as those for the *Eucalyptus pellita* SPA (Appendix 3.1). At Berrimah soils are similar to those at Howard Springs.

Aspects

The CSO area is on a slight slope of 1:250 from the NW to the SE. The CCB area comprises a slight slope running N-S.

Elevations

At the CSO site, the elevation is approximately 40 m.a.s.l., while it is approximately 36 m.a.s.l. at the CCB site.

AMG COORDINATES. CSO: 8620500N Latitude 12° 28' 17/18" S

721500E Longitude 131° 02' 15" E

AMG COORDINATES. CCB: 8624000N Latitude 12° 26' 34" S

709050E Longitude 130° 55' 57" E

Climate

Some climatic details for the Howard Springs area are given in the previous chapter in Table 3 and Appendix 3.3, and for Berrimah Farm in Table 4.2.

Table 4.2. Rainfalls for Berrimah Farm (2001 and 2002) and temperatures for Darwin Airport (approximately 5 km to the north-west).

2001	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Max (C ⁰)	31.7	31.4	31.8	32.6	32.0	30.6	30.4	31.3	32.5	33.1	33.2	32.5
Min (C ⁰)	24.8	24.7	24.5	24.0	22.1	20.0	19.3	20.5	23.1	25.0	25.4	25.3
Rain (mm)	274.2	486.4	318.4	64.8	17.8	0.0	18.8	0.2	0.0	36.2	188.0	188.0

2002	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Max (C ⁰)	34.5	33.9	34.5	34.8	35.3	33.9	33.0	34.1	34.7	36.2	35.9	35.3
Min (C ⁰)	22.5	21.2	21.9	22.6	16.2	15.4	14.6	13.9	19.9	20.4	21.6	20.8
Rain (mm)	139.8	426.8	181.0	80.2	15.7	0.0	0.0	0.0	46.2	28.2	232.2	117.8

Site Preparation and Other Establishment Activities

The original clearing of the Howard Springs area for species evaluation and silvicultural trials took place in the 1960s. The section selected for the *K. senegalensis* CSO required the removal of natural bush regeneration and exotic invaders from previous trials, the predominant species being *Eucalyptus tetrodonta* and *K. senegalensis*. The clearing and windrowing were undertaken in August 2001, and burning of the windrows in October, 2001. Ripping was done across the slope from NE to SW at intervals of 5 m to a depth of 500 mm with a single-tynd implement in October, 2001. No mounding was undertaken.

Glyphosate herbicide at 1.5 litres /ha was applied along planting lines only in November, 2001, followed by another application of Glyphosate and an initial application of Simazine just prior to planting. These and details of other establishment activities are given in Appendix 4.2.

The Berrimah site of the CCB was also deep ripped in to a depth of approximately 500 mm in November, 2001. Occasional ironstone outcrops were encountered during preparation of this site. The weed control was the same as for the CSO at Howard Springs.

Design and Layout of the CSO and CCB

A non-blocked, permuted neighbourhood design for 96 clones was used in both the CSO at Howard Springs (four ramets per clone) and the CCB at Berrimah (two ramets per clone). This computer-based design, which maximises opportunity for crossing between clones, was developed and described by Vanclay 1991.

The CSO comprises 32 rows x 12 trees per row (384 ramets) with an espacement of 5 m x 6 m (333 trees/ha), contains 96 clones and occupies a net area of 1.15 ha. In order to fit the land available, the CCB at Berrimah comprises 8 rows x 24 trees per row (192 ramets) with an espacement of 4.37 m x 5 m (457 trees/ha), contains 94 clones and occupies 0.42 ha. The layouts of the CSO and CCB are shown in Appendices 4.3 and 4.4. Two columns on the southern side of the CCB were planted with surplus stock of clones 16, 21, 122, 85 and 97.

Two additional clones (9 and 10 both from seedlot D522, New Caledonia) were planted beside the designed CSO area at Howard Springs. This brought to 98 the total number of clones that have been established as grafts.

Initial Planting and Refilling

The CSO at Howard Springs and the CCB at Berrimah were planted on 10 - 11 and 13 December 2001 respectively.

A first assessment of survival was undertaken soon after planting. Losses were few – survivals in January, 2003 were in excess of 99% in both the CSO and the CCB. Where a loss for any reason occurred, the vacant position was replanted either with a ramet of the same clone (if available), or of the best clone (based on ortet phenotype) of the same provenance, from the excess stock of grafts that had been kept in reserve in the Berrimah nursery.

The CCB established at Berrimah Farm was treated in exactly the same manner with regard to replacing failed grafts.

In some cases the grafted scions grew very rapidly and the whole plants became unbalanced and bent over. These were staked and some were topped, but most recovered.

Fertiliser

The Howard Springs site was first fertilised on 19 December 2001 and the Berrimah site on 24 December 2001. Each graft received 100 grams of fertiliser placed in two pockets each side of and approximately 25 cm from the stem. The same amount was applied again in December 2002.

Table 4.3. Indicates the amount of each element within the fertiliser applied per hectare (kg) at the two stocking rates when 100grams of fertiliser is given to each tree at establishment.

Trial site	N(6%)	P(13.6%)	K(14%)	S(1.8%)
CSO (333 trees/ha)	1.99	4.5	4.66	0.59
CCB(457 trees/ha)	2.7	6.22	6.4	0.82

Results

Results of the informal testing of different grafting techniques that began on 25 July, 2001, and the overall success rate of 85%, were mentioned above under COLLECTION AND GRAFTING OF SCIONS, and of the highly successful planting under INITIAL PLANTING AND REFILLING. Figures 4.2 (above) and 4.3 show successful grafts in the nursery or field.



Figure 4.3. Left – a general view of the CSO at Howard Springs in May, 2003, age 17 months; right – one of the tallest grafts (of clone 14, 4 m high) in the CSO in May, 2003.

4.5 Discussion of Results

The highly-successful: raising of grafting stock plants, selection of superior phenotypes, collection of scions high in 30-yr-old selected trees, grafting and planting of the CSO and CCB and the full documentation of this work - all first-time activities for the project team has been a remarkable achievement. Although it is possible that a few to several of the clones may not survive until adequate flowering takes place (perhaps in 2007 or so) due to stock-scion incompatibility or other causes, it seems likely that a large number (perhaps more than 80) will survive and flower adequately. In this case, the objectives of the work are highly likely to be achieved.

4.6 Implications

The successful establishment of the CSO means that, within several (perhaps 6) years, farm forestry and industry stakeholders in the NT, at least, can anticipate the ongoing availability of improved *K senegalensis* seed with a known broad and large genetic base that will be suitable for local plantings since the parent trees have been selected for local adaptation (and for other desirable traits). It also means that there will be a sound base from which to undertake a genetic improvement program. Some options for this include: recurrent selection for general combining ability, initially using open-pollinated progeny trials from seed of the orchard clones; and clonal testing from forward selections in progeny trials with deployment via clonal forestry.

The genetic gain obtainable as a result of using seed from the unculled CSO may be significant, even though the heritability of the selection traits in the stands that were screened may be low, and selection intensity was not intensive at about 10 per screen hectare. Even so, the parent selection, plus the isolation of the orchard from contaminating pollen, and its large and broad genetic base, should assure seed superior to that presently available (from stands, single lines or numbers of isolated, individual trees) which may be considerably inbred and give progeny exhibiting inbreeding depression of growth and form.

Thus the near-future availability of seed of genetically-improved quality, potentially obtainable as a result of this sub-project, could have a significant impact on forestry industry development in the NT and elsewhere with this species. It is impossible to quantify such impact in view of the many uncertainties and unknowns – especially when and how extensive plantings of the species might be the rotation length, etc.

The results to date indicate that the initial objectives of establishing both a broadly-based CSO and a back-up CCB have been achieved. The necessary follow-up is now required for the whole objective to become a reality.

4.7 Recommendations for future management

Tending

Weeds and grasses must be kept at a minimum with slashing between the rows and herbicide application within the rows, both to help ensure fire protection, and to enhance height and crown development of the grafts so as to hasten the onset of seed production.

Fertilising

It may be necessary to apply more fertiliser to promote tree growth (especially in diameter and crown spread) and early and regular seeding. Thus tree health and foliage colour at least should be monitored. It is anticipated that when flowering occurs, further applications of fertiliser high in potassium will be required to enhance the prospects of high seed yields.

Thinning

Thinning of the orchard is not planned for the near future as the trees have been planted at a low stocking rate to encourage crown development and early seed production. However, any trees that show very poor development after a few years, such that they are most unlikely to contribute usefully to pollen and seed production, should be removed as the extra space available to neighbours will probably be utilised. Ultimately, it may be possible to undertake some preliminary culling of clones by removing those with very inferior means for form and branching (as revealed by the assessments suggested below), and later of clones with inferior breeding values based on progeny trials (see below).

Measures and Assessments

On going assessments will be maintained to determine when flowering occurs and, when appropriate, assessments of stem straightness, branching, health, flowering and seed production could be considered (in both CSO and CCB to maximise the numbers of observations). This will assist the recording and monitoring of variation in clone performance, perhaps in relation to the initial measures and assessments of the ortets. The data obtained might be of use in undertaking a light culling of clones in the hope of improving the genetic quality of the orchard. The assessment of flowering should be such as to enable a sound decision to be made as to when seed collection for research and operational purposes can be undertaken, ie after a heavy, general flowering.

Seed Collection

The first seed collection for progeny trials and operational plantings should be delayed until after the first heavy flowering of all or nearly all clones present in the CSO.



Figure 4.4. indicates a ramet from clone number 62 (Yola – Nigeria) in the CCB flowering at 22 months after planting.

5. Chapter Five - Taxa Trial planted at Howard Springs in 2002/2003

5.1 Introduction

With an increase in the demand for hardwood timbers predicted, and the supply from native forests diminishing, it is necessary to establish hardwood plantations to meet this shortfall. (Applegate, 1997) The availability of land for establishing hardwood plantations is in the agricultural regions of the Top End of the Northern Territory which range from Darwin in the north to Katherine in the south where the potential for growing millions of hectares of hardwood species is available. Rainfall in this region is highest in the north, MAR for Darwin is 1800ml, decreasing in the south of this region to Katherine that has MAR of 1050ml.

Due to the lack of knowledge on suitable fast growing, marketable dryland species, the Queensland Forest Research Institute (QFRI) has initiated a hybrid eucalypt development program for such regions in Queensland. This cloning and use of hybrid eucalypts has extended Forestry to marginal sites. Ongoing observation and assessment of seedlings planted in this trial for survival, stress tolerance, vigour, and marketability, will enable QFRI to increase its taxa-site data base providing for the establishment of commercial Forestry over large areas, previously non viable.

The testing of pure species taxa is important for comparing their growth and survival to that of the performances of the hybrid species. This will also provide growth performance data for the provenances of tested dryland species.

5.2 Objectives

1. To assess and compare the growth of a number of 'best bet' dryland species.
2. To observe and assess the growth and variation of inter-specific eucalypt hybrids.
3. To compare the growth of hybrid seedlings with pure species eucalypt seedlings and a range of "best bet" dryland species.
4. Evaluate the growth of a suite of species when applying lime to acid soils.

5.3 Methodology

The methodology used for this project is a logical, staged approach for the rapid development of high-yielding forest tree varieties. The stages comprise: parallel testing of 'best bet' taxa (species, provenances and hybrids); development of commercial varieties matched to sites, from the superior taxa; infusion of new genetic material including various locally-produced hybrids; and on-going breeding for refinement of superior varieties. The first of the taxa trials was established at Berry Springs in December 2000, (see chapter 2 of this report). The aim was to replicate that trial at a different site to gain a better understanding of the species over a variety of sites. Most of the soils in the Darwin region are moderately low in pH levels. The addition of Agricultural lime to half of the replicates in the experiment is expected to result in an improved growth response.

Site Preparation

Cultivation consisted of deep ripping lines at 4.0 metre intervals to a depth of 50cm followed by application of agricultural lime directly into the ripped line (treatment plots only). This was followed by further cultivation with off-set disc harrows along all rows about 1.5 metres wide. The secondary cultivation aided with incorporation of the lime into the soil and provided an adequate seed bed in which to plant seedlings. Follow up weed control etc can be seen at attachment of 'Performance table'.

Genetic Material

The species that will make up the treatments will consist of "best bet" species. This is species and specific provenances that are more than likely to be successful in northern monsoonal areas of less than 1000-1800mm /annual rainfall. These species / provenances fall into 8 taxa groups.

Eucalyptus pellita

This species has been established on Melville Is. in 1989, 1992 and recent plantings, and in the Darwin region, in farm forestry planting, over the last few years. It is possibly the most promising eucalypt species, with fast growth, good form, resistance to fungi and some drought tolerance. Planted provenances:

- Melville Island seed orchard bulk (19718)
- Natural stand PNG – Serisa (18199/18955)
- NTH QLD SSO (5203)
- Natural stand PNG – Goe (19207)

Acacia crassicarpa

This acacia has been planted in trials both on Melville Is (since 1992) and the mainland since about 1996. It has shown good growth and wind firmness. On some sites it is comparable to *A. mangium*, but most plantings show better growth and resistance to butt sweep. Timber quality is similar to *A. mangium* and although suited as a pulping species can be used for heavy grade furniture, flooring etc. Planted provenances:

- Fiji Seed orchard bulk (20003)
- Natural stand PNG (19731)

E.camaldulensis.

This species has the widest geographical range of any eucalypt. It has tolerance to drought and high temperatures and occurs on a range of soil types. Timber is construction grade but can be used for poles and furniture. Possible suited provenances:

- Katherine (10537)
- Thailand S.O (20383)

Eucalypt hybrid clones

The camaldulensis x grandis (C x G) – selected clones (Kleinig) have performed well in 98 trials in NQ. The best clones as determined by performance in the NT taxa trial established in December 2000 are:

- Clone 9
- Clone 10
- Clone 11
- Clone 12

Eucalypt hybrid seedlings

There are several inter-specific eucalypt hybrids that are suited to dry regions. The U x G hybrid clones are Dendros clones imported from superior trees grown in South American plantations. They were raised by Yuruga nursery, Walkamin from imported hedges. These parental species are crossed so that the best traits of individual species complement each other. Hybrids that we are testing here are:

- Grandis x Urophylla hybrid clone 58
- Grandis x Urophylla hybrid clone 59
- Grandis x Urophylla hybrid clone 60
- Grandis x Urophylla hybrid clone 61

Corymbia hybrid complex

The *C. torrelliana* x *C. citriodora* subsp. *variegata* are control crosses produced in South east Queensland by QFRI. The seed was a bulk of 250 seeds comprising 5 families with 50 seeds from each family and only the most vigorous seedlings were selected for planting, the remainder were destroyed. The cross represented here is;

- ct2-2 x cv2-6

Exotic dryland hardwood

Khaya senegalensis

This species is an exotic cabinet quality timber tree. Has shown great potential in trial planting in a number of regions in the Top End of the NT including the recent NHT funded Farm Forestry project conducted from 1998 to 2001. The main problem appears to be short bole length, but this should be overcome with provenance selection and breeding program.

- Provenance from a better tree previously selected (No. 118) at Berrimah Farm.

Khaya anthotheca

This species is very similar to *Khaya senegalensis* but usually has a much better form and grows into a large tree. However it requires more moisture and it may not be suited to the harsh dry season. However, insufficient testing of this species has been undertaken on the more suitable coastal plains and monsoon fringe sites. Indications are that it could perform well on such sites.

- Seed was collected from selected street trees in Darwin suburb.

Swietenia humilis

Pacific Mahogany is one of the true Mahoganys (*Swietenia* species) but unlike its close relatives, (*S. macrophylla* and *S. mahoganii*) grows in an area having a similar climate (dry season) to the Top End of the NT. The uses of Mahogany are well known in the furniture industry.

- Seed was sourced from Honduras.

Chukrasia tabularis

Chukrasia is a most attractive timber found in various forest regions of India, Burma, Thailand and Malaysia. The timber is highly prized for high-grade cabinet work and interior joinery. Uses include good class furniture, carving and panelling in solid and veneered forms. In India it is used for medium to heavy construction work for posts, beams and planks. Earlier plantings in the NT during the 1960's of the closely related species *C. velutina* indicated good early survival and form, but poor growth after 2 years.

- Provenance planted is seedlot number 20035 from Thanh Hoa Vietnam based on a provenance evaluation established in Darwin rural area in 1999.

Rosewood evaluations

Pterocarpus macrocarpus

Padauk is an exotic cabinet timber tree. Highly suitable for decorative veneers, high-class furniture, cabinet work, panelling and other types of high-grade interior finish.

- Planted provenance (ATSC # 19852 or 19853)

Pterocarpus dalbergioides

This species has only been recorded from the Andaman Islands in mixed deciduous or semi-evergreen forest on well drained sites up to 100m altitude. The density of the wood is about 775 kg/cubic metre and like Padauk is from the Family Leguminosae. The timber of the two species is very similar in colour and its uses.

- Planted provenance (20235)

Pterocarpus indicus

Narra is an important timber tree of the Philippines, Papua New Guinea and Thailand and in many south-east Asian countries it is a protected species and trade of the timber is controlled. The timber is medium weight, moderately hard to hard (550-900 kg/cubic metre) and the wood is generally reddish and distinctly demarcated from the lighter coloured sap-wood. It is ranked among the finest for furniture, panelling, musical instruments and high grade cabinet work, but is also used as a structural timber for joists rafters and beams. Planting material was sourced locally in Darwin rural area from previous plantings established in the late 1960's. It propagates readily from seed and striplings.

- Striplings for planting were sourced from Howard Springs trials established in 1970's

Pterocarpus santalinus

Amboyna or red sandalwood has its origins in India and is renowned for the deep red dye that the wood yields. The timber qualities are similar to that of Narra.

- Striplings for planting were sourced from Howard Springs trials established in 1970's.

Other Eucalyptus species

C. citriodora

Occurs in drier regions of north eastern and western Queensland on a variety of soils but commonly on poor gravelly soils. Has good timber qualities and is used for construction, framing, flooring and casing. Planted provenance:

- Glenden, CQ (10895)

E. tetradonta

Darwin Stringybark is found only in north Queensland, northern NT and in the Kimberley region of WA. Found on a range of soil type, but prefers well drained sandy soils. Timber is moderately durable and used for poles and general construction. Seed in store is limited. Planted provenances:

- Seed collection – Dry River Station, south west of Katherine

C. nesophila

Melville Island bloodwood is also found only in far north Queensland, northern NT and in the Kimberley region of WA. It was planted in significant areas around Darwin pre-1970. It has grown very well with outstanding form. It appears to be resistant to, or can grow through, the inevitable insect attack. Found on a range of soil type, but prefers well-drained sandy soils. Timber is moderately durable and used for poles and general construction. Planted Provenances:

- Seed collection – Cape York, North Queensland

E. argophloia

Western white gum has a very small natural occurrence in southern Queensland, northeast of Chinchilla where the MAR is 700mm. The tree is medium to tall, up to 40m and is generally of excellent form and the timber has deep red heartwood that is hard, strong and durable that can be used in general construction. In its natural occurrence the soils are red loams or grey-brown clays and clay loams of moderate fertility.

- Seed collected from selected street trees in Kingaroy Qld August – 2000

Plants

All stock was raised at the NT DPIF Forestry Nursery, Berrimah farm. The *Corymbia* hybrid complex and the *Eucalyptus argophloia* seed was direct sown into Hico Trays (40 cells per tray, 93cubic centimetres volume per cell) on 6th to 13th September 2002 respectively. Individual plastic inserts were used in each cell of the Hyco trays, so as to make sorting for height and vigour much easier in the nursery phase.

The other Eucalypt species, the Acacia species and the Chuckrasia were all sown in the first week in August into flat trays and pricked out into Lannen 35 trays (270 cubic centimetre cells). The mahogany seed was sown into larger trays and pricked out into individual forestry pots (540 ml). Germination of the above species commenced within a range of 12-20 days. Striplings of *Pterocarpus santalinus* and *Pterocarpus indicus* were dug up from under existing plots at Howard Springs plantation and potted on into forestry pots. The *Pterocarpus macrocarpus* seedlings were bought from an outside nursery, and were in the Lannen 35 trays.

The potting mix consisted of 25% clean course Mary River sand, 50% Coco Peat and 25% mixture of Vermiculite and Perlite (50-50). A slow release fertiliser (Osmocote 9-12 months) was added to the potting mix at a rate of 6 kg/m³. All seedlings were transferred from 60% shade to direct sun 6 weeks after germination. The overall quality of the seedlings was good and height ranged to 45cm. Some of the taller Eucalyptus species had to be topped prior to planting because of their excessive height.

Rhyparida beetles (swarming beetles) were noticed in the nursery on 27/11/02 and from previous experience, their uncontrolled activity in the nursery resulted in most plants being completely defoliated and in some cases plants died. To avoid a repeat of the situation, an application of Rogor, (Dimethoate) at 1 ml / litre was sprayed over all plants in the nursery on 28/11/02. As a result, many of the plants received leaf burn due to the warm weather. This was especially so for the Eucalyptus and Corymbia species that had many of their leaves actually die and fall off. Within two weeks most plants had begun to recover and new growth was evident on most plants. In some cases deaths did occur, but it was fortunate that enough young plants were propagated initially to make up for the deaths. Only the best and healthiest plants were put into the trial after much sorting. This event did, without a doubt slow growth, and in some cases retarded growth and development of some plants. By the time of planting, most plants had grown through the set back and the few that hadn't were removed from the planting program. Only the most vigorous seedlings were planted into the trial. During the hardening-off stage in the nursery it was necessary to top the *E. camaldulensis* and *E. pellita* seedlings to restrict the overall height and make seedlings more robust.

The *Eucalyptus grandis* x *Euc. camaldulensis* hybrid clones and the *E. grandis* x *E. urophylla* hybrids were produced by Yuruga nursery in North Queensland and were very healthy and vigorous. The plants had been topped at some stage of propagation to reduce height and new growth was flourishing when the plants reached Darwin. All stock was tagged for field entry identification purposes prior to planting. Clone number 10 of the G x C hybrids suffered from gall wasp attack at Yuruga and only minimum numbers were available for shipment to Darwin. Sufficient numbers were available of clone number 10 to plant all replicates and there was no need to substitute with another clone number.

Design and Layout

The design is a randomised complete block with 4 replications. Plot size is 24 trees, 4 rows x 6 trees. Spacing is 4 metres between rows and 2 metres between trees. This realises a stocking of 1250 stems / hectare. The net area required is 0.62 ha for the net plots.

For those treatments with more than one provenance, each row within each plot will consist of a different provenance. These provenances will be randomised within each plot.

For example:

- Treatment 1 (*E.pellita*) has 4 provenances, therefore each row within the plot is randomly be allocated to each provenance.
- Treatment 2 (*A.crassicarpa*) has 2 provenances, and *E. camaldulensis* has 2 provenances therefore each row within the plot is randomly allocated to each provenance.
- Treatment 3 (G x C Hybrid clones), there are 4 different clones within this treatment, therefore each seedlot will be randomly allocated a single row within each plot.
- Treatment 4 (G x U hybrids), there is 4 seedlots within this treatment, so allocation is the same for treatment 3.
- Treatment 5 (Corymbia hybrid complex) has only 1 treatment, therefore no within plot randomisation is required. All rows within a plot to be planted with the same hybrid complex.

- Treatment 6 (Exotic dryland hardwoods), there is 4 seedlots within this treatment, therefore each seedlot will be randomly allocated a single row within each plot.
- Treatment 7 (Rosewoods) there is 4 different seedlots so allocation is the same as for treatment 5.
- Treatment 8 (other eucalyptus spp, mixed hardwoods), as per treatment 6.

Planting and Initial Weed Control

The experiment was planted on 31/12/02 –2/1/03. Good rains occurred at planting and follow up days.

Planting positions were determined by measuring and marking all plots with pegs and then laying measuring tape along the lines and planting at 2 metre intervals. Holes were made using planting shovels for the plants in individual forestry pots and Lannen trays and a round pole was used to make holes for the smaller hico cells where appropriate. Seedlings planted immediately to avoid drying out. Following site preparation in previous months, the planting lines were sprayed with a mixture of Simazine @ 9l/ha and Round-up @ 3l/ha using a one metre boom spray delivering 300l/ha.

Fertilising

An application of NPK Fertiliser (6:14:14:2) at 35Kg P /ha as an Individual Tree Application (ITA) of 200 grams, 6/1/03. The fertiliser was placed in pockets approximately 20cm each side of the trees. It is intended to apply fertiliser again in year two at a rate of 90 grams per tree that will add another 15 kg/ha of P resulting in a total over the two split applications of 50kg of P/ha for the trees planted at 1250 stems per ha. This will result in approximately the same rate of phosphorus that was applied to the initial taxa trial established at Darwin River in December 2000 that was fertilised with one big application of 346 grams of mixed fertiliser (12:12:14:4) at establishment. It should be noted that fertiliser used in this second taxa trial contains only half the available nitrogen, ie 6% as the fertiliser used in the first taxa trial at Darwin River that contained 12% nitrogen. This reduced rate of nitrogen was intended, as the competition from grass based weeds at the Darwin River taxa trial was over whelming and a reduction in the amount of nitrogen applied was intended to reduce this competition. The revised weed control program at the site of second taxa trial by way of increased rates of Simazine should help reduce the competition from weeds also.

Table 1. Fertiliser regime for the Howard Springs taxa trial – December 2002

Element	% Active Element	Kg Element / ha
Nitrogen	6%	15
Phosphorus	13.68%	34.2
Potassium	14%	35
Sulphur	1.8	4.5

Post planting observations during health assessment on 13/2/03 indicated leaves of some species were showing signs of chlorosis (yellowing) and it was thought a trace element deficiency was evident. The species most affected were in treatment groups 6 and 7, the exotic dryland hardwoods and the Rosewoods. Initially it was thought that the lime treatment to replicates 1 and 3 maybe responsible in inhibiting zinc or iron uptake, but the chlorotic symptoms were across all four replicates. Zinc is suspected as being responsible for the symptoms and there was no elemental zinc available in the fertiliser applied at this trial. Previously zinc was available in the fertiliser as a trace element at 1.5% at the Darwin River site. Regardless of the initial deficiency, subsequent observations are indicating that the plants are growing through the problem as new growth and shoots are looking healthy and the new leaves are not showing signs of chlorosis. It is accepted that soils of the Top End of the Northern Territory are deficient in zinc for successful growing of improved pastures and

crops. As reported by Collins et al (2001), African mahogany grown in north Queensland is susceptible to zinc deficiency that maybe easily remedied with a foliar spray of zinc.

Lime Application

The amount of lime required was calculated using the known amount of calcium in the soil determined from the soil test. This amount was then subtracted from a figure considered the minimum adequate for that soil type which is a function of the buffering capacity of the soil type. The resulting figure is the amount of additional calcium required for the soil to be regarded as the minimum adequate amount for the soil type. For the particular soil type at Howard Springs, 600 ppm is considered the adequate minimum level of calcium, (the soils buffering capacity is the factor in determining this figure) and the Howard Springs soil contained 57 ppm at the time of the soil test. This meant a deficit of 543 ppm had to be added to the soil to be regarded as the adequate minimum. A factor of 2.7 is used to convert ppm to kg per hectare that meant a total of 1,446 kg of calcium per hectare was needed on this soil type. The calcium was applied as agricultural lime, which is 38% calcium, (approx.) so a total of 3,858 kg of agricultural lime was needed per hectare.

The trial site was divided into four replicates each containing a block of each treatment randomly allocated in each replicate. The lime was applied to only two replicates and the other two are to act as controls for the liming treatment. The total area of the trial is 6,144 square metres and each replicate covers an area of 1,536 square metres. Each replicate required 592 kg of agricultural lime. Two replicates therefore required 1,184 kg of lime applied. This was done by first deep ripping the planting lines across all replicates and then applying lime directly into the rip lines of reps 1 and 3 only. After a period of about 3 weeks and some early rains, an off-set disc plough approximately 1.5 metres wide was used to cultivate the rows in all four replicates and incorporate the lime in the rows where applied. This operation also assisted in breaking down the large clods and provide a suitable seed bed in which to plant seedlings.

Refilling

Initial measurements of all plants were done on 10/1/03 with some re-filling where required. A health assessment was undertaken on the trial on the 13/2/03, where any deaths were replaced.

Tending

Weeds and grasses have been kept to minimum with inter-row slashing. Follow up spraying for weeds has not been required thus far.

Fencing

Fencing of the entire site was undertaken to ensure security of the site as it is on accessible public land.

5.4 Results

The first measurement was taken on 28/4/03 to indicate plant survival and height. Plant survival at age 4 months (April 2003) was acceptable (83-100%) with the exception of the *Corymbia* complex treatment (67%) and *Eucalyptus argophloia* (17%). Mean height measurements ranged from *P. indicus* (150cm), *A. crassicaarpa*, Fiji SO (148.5cm) to *S. humilis* (31.5cm) and *E. tetradonta* and *E. argophloia* (45cm). See figure 5.1. Due to the very young age of the trial at time of going to print, further statistical analysis has not been possible.

Some trends appear to be evident in the lime versus the unlimed treatments. It appears that the Acacia treatments are showing better growth in the un-limed situation and the legume species, ie the *Pterocarpus* spp are performing better where lime has been applied. (See graph in appendix 5.3).

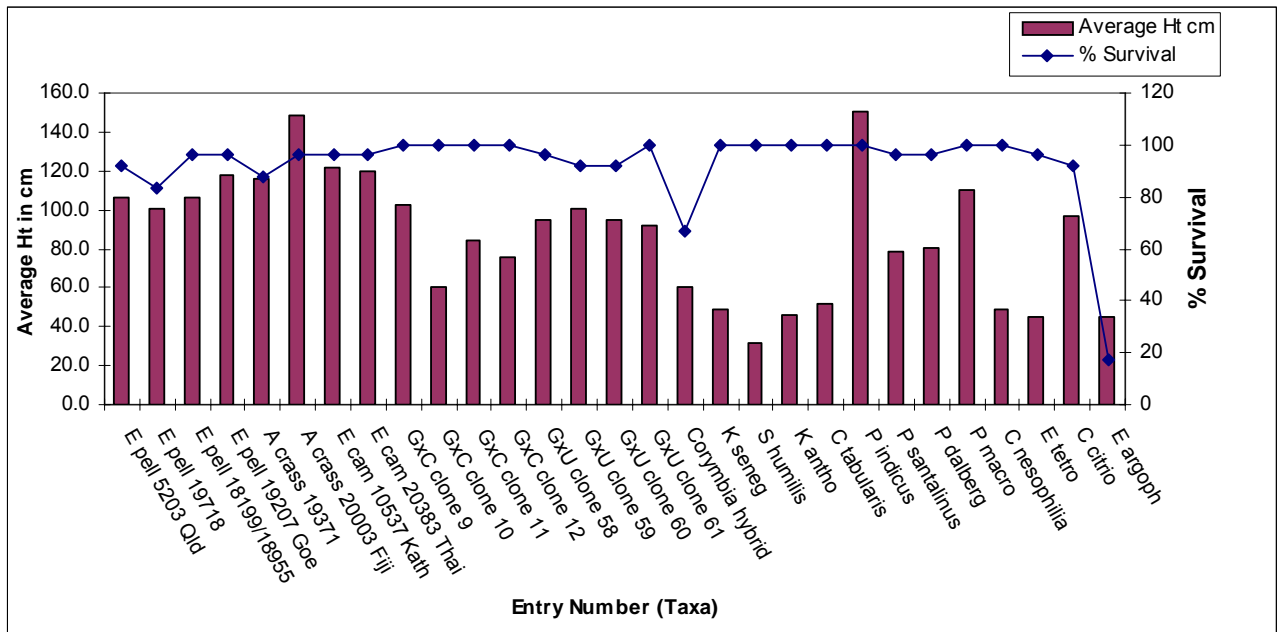


Figure 5.1. Howard Springs taxa trial age 4 months

5.5 Implications

The taxa trial at Howard Springs is the second of two taxa evaluations under taken within this project. The aim of comparing growth of inter specific Eucalypt hybrids with 'best bet' dryland species with pure eucalypt species and exotic hardwoods has been achieved. This experiment has an additional treatment of lime applied to determine the value in terms of raising pH and improving plant performance. This experiment should be viewed as a valuable resource for the on-going evaluation of the better performing species in this trial and for the Top End of the Northern Territory. Based on the preliminary results, there maybe incentive for commercial interests to pursue plantation establishment of some of these species in the future. A commercial plantation company presently operating in the Northern Territory is already trialing eucalypt hybrids as part of its Research and Development program to evaluate fast growing Acacias and Eucalypts for its fibre project.

5.6 Recommendations for future management.

The next stage of this project will be to commence thinning where necessary to allow the remaining trees to express their full growth potential.(Haines, 1986) It is intended that this work will be undertaken in the dry season of 2005 or 2006. All future assessments will include diameter measures so a productivity index score can be calculated to gain more information on volume production and economic potential. The effect of lime application across the two treated plots will be analysed against the two untreated plots.

6. APPENDICES

APPENDICES – CHAPTER TWO

APPENDIX 2.1

Soil description for the Berry Springs taxa evaluation site.

Soil Description for Taxa Trial (Darwin River) site

Soil classification according to 'The Australian Soil Classification' – R. F. Isbell, 1996.

KA AA AG BU B E L O - - Ferric, Mesotrophic, Red, Kandosol; medium, non-gravelly, loamy/clayey, unknown depth

Horizon	Depth (m)	Description
Surface	-	Dry, hard.
A1	0.00 – 0.12	Dark brown (7.5YR3/2) sandy loam; massive structure; earthy fabric; dry, firm consistence; 1%, 4mm, subrounded, ironstone gravel; field pH 5.5; gradual change to
A3	0.12 – 0.20	Dark brown (7.5YR3/4) sandy clay loam: massive structure; earthy fabric; dry, very firm consistence; 1%, 4mm, subrounded, ironstone gravel; field pH 6.0; gradual change to
B1	0.20 – 0.35	Yellowish red (5YR4/6) clay loam sandy; massive structure; earthy fabric; dry, very firm consistence; 1%, 4mm, subrounded, ironstone gravel; field pH 6.0; gradual change to
B21	0.35 – 0.45	Strong brown (7.5YR5/6) light clay; massive structure; earthy fabric; dry, very firm consistence; slightly sticky; 1%, subrounded, ironstone gravel; field pH 6.0; gradual change to
B22	0.45 – 0.57	Yellowish red (5YR5/8) light medium clay; massive structure; earthy fabric; dry, very firm consistence; slightly sticky; 20%, 4mm, subrounded ironstone, 5%, 8mm, subangular, ironstone and 2%, 10mm, subangular quartz gravels; field pH 6.0; gradual change to
B23	0.57 – 0.75	Yellowish red (5YR5/6) light clay, fine sandy; massive structure; earthy fabric; dry, firm consistence; slightly sticky; 5%, 2mm, distinct, red mottles; 2%, 4mm, subrounded, ironstone gravel; field pH 6.0; gradual change to
B24	0.75 – 1.00	Yellowish red (5YR5/6) light clay, fine sandy; massive structure; earthy fabric; moderately moist, firm consistence; slightly sticky; 10%, 2mm, distinct, red mottles; 5%, 4mm, subrounded, ironstone gravel; field pH 6.0; gradual change to

B25	1.00 – 1.45	Yellowish red (5YR5/8) clay loam fine sandy; massive structure; earthy fabric; moderately moist, firm consistence; slightly sticky; 20%, 2mm, distinct, yellow and 10%, 2mm, distinct, red mottles; 25%, 4mm, ferruginous nodules; field pH 6.0; clear change to
B26	1.45 – 2.10	Red (2.5YR) fine sandy clay loam; massive structure; earthy fabric; moderately moist, firm consistence; 25%, 5mm, prominent, red and 10%, 3mm, distinct, yellow mottles; 10%, 4mm, ferruginous nodules; field pH 5.5.



Figure (a). Soil test pit at Berry Springs taxa site

APPENDIX 2.2

Soil chemical analysis for the Berry Springs taxa site.

Site	Depth (cm)	pH units	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	P mg/kg	S mg/kg	TKN %	Zn mg/kg	Cu mg/kg	Mn mg/kg
(a) 1	0-10	6.8	70	710	120	<25	<5	3.5	0.11	0.1	0.9	54
(a) 2	10-25	7.0	30	460	80	<25	<5	3.8	0.06	<0.1	0.9	32
(a) 3	25-40	6.4	30	330	80	<25	<5	3.4	0.04	<0.1	0.6	23
(b) 1	0-10	6.8	30	270	80	<25	<5	3.5	0.09	0.2	0.9	9.8
(b) 2	10-25	6.9	<25	280	90	<25	<5	3.2	0.05	0.6	0.6	6.2
(b) 3	25-40	5.9	<25	260	120	<25	<5	4.1	0.03	0.3	0.4	7.5
© 1	0-10	5.6	40	210	70	<25	<5	4.1	0.13	3.4	1.2	6.4
©2	10-25	7.1	<25	80	40	<25	<5	4.7	0.07	0.5	0.7	1.9
© 3	25-40	7.6	<25	80	40	<25	<5	5.2	0.04	0.4	0.5	1.0

APPENDIX 2.3

Layout of the Berry Springs taxa trial.

Three rows isolation																																																																									
1	5	5	5	5	5	5	5	6	1	1	1	1	1	1	1	1	7	8	8	8	8	8	8	8	14	6	6	6	6	6	6	6	15	9	9	9	9	9	9	9	17	2	2	2	2	2	2	2	24	21	21	21	21	21	21	21	25	6	6	6	6	6	6	6	6	32	18	18	18	18	18	18	18
	4	4	4	4	4	4	4	2	2	2	2	2	2	2	2	2	7	7	7	7	7	7	7	7	14	6	6	6	6	6	6	6	15	10	10	10	10	10	10	10	17	2	2	2	2	2	2	2	24	23	23	23	23	23	23	23	25	6	6	6	6	6	6	6	6	32	17	17	17	17	17	17	17
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	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19	27	27	27	27	27	27	27	19	27	27	27	27	27	27	27	22	7	7	7	7	7	7	7	27	8	8	8	8	8	8	8	30	2	2	2	2	2	2	2		
	6	6	6	6	6	6	6	22	22	22	22	22	22	22	22	22	1	1	1	1	1	1	1	12	18	18	18	18	18	18	18	19</																																									

APPENDICES – CHAPTER THREE

APPENDIX 3.1

Soil description for the *E. pellita* seed production area site at Howard Springs

Soil classification according to 'The Australian Soil Classification' – R. F. Isbell, 1996.

Determination:KA AA AG BU B H L O W – Ferric, Mesotrophic, Red Kandosol; medium, moderately gravelly, loamy/clay, deep.

Horizon	Depth (m)	Description
Surface	-	Moist, firm; 20%, 8mm, subrounded, ironstone and 5%, 4mm, subrounded, ironstone gravels.
A11	0.00 – 0.06	Very dark brown (7.5YR2.5/3) sandy loam; massive structure; earthy fabric; moist, very weak consistence; 15%, 8mm, subrounded, ironstone and 5%, 4mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
A12	0.06 – 0.13	Dark brown (7.5YR3/2) sandy loam; massive structure; earthy fabric; dry, weak consistence; 8%, 4mm, subrounded ironstone and 2%, 8mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
A3	0.13 – 0.24	Reddish brown (5YR4/4) heavy sandy loam; massive structure; earthy fabric; dry, weak consistence; 30%, 4mm, subrounded, ironstone and 10%, 12mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
B1	0.24 – 0.45	Red (2.5YR4/6) sandy clay loam; massive structure; earthy fabric; dry, firm consistence; 14%, 6mm, subrounded, ironstone and 1%, 12mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
B21	0.45 – 0.70	Red (2.5YR4/8) clay loam sandy; massive structure; earthy fabric; dry, firm consistence; slightly sticky; 30%, 6mm, subrounded, ironstone gravels and 10%, 12mm, subangular, weathered parent material, field pH 6.0; gradual change to
B22	0.70 – 1.05	Red (10R4/8) light clay; massive structure; earthy fabric; dry, firm consistence; moderately sticky; 40%, 4mm, subangular and 20%, 12mm, subangular, weathered parent material, field pH 6.0; clear change to
C	1.05 – 2.00+	Weathered parent material.

APPENDIX 3.2.

Soil chemical analysis – results for the Howard Springs seed production area site

Sample position & depth	Depth (cm)	pH units	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	P mg/kg	S mg/kg	TKN %	Zn mg/kg	Cu mg/kg	Mn mg/kg
(a) 1	0-10	5.5	<25	60	30	<25	<5	13	0.06	0.2	<0.1	0.4
(a) 2	10-25	5.7	<25	50	30	<25	<5	13	0.05	<0.1	<0.1	0.6
(a) 3	25-40	5.7	<25	50	50	<25	<5	16	0.04	0.2	<0.1	1.0
(b) 1	0-10	5.9	<25	680	240	<25	<5	5.5	0.15	0.2	0.2	3.0
(b) 2	10-25	6.0	<25	410	200	<25	<5	6.5	0.10	0.1	0.2	3.4
(b) 3	25-40	5.8	<25	250	130	<25	<5	8.3	0.06	<0.1	0.1	2.5
(c) 1	0-10	7.0	<25	380	90	<25	<5	9.4	0.09	<0.1	0.2	1.1
(c) 2	10-25	7.1	<25	370	100	<25	<5	6.9	0.06	<0.1	0.2	2.0
(c) 3	25-40	6.8	<25	260	100	<25	<5	6.1	0.04	<0.1	0.2	2.3

The soil samples were taken at three positions (a to c) across a transect in the orchard area, and at three depths (1 to 3) at each position as indicated in the table.

APPENDIX 3.3

Climate data

Monthly rainfall (mm) 2000 to April, 2003 for Darwin Airport (20 km NW of Howard Springs)

Rainfall	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
2000	441.2	667.4	363.6	307.6	8.6	0.2	0.0	0.0	0.4	77.4	68.8	205.6	2140.8
2001	262.8	429.4	293.4	47.2	7.4	0.0	26.6	0.0	0.0	30.4	164.6	182.0	1443.8
2002	147.6	407.4	247.4	55.8	44.2	0.0	0.0	0.2	26.6	9.0	181.4	94.8	1214.4
2003	466.2	727.2	121.2	12.0									
Mean	421.3	354.9	320.5	100.9	21.2	1.2	1.4	5.7	15.6	71.0	140.8	245.8	1700.3

Summary of monthly rainfall (mm) for Darwin airport using data from 1941-2002

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Median	381.4	348.5	291.4	77.7	4.3	0.0	0.0	0.0	6.2	54.4	140.5	207.1	1683.7
Lowest	136.1	103.3	88.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	17.2	18.8	1024
Highest	940.4	814.5	1013.6	357.0	298.9	41.4	26.6	83.8	129.8	338.7	370.8	664.5	2776.6

Monthly air temperature (C⁰) 2000 to April, 2003 for Darwin Airport

		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
2000	Max (C ⁰)	33.4	34.0	33.0	33.3	33.3	32.8	32.4	35.3	35.9	35.8	35.4	33.5
	Min (C ⁰)	22.2	22.4	21.8	22.5	15.9	12.5	15.7	16.9	19.8	19.0	22.8	24.0
2001	Max (C ⁰)	33.5	34.1	32.8	34.6	34.0	33.6	33.2	33.5	36.6	35.7	35.9	34.5
	Min (C ⁰)	22.4	22.5	22.5	21.7	17.1	18.4	15.6	15.3	19.2	22.1	22.0	22.8
2002	Max (C ⁰)	34.5	33.9	34.5	34.8	35.3	33.9	33.0	34.1	34.7	36.2	35.9	35.3
	Min (C ⁰)	22.5	21.2	21.9	22.6	16.2	15.4	14.6	13.9	19.9	20.4	21.6	20.8
2003	Max (C ⁰)	34.0	33.9	34.9	36.7	35.9							
	Min (C ⁰)	21.0	22.6	22.4	20.7	20.0							

Summary of monthly air temperatures (mean max. and mean min. – °C) for Darwin airport using data for 1941 - 2001

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean Max (C ⁰)	31.7	31.4	31.8	32.6	32.0	30.6	30.4	31.3	32.5	33.1	33.2	32.5
Mean Min (C ⁰)	24.8	24.7	24.5	24.0	22.1	20.0	19.3	20.5	23.1	25.0	25.4	25.3

APPENDIX 3.5

Survival (percent) and (rank) of provenances in each of the 7 refilled blocks of the seed production area at 28 months and overall means and (ranks).

	Melville Is	Serisa PNG	Kiriwo PNG	Goe PNG	Mean
Provenance →	19718	18199/18955	19206	19207	
Block no ↓					
7	81 (1)	81 (1)	69 (4)	72 (2)	76(2)
8	81 (1)	75 (2)	75 (2)	75 (2)	77(3)
11	50 (3)	63 (1)	63 (1)	13 (4)	47(6)
12	69 (1)	31 (4)	37 (2)	37 (2)	44(7)
18	69 (1)	63 (2)	44 (4)	66 (3)	61(5)
20	94 (1)	88 (2)	47 (3)	47 (3)	69(4)
24	88 (1)	81 (2)	81 (2)	69 (4)	80(1)
Mean	76	69	59	54	64.5
Rank	1	2	3	4	

APPENDIX 3.6

Survival (%) in all blocks and plots (provenances) in the seed production area, block and overall means and number of plots with survival < 50% at 28 months.

Provenance →	Melville Is	Serisa PNG	Kiriwo PNG	Goe PNG	Mean
	19719	18199/18955	19206	19207	
Block no. ↓					
1	31.3	12.5	9.4	12.5	16.4
2	31.3	25	18.8	3.1	19.6
3	25	25	3.1	9.4	15.6
4	43.8	31.3	18.8	46.9	35.2
5	50	50	28.1	56.3	46.1
6	56.3	50	15.6	56.3	44.6
7	81	81	69	72	75.8
8	81	75	75	75	76.5
9	68.8	25	37.5	34.4	41.4
10	62.5	25	46.9	28.1	40.6
11	50	63	63	13	47.3
12	69	31	37	37	43.5
13	18.8	12.5	0	0	7.8
14	43.8	18.8	46.9	46.9	39.1
15	62.5	56.3	9.4	34.4	40.7
16	62.5	31.3	28.1	50	43.0
17	50	12.5	3.1	0	16.4
18	69	63	44	66	60.5
19	50	37.5	3.1	0	22.7
20	94	88	47	47	69.0
21	50	56.3	50	46.9	50.8
22	81.3	56.3	78.1	56.3	68.0
23	56.3	62.5	56.3	12.5	46.9
24	88	81	88	61	79.5
25	50	56.3	65.6	9.4	45.3
26	81.3	37.5	59.4	71.9	62.5
27	62.5	50	71.9	40.6	56.3
28	81.3	43.8	34.4	34.4	48.5
29	81.3	50	65.6	12.5	52.4
30	68.8	93.8	46.9	75	71.1
31	68.8	37.5	50	34.4	47.7
32	62.5	62.5	40.6	34.4	50.0
33	62.5	62.5	21.9	43.8	47.7
34	37.5	43.8	9.4	0	22.7
35	50	25	50	34.4	39.9
36	18.8	25	28.1	34.4	26.6
Mean	58.4	46.0	39.4	35.8	44.9
No. plots < 50%	8	18	23	26	

APPENDICES – CHAPTER FOUR

APPENDIX 4.1

Distribution of the numbers of superior trees (119) of *Khaya senegalensis* selected in the trials at Gunn Point by provenances and years of planting. (Four additional trees were selected, two at each of Howard Springs (seedlot D417) and Berrimah Farm (seedlot unknown)).

Seedlot code	Provenance	1970/71 planting	1971/72 planting	1972/73 planting
D391	Central African Republic	7	1	-
D407	Uganda	5	-	-
D408	Uganda (West Nile)	3	-	-
S9620	Uganda (West Nile)	2	3	-
S10053	Uganda	-	-	4
D411	Togo	6	-	-
D415	Upper Volta	4	4	-
D416	Upper Volta	4	5	-
D417	Senegal	5	4	-
S9392	Senegal (69)	5	-	-
S10066	Senegal	-	-	5
S9368	Sudan	2	-	-
S9687	Sudan	5	5	-
D477	New Caledonia	-	3	-
D487	New Caledonia (ex Ivory Coast)	-	6	-
D522	New Caledonia	-	-	4
S10050	Ivory Coast	-	5	-
D480	Nigeria (Jos)	-	6	-
D486	Nigeria (Yola)	-	5	-
D500	Ghana	-	5	6

APPENDIX 4.2

Summary of the details of the establishment and management activities for the *Khaya senegalensis* clonal seed orchard at Howard Springs

Task	Details	Date	Comments
Site clearing of native re-growth and <i>Khaya</i> volunteers		2-5/7/01	Loader used to clear areas of re-growth into single windrow for burning
Rip planting rows	Single tyne plough, (no mounding discs) rows @ 5 metre intervals	15/10/01	
Site preparation	Glyphosate spraying	7/11/01	Rows sprayed @ 1l/ha
Sucker control	Brush off application @ 1mg/1 of water sprayed over all rows.	26/11/01	Tuberous re-growth and volunteer <i>Khaya</i> seedlings were not controlled by previous spraying
Weed control	Simazine and Glyphosate spraying on planting rows using 1 metre boom over 32 rows of 72 metres long	4/12/01	Simazine @ 9l/ha Glyphosate @ 3l/ha
Planting out trees into clonal seed orchard at Howard Springs	Seedlings planted in rows @ 6m intervals and 5m between rows. Holes dug by hand in the ripped lines.	10 & 11/12/01	Good weather during planting with intermittent rain and showers at night.
Planting out trees for back up clonal seed bank	Seedlings planted into rows at 4.37m intervals and 5m between trees	13/12/01	Good weather at planting. 8 rows planted with 24 trees per row
Fertilising trees	100grams of NPK applied in pockets each side of trees	19/12/01 at Howard Sp. 24/12/01 at BARC	NPKS ratio: 6%, 13.6%, 14% & 1.8%
Staking prostate trees & survival count, (only 1 tree dead)	To reduce stress at the graft union, sprawling trees tied to stakes	3/1/02	New shoots below graft union removed where necessary
Weed control	Slashing interrows	16/1/02	Weed growth within rows remains minimal
Weed control	Slashing interrows	As required	
Remove stakes		As required	
Health assessment of CSO and CSB	Assess compatibility of graft union to determine success of graft.	7 & 8/5/02	Rankings given to indicate compatibility.
Measure height @ CSO & CSB	Assess growth performance	26/8/02	Rank performance
Health assessment CSB	Assess compatibility of grafts	6/11/02	Rankings given to indicate success

Task	Details	Date	Comments
Measure height @ CSO	Assess growth performance	28/11/02	Performance ranked
Measure height @CSB	Assess growth performance	2/12/02	
Weed control @ CSB	Spot spraying Glyphosate @ 10ml/litre between trees	9/12/02	
Fertiliser applied	100 grams of NPK in pockets each side of trees	2/12/02 @ CSB 11/12/02- CSO	NPKS ratio: 6%, 13.6%, 14% & 1.8%
Weed control	Slashing interrows & Round-up spraying weeds	12/2/03	
Health assessment and height measurement	Assess growth performance	8/5/03	

APPENDIX 4.3

Layout of the CSO at Howard Springs showing the 12 row x 32 tree matrix and positions of the ramets of the 96 clones that have numbers between 1 and 124. The four ramets highlighted(*) are replacements.

Row no.→	1	2	3	4	5	6	7	8	9	10	11	12
Tree no.↓												
1	85	107	108	60	*8	84	64	118	72	61	19	89
2	1	103	52	78	113	49	42	2	90	55	92	4
3	94	13	73	56	15	38	31	16	36	68	79	101
4	80	27	45	22	25	83	88	6	86	75	95	124
5	121	108	47	29	53	95	98	116	34	33	122	62
6	65	12	92	16	3	55	30	8	73	107	42	17
7	7	26	103	97	14	58	38	123	60	68	78	22
8	86	113	18	72	45	28	21	96	56	46	49	12
9	80	88	62	100	15	90	92	34	119	116	89	50
10	3	91	75	108	124	104	93	78	112	42	47	95
11	45	101	21	119	6	19	37	55	8	72	123	14
12	31	53	68	85	99	64	94	86	66	32	93	27
13	76	14	38	47	56	12	95	60	91	103	33	*94
14	49	124	4	84	102	72	16	7	79	100	89	36
15	25	65	80	45	20	21	25	27	19	96	88	1
16	118	74	55	77	18	1	31	28	49	8	17	26
17	113	116	24	29	6	78	23	33	2	104	107	74
18	13	75	67	37	5	101	83	76	22	123	62	46
19	18	63	3	36	50	58	73	26	13	121	90	77
20	85	92	98	108	52	46	15	61	42	97	34	67
21	5	122	23	7	29	112	24	11	102	28	20	22
22	2	73	38	103	68	84	65	122	96	16	63	83
23	20	66	11	64	121	32	94	97	118	4	61	17
24	98	19	76	30	79	5	53	6	107	67	52	60
25	13	84	1	24	86	74	27	23	89	66	31	99
26	101	37	100	93	36	104	50	2	77	63	102	75
27	85	118	99	113	64	83	94	25	79	112	124	15
28	32	20	5	17	4	90	119	52	11	88	61	91
29	46	23	65	18	76	37	30	3	21	29	14	56
30	67	91	102	50	28	80	7	74	100	104	33	26
31	96	*80	34	24	8	93	63	123	47	58	77	97
32	122	30	*113	99	66	121	116	32	62	119	53	12
Row no.	1	2	3	4	5	6	7	8	9	10	11	12

APPENDIX 4.4

Layout of the CCB at Berrimah showing the 12 row x 24 tree matrix and positions of the ramets of the 96 clones that have numbers between 1 and 124. The ramets highlighted(*) are replacements.

		Tree																			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Row	1	60	100	3	88	93	108	12	66	121	107	34	101	42	116	24	8	6	78	23	33
	2	83	86	104	97	124	92	23	116	80	13	96	50	7	75	67	38	5	101	83	76
	3	45	95	21	58	118	18	37	20	73	52	5	33	72	63	36	29	2	58	73	26
	4	1	53	68	100	112	17	64	122	4	66	85	61	77	92	55	52	88	46	50	42
	5	16	14	61	47	4	86	80	95	91	60	93	75	3	78	34	6	76	79	30	8
	6	49	124	79	84	102	72	16	11	7	103	121	11	38	123	94	102	68	62	36	103
	7	26	65	85	45	20	21	99	27	19	97	74	33	89	47	65	74	56	4	85	90
	8	27	56	3	77	18	121	1	28	49	12	96	29	30	122	15	17	113	119	91	99

Tree

		21	22	23	24		
Row	1	31	123	90	25	16	21
	2	22	104	107	53	16	21
	3	13	62	94	31	16	122
	4	15	98	108	63	16	122
	5	118	113	28	24	16	85
	6	84	55	16	22	16	85
	7	64	14	67	2	16	97
	8	97	3	98	19	16	97

APPENDICES – CHAPTER FIVE

APPENDIX 5.1

Soil Chemical Analysis Test Results for Howard Springs taxa site.

Site	Depth (cm)	pH units	K mg/kg	Ca mg/kg	Mg mg/kg	Na mg/kg	P mg/kg	S mg/kg	TK N %	Cu mg/kg	Mn mg/kg	Zn mg/kg
Hwd Sp 1	0-15	5.3	37	56	38	<25	<5	14	0.1	<0.1	0.6	<0.1
Hwd Sp 2	15-30	5.3	36	58	44	<25	<5	14	0.08	<0.1	0.7	0.2

APPENDIX 5.2

Soil Description for the Howard Springs taxa site

Soil Description for taxa site Howard Springs

Soil classification according to 'The Australian Soil Classification' – R. F. Isbell

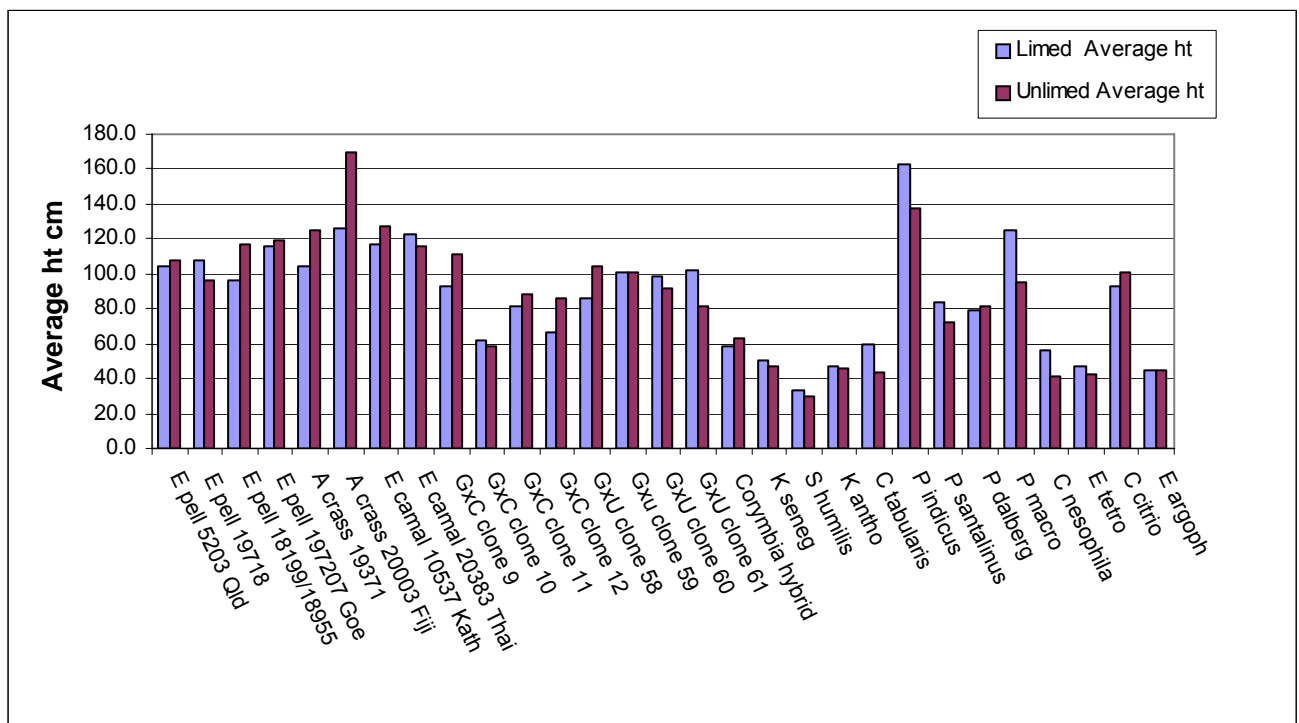
KA AA AG BU B H L O W – Ferric, Mesotrophic, Red Kandosol; medium, moderately gravelly, loamy/clayey, deep.

Horizon	Depth (m)	Description
Surface	-	Moist, firm; 20%, 8mm, subrounded, ironstone and 5%, 4mm, subrounded, ironstone gravels.
A11	0.00 – 0.06	Very dark brown (7.5YR2.5/3) sandy loam; massive structure; earthy fabric; moist, very weak consistence; 15%, 8mm, subrounded, ironstone and 5%, 4mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
A12	0.06 – 0.13	Dark brown (7.5YR3/2) sandy loam; massive structure; earthy fabric; dry, weak consistence; 8%, 4mm, subrounded ironstone and 2%, 8mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
A3	0.13 – 0.24	Reddish brown (5YR4/4) heavy sandy loam; massive structure; earthy fabric; dry, weak consistence; 30%, 4mm, subrounded, ironstone and 10%, 12mm, subrounded, ironstone gravels; field pH 6.0; gradual change to
B1	0.24 – 0.45	Red (2.5YR4/6) sandy clay loam; massive structure; earthy fabric; dry, firm consistence; 14%, 6mm, subrounded, ironstone and 1%, 12mm, subrounded, ironstone gravels; field pH 6.0; gradual change to

B21	0.45 – 0.70	Red (2.5YR4/8) clay loam sandy; massive structure; earthy fabric; dry, firm consistence; slightly sticky; 30%, 6mm, subrounded, ironstone gravels and 10%, 12mm, subangular, weathered parent material, field pH 6.0; gradual change to
B22	0.70 – 1.05	Red (10R4/8) light clay; massive structure; earthy fabric; dry, firm consistence; moderately sticky; 40%, 4mm, subangular and 20%, 12mm, subangular, weathered parent material, field pH 6.0; clear change to
C	1.05 – 2.00+	Weathered parent material.

APPENDIX 5.3

Results showing the difference in heights between limed and unlimed treatments



APPENDIX 5.4

Monthly weather data for Darwin Airport (20 km NW of Howard Springs)

Climate data (rainfall)

Rainfall	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
2000	441.2	667.4	363.6	307.6	8.6	0.2	0.0	0.0	0.4	77.4	68.8	205.6	2140.8
2001	262.8	429.4	293.4	47.2	7.4	0.0	26.6	0.0	0.0	30.4	164.6	182.0	1443.8
2002	147.6	407.4	247.4	55.8	44.2	0.0	0.0	0.2	26.6	9.0	181.4	94.8	1214.4
2003	466.2	727.2	121.2	12.0									
Mean	421.3	354.9	320.5	100.9	21.2	1.2	1.4	5.7	15.6	71.0	140.8	245.8	1700.3

Climate data (mean max. and mean min. using data)for 1941 - 2001

	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mean Max (C ⁰)	31.7	31.4	31.8	32.6	32.0	30.6	30.4	31.3	32.5	33.1	33.2	32.5
Mean Min (C ⁰)	24.8	24.7	24.5	24.0	22.1	20.0	19.3	20.5	23.1	25.0	25.4	25.3

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