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Testing and Breeding Forest Trees for Plantations in the Northern Territory

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Foreword

This project was initiated to provide an opportunity to develop farm forestry in the Northern Territory. The Northern Territory has land available in the 1000 to 1800 mm rainfall zone and considerable potential for agroforestry, if species that can thrive in the extreme climatic conditions and poor soil conditions of the region are identified and adapted. The research reported here is an essential step in determining the adaptability and potential growth rates of high quality forestry species in a range of sites in the region.

The project tested the suitability of selected genotypes of acacias, eucalypts and other potentially useful hardwood species. It also established taxa evaluation trials in the 1000-1800 mm rainfall zone of the Northern Territory to continue these species' breeding and selection.

Four sub-projects were established:

- a dryland taxa trial near Berry Springs, Darwin River to assess and compare imported eucalypt hybrids, pure eucalypt species, 'best bet' local species, and dry zone exotic hardwoods for suitability to the 1000 – 1800 mm rainfall zone. The best performing species in this trial included the fast growing exotic *Pterocarpus macrocarpus* (padauk), fast growing tropical acacias, and *Eucalyptus camaldulensis* (river red gum) from a Thailand seed orchard.
- a *Eucalyptus pellita* (red mahogany) provenance seedling seed orchard (PSSO) intended to develop sources of seed and vegetative material suited to the Northern Territory
- a clonal seed orchard (CSO) and a clonal seed bank (CSB) of *Khaya senegalensis* (dry zone mahogany) to enable gene conservation and genetic improvement of the population
- a second taxa trial planted at Howard Springs (to replicate the first taxa trial at a different site) and to determine the impact of lime on plant performance. Acacias displayed better growth in the un-limed treatment, and *Pterocarpus* spp. showed better performance in the limed treatment.

As a result of the breeding and improvement facilities which were successfully established within this project, the Northern Territory is now in a good position to become self sufficient in producing plantation tree species and provenances suited to the environment of the Top End.

This project was funded by the Natural Heritage Trust through the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations—Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia, and Forest and Wood Products Research and Development Corporation (FWPRDC), together with the Murray-Darling Basin Commission (MDBC). These agencies are funded principally by the Australian Government. State and Australian Governments contribute funds to the MDBC.

This report is an addition to RIRDC's diverse range of over 1600 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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 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 ongoing support with design and collection of data in the field and Mr Nick Kelly for his contribution to trial layout and planting.

Thanks also 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, Yuruga nursery for supply of clonal material and 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 during planting of the trials and subsequent measurements.

We thank Dr Sarah Bruce, Alex Pelvin and Dr Rosemary Lott for review and technical edits to the report.

Abbreviations

AFFS	Agency for Food and Fibre Sciences (now Queensland DPI&F)
ATSC	Australian Tree Seed Centre
CCB	clonal conservation bank
CQ	central Queensland
CSO	clonal seed orchard
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBHOB	diameter at breast height over bark
DBIRD	Northern Territory Department of Business Industry and Resource Development (now Department of Primary Industries, Fisheries and Mining)
GANT	Greening Australia – Northern Territory
ITA	individual tree application
MAR	mean annual rainfall
m.a.s.l	mean height above sea level
NNW	north north west
NQ	North Queensland
NT	Northern Territory
NTCL	Northern Territory Conservation Commission
NWQ	North West Queensland
OP	open pollinated
PNG	Papua New Guinea
QFRI	Queensland Forestry Research Institute (now part of Horticulture and Forestry Science, within Queensland DPI&F)
RCB	randomised complete block
SO	seed orchard
SPA	seed production area
SSO	seedling seed orchard

Glossary

Clonal forestry
Plantation forests comprising genetically uniform planting stock derived from mass propagation of selected superior trees. The planting stock is produced by vegetative propagation techniques such as rooted stem cuttings. An individual clone is comprised of the original selected tree (the ortet) and all of the plants (the ramets) propagated from the ortet. All the plants of a clone are genetically identical. Typically, clonal plantations incorporate a number of different clones rather than just one clone (Harwood and Bush 2002).

Clone
A set of genetically identical cells or individuals produced by vegetative propagation

Grafting
The cut surface of a shoot (the scion) from a selected tree is matched with the cut surface of a seedling (the root stock) and the tissues grow together forming a graft union. The grafted plant is then grown on so that the scion can be represented in a clone bank or a seed orchard (Harwood and Bush 2002).

Graft
A composite plant resulting from affixing a scion onto a rootstock through binding after complimentary surfaces are prepared by cutting the surfaces to allow similar tissues, including cambia, to join through mutual growth

Ortet
The original seedling or tree from which a clone may be produced via vegetative multiplication

Provenance
The place of origin of a population of trees (usually referring to a location of natural occurrence). Can also be used to refer to the seed collected from the provenance location, or the trees raised from the seed. Example: a *Eucalyptus camaldulensis* plantation of Lake Albacutya provenance (Harwood and Bush 2002).

Ramet
A single plant of a set (clone) produced by grafting or other means vegetatively from an original seedling

Root stock
A plant raised for the purpose of having a scion grafted onto it

Scion
Top part of a graft, comprising a vigorous top shoot cut from a selected parent plant for subsequent grafting or propagation

Stripling
A seedling pulled or dug from the wild with consequent partial stripping of roots that may be further reduced before planting

(Definitions provided by Garth Nikles unless otherwise stated.)

Contents

Executive summary

What this report is about

This report is about research to identify and improve forest trees for sawlog production in the Top End (1000-1800 mm rainfall zone) of the Northern Territory (NT). The report outlines the successful establishment of four trials to test species and provenance performance, and to establish breeding and seed production orchards. The species trials tested a wide range of eucalypt, acacia, hybrid and exotic species. Seed orchards were established for red mahogany *Eucalyptus pellita* and African mahogany *Khaya senegalensis*. Early results for growth and species performance are given for the species-provenance trials.

Who is this report targeted at?

This report is intended for use by researchers, industry, and government agencies that are involved in the development of farm forestry and forestry in the Northern Territory (NT) and northern Australia.

Background

A recent analysis identified considerable potential for agroforestry in the NT. This analysis also indicated that genetic development and testing of key species was a major research priority to support the development of farm forestry in the region.

Previous tree evaluation research in the Northern Territory has only occurred sporadically since 1950. Some of that research provided early 'best bet' species recommendations, and locally adapted material for seed and clonal collections. The species and provenances selected for this project are likely to perform well on suitable sites in the NT as they were obtained from previous work undertaken in northern Australia by the Queensland Forestry Research Institute in collaboration with the CSIRO Australian Tree Seed Centre, and the Northern Territory Conservation Commission. Two of the four best bet species previously identified were red mahogany *Eucalyptus pellita* and African mahogany *Khaya senegalensis*, which were recommended for breeding and selection research to improve growth rates and profitability of plantations.

Eucalyptus pellita does not naturally occur in the NT but has performed well in trials planted on Melville Island in 1992 and 1989. 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.

Aims and objectives

This project undertook to test the suitability of important genotypes of acacias, eucalypts and other potentially useful hardwood species for growing as plantation species in the Top End of the Northern Territory. The research also aimed to establish:

- a clonal seed orchard and a clonal conservation bank of *Khaya senegalensis* (dry zone mahogany) to enable gene conservation and genetic improvement of the population
- a *Eucalyptus pellita* provenance seedling seed orchard that aims to develop sources of seed and vegetative material suited to that particular environment.

The project is the first step in a logical, staged approach for 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 from the superior taxa matched to sites; infusion of new genetic material including various locally-produced hybrids; and ongoing breeding for refinement of superior varieties. Following on from this project, the research intends to contribute to ongoing genetic development by establishing breeding facilities in a range of sites in the NT and by further development of improvement facilities in north Queensland.

Methods used

Four sub-projects were established:

- a dryland taxa trial near Berry Springs, Darwin River to assess and compare imported eucalypt hybrids, pure eucalypt species, 'best bet' local species, and dry zone exotic hardwoods for suitability to the 1000 – 1800 mm rainfall zone
- establishment of seed production areas (SPA) of genetically superior *E. pellita* collected from Melville Island provenance progeny trials and selected provenances from Papua New Guinea (PNG) for use in the NT
- clonal propagation of superior *K. senegalensis* provenances identified in the Gunn Point trials and other NT sources to establish a clonal seed orchard and clonal seed bank for the species.
- a second taxa trial planted at Howard Springs to replicate the first taxa trial at a different site and to determine the impact of lime on plant performance.

The dryland taxa trial near Berry Springs southwest of Darwin was planted and fertilised in December 2000 (2000-01 wet season). Measurements were taken in April of each year subsequent to planting.

In the same wet season, the *Eucalyptus pellita* provenance seedling seed orchard was established on crown land at Howard Springs, 20 km south east of Darwin. The composition of the *E. pellita* seed production area was made up of three provenances from natural stands in PNG and open pollinated bulked seed from phenotypically-superior trees selected in the Melville Island provenance-progeny trial.

The *Khaya senegalensis* (African mahogany) clonal seed orchard and clonal conservation bank were established in the 2001-02 wet season at Howard Springs and Berrimah Farm respectively. The source of genetic material was the Gunn Point provenance trials that were established by CSIRO in the 1970-71 wet season. Within the three provenance trials that were screened for selection of superior trees, there were 20 provenances (18 from African countries and two from New Caledonia, ex Ivory Coast) included in the clonal seed orchard. Two additional trees from Berrimah Farm with outstanding characteristics, but of unknown origin, were included. Collection of suitable scion material began in July 2001 with the aim of selecting four trees per provenance. From each tree (ortet) six clones (ramets) were taken to provide four clones for the clonal seed orchard and two for the clonal seed bank. The 'top-cleft' grafting method was chosen after trialling a range of grafting techniques. 850 grafts were made with an overall success rate of 85%. The clone sites were planted out in December 2001.

The second of the dryland taxa trials was established in December 2002 and January 2003 on government land at the Howard Springs site adjacent to the *E. pellita* seed production area. The aims of the other trials included assessment and comparison of 'best bet' species, and the evaluation of lime application to the growth or range of species.

Results/Key findings

This report presents the early results from four sub-projects:

- the three-year results for the dryland taxa trial near Berry Springs
- design and establishment of the *Eucalyptus pellita* provenance seedling seed orchard
- two years of results for the *Khaya senegalensis* clonal seed orchard and clonal conservation bank establishment
- the first year's results for the second dryland taxa trial established at Howard Springs in the 2002-03 wet season.

In the dryland taxa trial near Berry Springs, after three years the best performing species included the fast growing exotic *Pterocarpus macrocarpa,* and the fast growing tropical *Acacia*s and *Eucalyptus camaldulensis* from a Thailand seed orchard. The poorer performing entries (although few) were notable as their persistency was very low or non-existent after only 28 months and susceptibility to insect damage was evident.

The *Eucalyptus pellita* provenance seedling seed orchard was successful established, despite the difficulties in establishment due to rainfall distribution and the giant termite, *Mastotermes darwinensis*. Average survival at 27 months was 64.5%. 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 seed production area can be expected to fulfil its planned function successfully.

The *Khaya senegalensis* (African mahogany) clonal seed orchard and clonal conservation bank were successfully established at Howard Springs and Berrimah Farm. This was the first time that genetic improvement facilities have been established for this species in northern Australia.

The establishment of both the clonal seed orchard and clonal conservation bank was very successful, and when the trees begin to set seed suitable for local plantings, seed will be available for farm forestry activities in the NT and possibly other regions in northern Australia. In addition there is a sound base from which to undertake a genetic improvement program.

In the second of the dryland taxa trials, plant survival at age four months was acceptable (83-100%) with the exception of the *Corymbia* complex treatment (67%) and *E. argophloia* (17%). *Acacias* displayed better growth in the un-limed treatment, and *Pterocarpus* spp. showed better performance in the limed treatment. As only the first year's results are reported here, the results must be regarded as preliminary.

Implications for relevant stakeholders

Breeding and improvement facilities were successfully established within this project at Howard Springs, Berrimah Farm and a private property at Darwin River. As a result, the Northern Territory is now in a good position to become self sufficient in producing plantation tree species and provenances suited to the environment of the Top End.

The implications from each sub-project are as follows:

- The dryland taxa trials are a valuable resource for the ongoing evaluation of the better performing species for the Top End. Based on the preliminary results, there may be commercial interest in pursuing plantation establishment of some of these species in the future.

- Satisfactory survival within the *E. pellita* provenance seedling seed orchard indicated that the seed production area can be maintained for future seed collection. The Howard Springs site is more conveniently located than the Melville Island seed production area, and provides an alternative future seed source, as there is uncertainty that the Melville site will be maintained.

- The successful establishment of the *K. senegalensis* clonal seed orchard means that farm forestry and industry stakeholders in the NT can anticipate the ongoing availability of improved *K. senegalensis* seed. This seed will have a known, broad genetic base that will be suitable for local plantings; the clonal seed orchard could also be used as a basis for a genetic improvement program.

1. Introduction

Timber harvesting by Europeans has been carried out in the Northern Territory (NT) since the mid 19th century. In general, native species suitable for timber production were scarce, the timber was hard, heavy and difficult to work, and the trees often had many defects due to termites. As termite attack was less frequent on the 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 1870s (Bateman, 1955). By 1953, the eight sawmills in the NT were cutting in total less than 3,500m^3 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 led to a low level of productivity in 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 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 were further investigated to refine the nursery and establishment techniques; as well, provenance and/or progeny testing was undertaken with several species. Due to a lack of resources or to deliberately allow expression of genetic potential, many of the plots remained unthinned – and thus results did 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 Island.

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 1960s and 70s resulted in establishment of about 4200 hectares of cypress and Honduras Caribbean pines of reasonable quality, although cypress was very slow growing. An additional 1200 ha of these species was established on the mainland (Haines, 1986).

From the mid-1980s 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 (Applegate 1997) identified four areas on the mainland of the Top End of the NT 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 also revealed that research requirements for the successful development of farm forestry included further species trials for species-site matching; tree improvement activities with a range of species; land capability assessments; and wood processing and utilisation research. Research on wood processing with khaya is the subject of a subsequent report (Armstrong et al. 2007).

Following on from the feasibility study, funding was provided through the Natural Heritage Trust for the Top End Regional Tropical Hardwood Forestry Project. That project aimed 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. To achieve this 24 x 1 hectare sites were established on a range of soil types across the four main agricultural sub-regions of the Top End. 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 three-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. These were *E. pellita, K. senegalensis*, teak *Tectona grandis*, and rosewood *Pterocarpus* spp..

The JVAP project reported here was designed to further evaluate and fine tune species/provenance performance and silvicultural requirements for optimum production. Of the four species recommended from the earlier trial work, two were identified for breeding and improvement work in this JVAP project: African mahogany (*Khaya senegalensis*) and red mahogany (*Eucalyptus pellita*).

1.1 Scope of this project

This project is the first step in 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 from the superior taxa matched to sites;
- infusion of new genetic material into breeding populations including various locally produced hybrids; and
- ongoing breeding for refinement of superior varieties.

The NT Department of Business Industry and Resource Development (DBIRD) (now Department of Primary Industry Fisheries and Mining) collaborated with Queensland Forestry Research Institute (QFRI) for this research project commencing in 1999. The project was 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 germplasm 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 that QFRI (in collaboration with the Australian Tree Seed Centre of CSIRO and the NT Conservation Commission) had undertaken 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, NT. These facilities (seedling and clonal seed orchards, clonal testing and some hybridising facilities) were 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 had out-performed local north Queensland provenances in trial plantings in north Queensland and overseas. As a result, these genotypes were considered likely to perform well on suitable sites in the NT and to be the most genetically superior material available for trial (Nikles, 2000).

c) Many eucalypt species have been tested in the NT and most suffered from drought and insect attack. Among a few exceptional species, *E. pellita* showed promise, especially in tests of adaptability and good growth where it was planted on Melville Island in 1992 (Harwood et al., 1997a). *Eucalyptus pellita* also showed good growth and form in the NHT Farm Forestry plantings undertaken in the three planting seasons between 1999 and 2001 across the Top End of the NT (Clark, 2003) referred to above. It is well known that forest tree species such as *E. pellita* which have 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.

d) 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 JVAP project reported herein aimed to address gaps in past and current work, and advance progress towards achieving viable farm forestry in the Top End of the NT. The report outlines two trials established and monitored to evaluate species performance, and two trials established to create tree breeding, selection and seed orchard facilities:

- Chapter 2: The dryland taxa trial planted near Berry Springs, Darwin River in December 2000

- Chapter 3: The *E. pellita* provenance seedling seed orchard seed production area planted at Howard springs in December 2000

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

- Chapter 5: The taxa trial planted at Howard Springs in 2002-2003.

2. Chapter Two – Dryland taxa trial planted near Berry Springs, NT

2.1 Introduction

In the Northern Territory, interest in establishing hardwood plantation has increased due to predicted increasing demands for hardwood timbers, and diminishing supply from native forests. Further, the land available for establishing hardwood plantations in the tropics is the sub-coastal belt with 1000-1800 MAR – here there is the potential for growing millions of hectares of hardwood species. 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 capitalises on the 13 years of previous genetic improvement work collaboratively undertaken by the NT Conservation Commission (NTCC), AFFS Forestry Research (formerly the Queensland Forestry Research Institute) and the CSIRO's Australian Tree Seed Centre. That collaborative improvement program focussed on improving tropical *Acacia* and *Eucalyptus* species by establishing joint projects in facilities in north Queensland and on Melville Island, NT. These facilities (seedling and clonal seed orchards, clonal testing and some hybridising facilities) were based on seed collections from difficult-to-collect places in northern Australia, Papua New Guinea, West Irian Jaya and other islands in the Indonesian archipelago (Harwood et al., 1994). Many of the genotypes outperformed local north Queensland provenances in trial plantings in north Queensland and overseas. As a result these genotypes were considered likely to perform well on suitable sites in the Northern Territory and to be the most genetically superior material currently available for trials.

The study reported here aims to compare the site suitability of a range of *Eucalyptus* 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 better match species to sites.

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

Chapter 2 targets testing of 'best bet' taxa. This has several elements:

- A replicated trial was established to compare imported eucalypt hybrids, '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, and this has been maintained by the landholder and DPIFM subsequently (D. Reilly pers comm. 2007).

- In the first year trees were measured (by AFFS FR and NT research staff) at six and 12 months. Subsequent measures at 16 and 28 months were carried out by NT Department of Business Industry and Resource Development (DBIRD). Data was entered directly into Husky Hunter hand held field computers and analysed using appropriate statistical packages. This report presents results at 16 and 28 months growth.
- Recommended follow up work is:
  - that subsequent measures occur at yearly intervals for four years.
  - Superior hybrid trees identified in trials will be propagated clonally for further testing.
  - Research findings are published in scientific journals and communicated 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 km 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 were *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. Appendices 2.1 and 2.2 give 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 12º 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 (45km NNW).

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 metre intervals was done on 5 December 2000. 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 and other field management practices are outlined in the 'Performance table' in Appendix 2.4.

Genetic material

Thirty-two (32) taxa were evaluated in this trial, allocated to 8 'taxa' treatments. These treatments were based on taxa that were thought to have potential for the low rainfall zone around Darwin. Specifically these taxa treatments comprise:

1. Eucalyptus pellita

This species was established on Melville Island 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)

2. Acacia crassicarpa

This acacia has been planted in several trials both on Melville Island (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 or flooring. Planted provenances:

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

3. 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 also has other uses. Planted provenances:

- PNG ex QLD SSO (10204)

4. 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 SO (20383)

5. Other eucalypts with potential

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)

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

C. citriodora subsp. *citriodora*

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

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

E. tetrodonta

It is found only in north Queensland, northern NT and in the Kimberley region of WA. Found on a range of soil types, 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

It 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 types, but prefers well-drained sandy soils. Timber is moderately durable and used for poles and general construction. Planted Provenances:

- Local collection North Queensland

6. Eucalypt hybrid clones

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

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

7. 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 Queensland 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

8. 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 with a similar climate (dry season) to the Top End. 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 seedlings were ready for planting in the field. All seedlings were transferred from 60 % shade to direct sun approximately six weeks after germination.

- The *E. pellita* and the eucalypt hybrid seed was direct sown into Hyco Trays (40 cells) during the period 25 to 29 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 course 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/m^3.
- The seed of all the other species was sown into flat trays from 21 to 25 of August 2000, 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 5 cm-30 cm. The smaller stock was mainly *E. cloeziana*, *E. tetrodonta* and *C. nesophila*. All stock was tagged for field entry identification purposes prior to planting.

Design and layout

The eight taxa treatments referred to above were established as a replicated trial. The design was a randomised complete block with four replications. Plot size was 48 trees as 6 rows x 8 trees. Spacing was four metres between rows and two metres between trees. This realised a stocking of 1250 stems per 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 consisted of a different provenance. These provenances were randomised within each plot.
For example:

- Treatment 1 (*E. pellita*) had only three provenances, therefore two rows within the plot were randomly allocated to each provenance.
- Treatment 2 (*A. crassicarpa*) had two provenances, therefore three rows within the plot were randomly allocated to one provenance and three rows were randomly allocated to the other provenance.
- Treatment 3 (*A. mangium*), had only one seedlot, therefore no within plot randomisation was required.
- Treatment 4 (*E. camaldulensis*) had two provenances, therefore three rows within the plot were randomly allocated to one provenance and three rows randomly allocated to the other provenance.
- Treatment 5 (other eucalypts), there were six seedlots within this treatment; therefore each seedlot was randomly allocated to a single row within each plot.
- Treatment 6 (Hybrid clones), there were six different clones, so allocation was the same as for Treatment 5.
- Treatment 7 (hybrid seedlings), there were six hybrids in this treatment, four were *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 Ux G hybrids (entry numbers 25 and 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 15 and 19 of December 2000. Planting positions along the ripped and mounded lines were marked out at two 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 December 2000 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. Ongoing weed control was maintained with applications of Glyphosate (10ml/litre) with hand sprayers and slashing the inter-rows.

Fertiliser application

An application of NPK Fertiliser (12:12:14:4) at 50 kg P/ha as an Individual Tree Application (ITA) of 346 grams on 22 December 2000. The fertiliser was applied in a circle around each tree about 20 cm from the stem.

Refilling
A survival count was undertaken three weeks after planting. The initial survival was 87 %. All dead seedlings 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 were actively growing.

Thinning
The third annual measure of performance was undertaken in May 2003 (trees aged 28 months) and because of this measure, no thinning was undertaken . Ideally thinning will be done within the next few years as the faster growing species reach canopy closure at the high stocking rate of 1250 stems/ha.

2.4 Results

The primary objective when growing these species in the NT is for the production of saw logs for 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 need to be regarded as very preliminary with respect to adaptation and growth.

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 height. This is to be expected with the large range of taxa under test. At 28 months reported here, the trials are too young to predict the best tree taxa for this site in the Northern Territory. At present it is of greater relevance to compare within similar species and treatments to ascertain their performance in a given set of conditions. That is, the most useful comparisons in Table 1 are between similar species/ clones within treatments e.g. within the U x P hybrid clone group. At a later stage it will be possible to compare the best performing individuals from each treatment group with the best from other groups[2]. This intended comparison has been accommodated with the trial design which allocating treatments 1 to 8 among the 32 taxa.

[2] Many hybrids have perished subsequent to the results reported here (D. Reilly pers. comm. June 2007).

Table 1. Comparative growth and survival in the taxa trial planted at Berry Springs at ages 16 and 28 months (April 2002 and 2003 respectively).

Taxa trial		**April 2002**			**April 2003**			
Entry No.	Species	Mean height (mm)	Max height (mm)	Survival %	Mean height (mm)	Max height (mm)	Survival %	Twelve month growth increment
1	*E. pellita* Melville	231.9	430.00	78	398.3	660.0	73	166.4
2	*E. pellita* Serisa	236.3	450.00	67	408.5	720.0	64	177.2
3	*E. pellita* SSO	200.1	380.00	64	371.1	620.0	56	171.0
4	*A. crassicarpa* PNG	321.1	530.00	69	460.0	720.0	67	138.9
5	*A. crassicarpa* Fiji	298.2	460.00	61	425.5	640.0	59	127.3
6	*A. mangium*	419.6	580.00	82	608.8	840.0	76	189.2
7	*E. camaldulensis* Kath	291.2	490.00	92	462.6	700.0	92	171.4
8	*E. camaldulensis* Thai	334.6	505.00	88	504.3	720.0	86	169.7
9	*E. cloeziana* Herb	60.0	60.00	3	0.0	0.0	0.0	0.0
10	*E. cloeziana* Koor	152.2	230.00	6	310.0	310.0	3.0	157.8
11	*E. citriodora* subsp. *citriodora* Hugh	185.3	340.00	53	359.0	550.0	31	173.7
12	*C. citriodora subsp. citriodora* Glend	158.2	290.00	56	292.2	360.0	28	134.0
13	*E. tetrodonta* local	64.7	180.00	59	158.3	260.0	25	93.6
14	*C. nesophila* local	46.9	65.00	50	75.0	110.0	13	28.1
15	G x C hybrid clone 4	246.6	340.00	91	327.9	490.0	91	81.3
16	G x C hybrid clone 10	265.2	410.00	97	371.0	520.0	97	105.8
17	G x C hybrid clone 11	252.6	370.00	91	349.6	460.0	84	97.0
18	G x C hybrid clone 12	274.2	440.00	94	401.4	580.0	88	127.2
19	G x C hybrid clone 13	220.8	330.00	94	300.0	430.0	78	79.2
20	G x C hybrid clone 20	237.1	355.00	75	320.5	450.0	59	83.4
21	UxP (77x34)	271.5	430.00	73	410.0	660.0	73	138.5
22	UxP (77x15)	234.4	380.00	84	407.6	650.0	84	173.2
23	UxP (84x2)	285.0	410.00	88	462.7	670.0	84	177.7
24	UxP (84x15)	240.6	390.00	81	471.0	690.0	65	230.4
25	UxG (5993)	265.0	290.00	13	420.0	460.0	8.0	155.0
26	UxG (10509)	195.0	330.00	50	328.3	560.0	17	133.3
27	*K. senegalensis*	197.9	340.00	81	398.4	540.0	78	200.5
28	*K. anthotheca*	75.0	130.00	34	137.8	230.0	28	62.8
29	*Swietenia humilis*	123.1	285.00	69	289.0	540.0	59	165.9
30	*P. dalbergioides*	114.4	200.00	28	196.7	350.0	19	82.3
31	*P. macrocarpus*	343.7	560.00	97	533.6	700.0	97	189.9
32	*Chukrasia tabularis*	184.2	300.00	75	287.0	420.0	72	102.8

Given the harsh environmental conditions, early survival is a key measure of species suitability to the site. 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. tetrodonta* and *C. nesophila*, at 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 ranged 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 in survival between species within 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), which averaged 4.7 m. The best growth of the *E. grandis x E. camaldulensis* clones was from clone number 12, which attained a mean height of 4.0 m.

The strong variability in growth between taxa indicates strong genetic responses to site and environment.

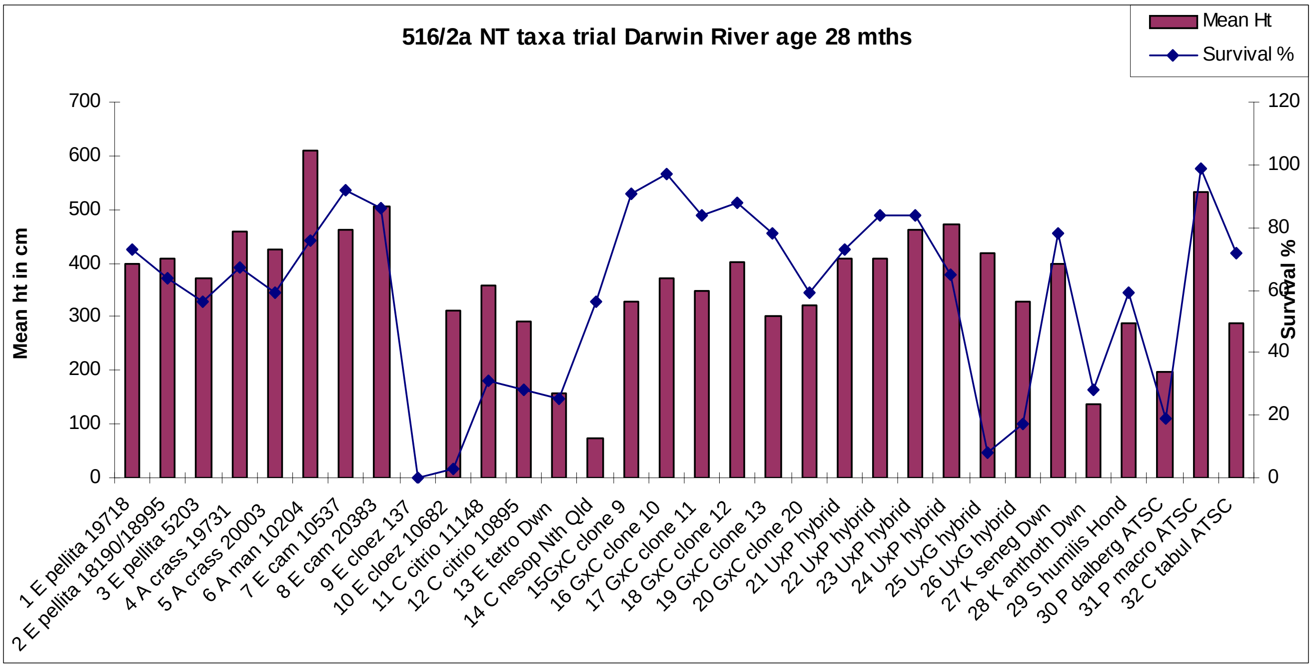


Figure 1. Mean height and survival % of species in at the Berry Springs taxa trial at 28 months. *x*-axis numbers signify entry number, species and seedlot/source.

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 exceeded that of all the *E. pellita*. There was 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.

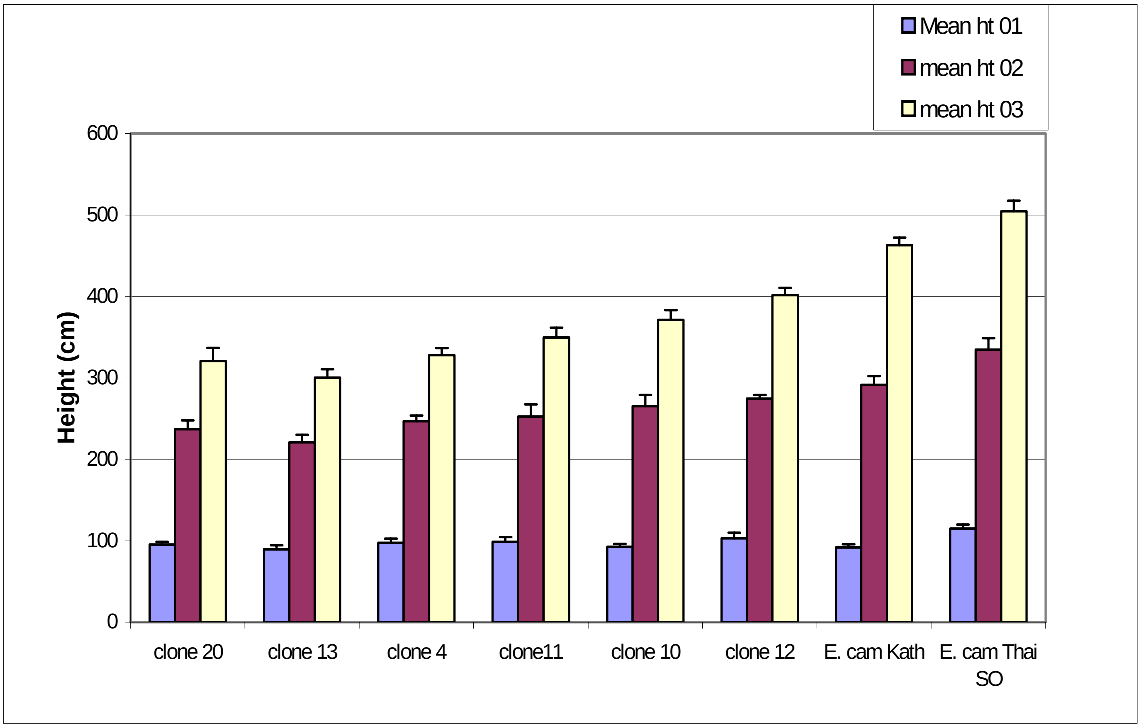


Figure 2. Mean height of *E. pellita* and *E. camaldulensis* at the Berry Springs taxa trial at 4, 16 and 28 months. * Error bars indicate standard error

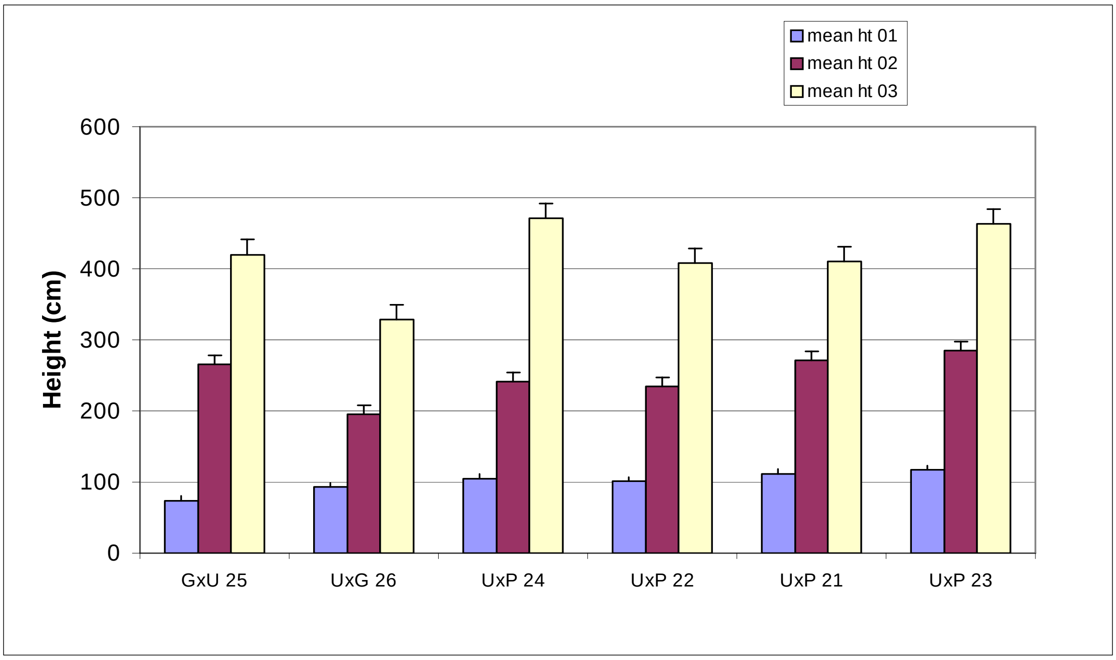


Figure 3. Mean height of U x P and G x U hybrids in at the Berry Springs taxa trial at age 4, 16 and 28 months. Treatments 25 and 26 share a single row in a plot, treatment 21 occupies two rows in a plot, others have one row each. * Error bars indicate standard error.

In the NT most work has been species and provenance evaluations to determine the most promising taxa for further commercial development. It is necessary to study provenance variation because many of the species have extensive natural distributions and the likelihood of important genetic variation.

The advent of improved cloning and hybrid technologies has 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 trial was the eucalypt hybrids thought to be most suited to the tropical dry savannah regions of the NT. These had indicated potential in field trials established in north Queensland during 1998 and 1999. Treatment 7 of the taxa trial had within it six combinations of hybrids made up of *E. urophylla* x *E. pellita* (four entries) and two entries of *E. urophylla* x *E. grandis* (See Table 1). The four entries of U x P hybrids all performed better than the U x G hybrids ($P < 0.05$) at age 16 months.

The second group of eucalypt hybrid clones consisted of six 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 ($P< 0.05$)

The opportunity also existed 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 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.

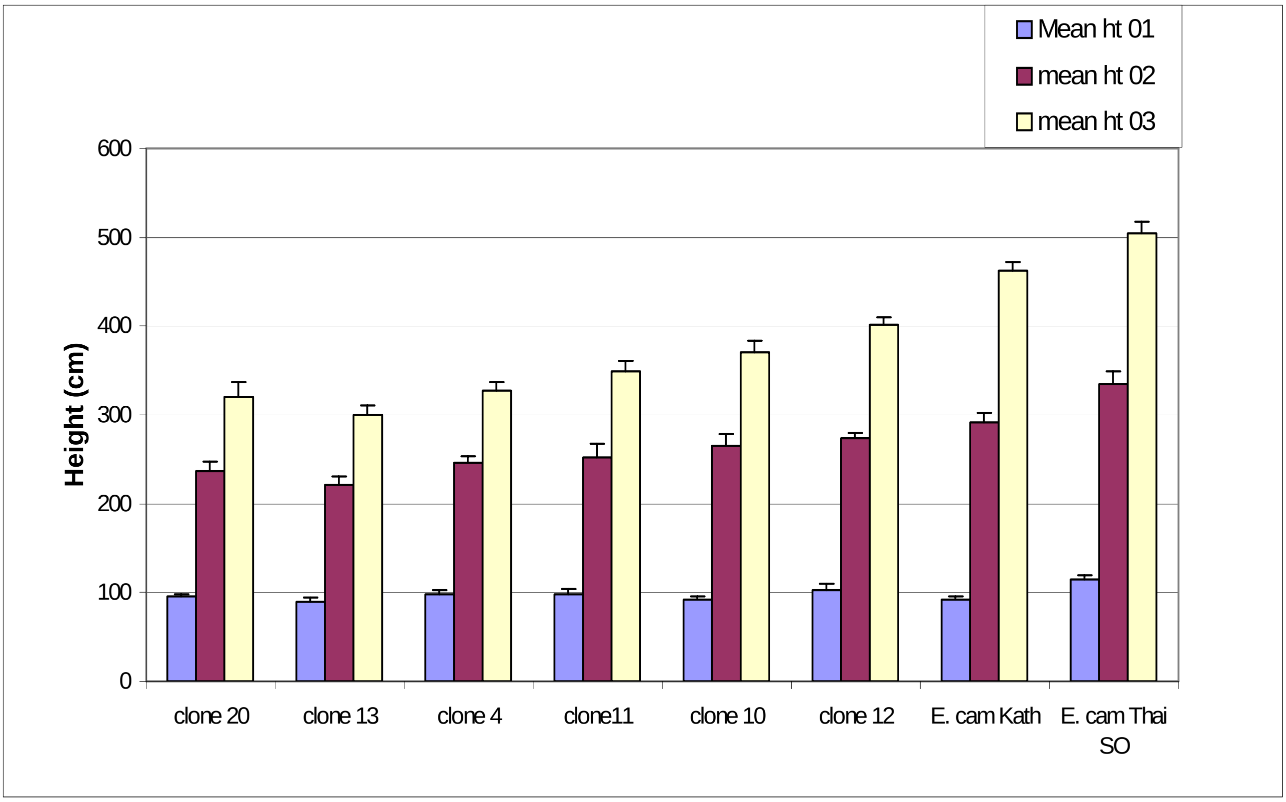


Figure 4. Mean height of C x G clones and two *E. camaldulensis* provenances in at the Berry Springs Taxa trial at 4, 16 and 28 months. * Error bars indicate standard error.

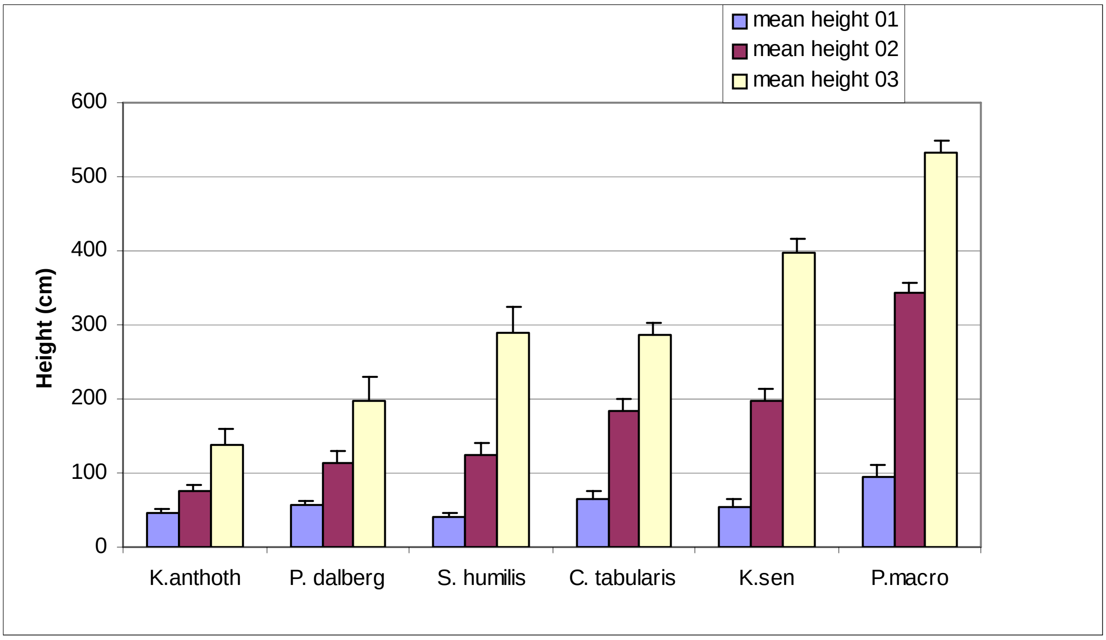


Figure 5. Mean height of the exotic hardwood species in NT taxa trial at 4, 16 months and 28 months. Error bars indicate standard error.

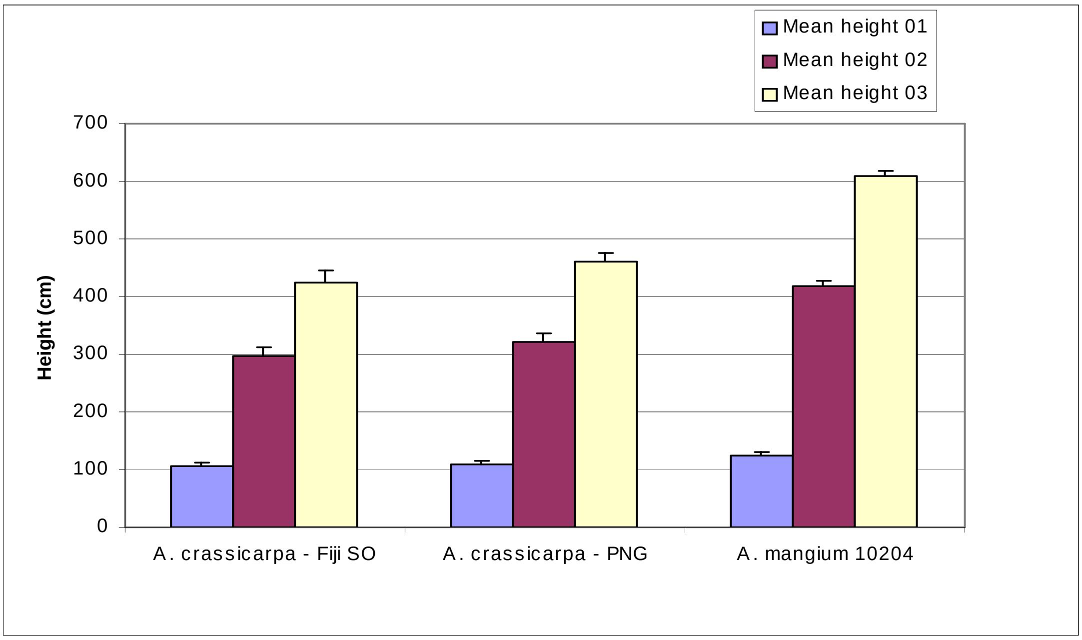


Figure 6. Mean height of *Acacia* species in the at the Berry Springs taxa trial at 4, 16 and 28 months. * Error bars indicate standard error.

Discussion

In the trial at Berry Springs the two best performing taxa at 16 months in terms of height were 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, personal communication, April 2001) and their growth rates will probably reduce as they grow older. The best growth rates achieved at 28 months were *A. mangium*, but the *P. macrocarpus* had overtaken the *E. camaldulensis* as the second best performing species.

It is interesting to note that growth of the interspecific hybrids and clones had not been that spectacular in comparison to local pure species such as *E. camaldulensis* – Katherine (entry 7). The latter entry was made up of collections from wild populations, whereas considerable work had gone into the selection and improvement applied to the hybrids and clones. The hybrids of G x U also exhibited damage from insect attack that may have accounted for early poor performance. Despite that, entries 23 and 24 of the eucalypt hybrids U x P both contained individuals that reached heights of 6.7 metres 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 displayed reasonable growth and survival.

The early results also indicated the genetic material (both pure species provenances and interspecific hybrids) that could be discounted at this early stage based on poor growth and survival rates. The provenances of *E. cloeziana*, *C. citriodora* subsp. *citriodora* and the interspecific hybrids of *E. urophylla* x *E. grandis* do not appear very productive in the NT taxa trial.

The promising early rapid growth of some of the exotic hardwoods in the trial was encouraging, especially the *Pterocarpus macrocarpus* and to some extent *Khaya senegalensis*, which 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. The data reported here is also very early in the life of the trials in the NT and it is therefore difficult to predict the best species and provenances (e.g. Nikles et al., 2000).

Productivity scores were not calculated for any of the taxa at this stage as diameter at breast height (dbh) had not been measured and was a critical component of the calculation.

Fire damage occurred 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 on 25 September 2001 where plots were graded into four categories on the severity of damage. 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 crassicarpa)* was the worst affected. All trees were killed, which 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 form 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 No. 11 (*A. crassicarpa*) the outside row received damage but no deaths were recorded. Plot No. 20 (G x C hybrid clones) and plot No. 21 (*A. mangium*) incurred similar damage and only the external row was affected.

Very little termite damage was incurred on the site. Weed growth was difficult to suppress despite all the efforts of staff and the landowner to maintain a weed free status. The main weed problem was the introduced legume, *Aeschenomene americana* (Glenn joint vetch) and the tall grass *Imperata cylindrica* (blady grass) that grew vigorously after the application of fertiliser at planting.

Figure 9. Example of weed problem in a U x G hybrids at 16 months at the Berry Springs taxa trial

Figure 10. A G x C hybrid clone exhibiting severe insect damage in May 2003 at the Berry Springs taxa trial

Figure 11. *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 was 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 . However some species performed well in terms of growth increments. Some of the better performing individuals 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 31 (*P. macrocarpus;* 1.89 metres) and entry 6 (*A. mangium;* 1.89 metres). All of the U x P hybrids showed 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 was 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 was achieved. This experiment should be viewed as a valuable resource for the ongoing evaluation of the better performing species in this trial for the Top End. 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 NT is already trialling 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 begin thinning where necessary to allow the remaining trees to express their full growth potential (Haines, 1986). Ideally this work will be undertaken in the near future. 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* provenance seedling seed orchard 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 has been increasing local and global demands for timber. To meet the increasing demand for hardwoods, it is necessary to establish plantations with species that are fast growing, stress and pest tolerant and produce marketable timber.

Eucalyptus. 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, personal communication, 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.

Many species of eucalypts have been tested in the NT and most suffered from drought and insect attack. Among a few exceptional species, *E. pellita* has shown promise, especially in tests of adaptability and gave good growth to 3.2 yr planted on Melville Island in 1992 (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 Island, and in the NHT Farm Forestry plantings undertaken in the three planting seasons between 1999 and 2001 across the Top End (Clark, 2003). 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 have shown promise also in the similar, seasonally-dry tropics of north Queensland (Harwood et al., 1997b).

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.

Some *E. pellita* orchards exist, but have not had ongoing management, or have insecure tenure. Although a seedling seed orchard of *E. pellita* was developed on Melville Island by early thinning of the provenance-progeny trial planted in 1992, no further management has been applied. In fact, the tree stumps were 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 Island (a 1998 planting by a private company, Sylvatech) a portion of which could possibly be converted into a seed production area if agreed to by the owners. Other seed orchards exist in north Queensland (Harwood et al., 1997a, b), although only one is being managed actively. Uncertainties about the long-term maintenance of the Melville Island 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 lower on the mainland than on Melville Island, 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 NT
- 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 seedling seed orchard (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 (for example, 1250 trees per hectare) to enable heavy, staged culling to retain the best 125 trees per hectare for seed collections and 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 also deliver significant genetic gains (*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 Island 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 Australian Tree Seed Centre (see below for details). This approach also provided the option to compare the Melville Island 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 30 km southeast of Darwin and approximately 15 km from the Berrimah administration office.

Original vegetation

This comprised open, mixed eucalypt forest with the predominant species being *E. tetrodonta* 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. Appendices 3.1 and 3.2 give a comprehensive description of the soil and results of soil chemical analyses.

Aspect

Slight slope of about 1:100 from the NW to SE. Planting lines were 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, rainfall for Howard Springs Nature Park and temperatures for Darwin airport 20 km to the north are given in Table 3.1 for this period. The critical establishment period was 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^o)	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^o)	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^o)	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^o)	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 one litre per hectare along the rows (only) when weeds emerged following the first substantial rains.

Figure 3. 1. *Eucalyptus pellita* (Melville Island provenance) in the Howard Springs seedling seed orchard in April 2001, four months after planting. Note the mounded rip line with low weed incidence.

Genetic material

Genetic material comprised open-pollinated (OP), bulked seed from phenotypically-superior trees selected in the Melville Island 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.

In total 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 Island, 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 Island 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 Australian 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 began 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/m^3. 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 six weeks after germination. Seedling stock ranged from good (35 cm) to poor (5 cm). Spray drift from Starane used to control weeds in the nursery caused seedling damage and some deaths 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) design was used. Each of the 36 replicates comprised six rows x 16 trees, two rows each for the Kiriwo and Goe provenances, and one 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. Spacing was 4.0 metres between rows and 2.0 metres along the rows, realising a stocking of 1250 stems/hectare. No guard or surround rows were planted, the latter due to shortage of stock. The SPA occupied 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 were regularly tested. One such product was tested in the dry season of 2002 with good results; however it was not registered for use in forestry at the time of the experiment.

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 2.0 m intervals. Holes were made using tree planting ‘pogo’ sticks, and seedlings were planted immediately to prevent them 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. The site establishment and measurement schedule is given in Appendix 3.5.

Fertiliser application

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 interows 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 JVAP project.

Thinning

No thinning was undertaken up to 2003, 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 (trees aged 28 months, all provenance mean heights less than five metres). At the time of writing this report, thinning was anticipated for the 2004 dry season[3].

[3] Due to a lack of NT forestry staff and funds, this trial had not been thinned as at 2007. However attention to the *E. pellita* and taxa evaluation trials is warranted (D. Reilly pers. comm.).

3.4 Results

Plant survival at 27 months (April 2003) in the seven refilled blocks averaged 64.5%, ranging from 54% to 76% among provenances (Table 3.1), and 44% to 80% among blocks (Appendix 3.6). It was highest for the Melville Island (76%) and Serisa (69%) provenances, and considerably less for the Kiriwo (59%) and Goe (54%) provenances. Analyses of the RCB design, with seven 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 Island 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). Plant survival across all plots, provenance and block means, and the numbers of plots per provenance with 28-month survival less than 50%, are shown in Appendix 3.7. These data, too, suggest superiority of Melville Island versus Goe provenance with the other two intermediate (survival %ages of 58.4, 46.0, 39.4 and 35.8 for Melville Island, 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 and give provenance means with the standard error + 1 shown by the vertical bars. Views of trees of two of the provenances are shown in Figure 3.3.

Statistical analyses have not been undertaken because experience shows it would be virtually meaningless when applied to data from trees only 27 months old, and with provenance average heights all less than five metres (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. Data includes 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 increase15-27 months (cm) (and rank)	Survival (%) (and rank)
Melville Island	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)

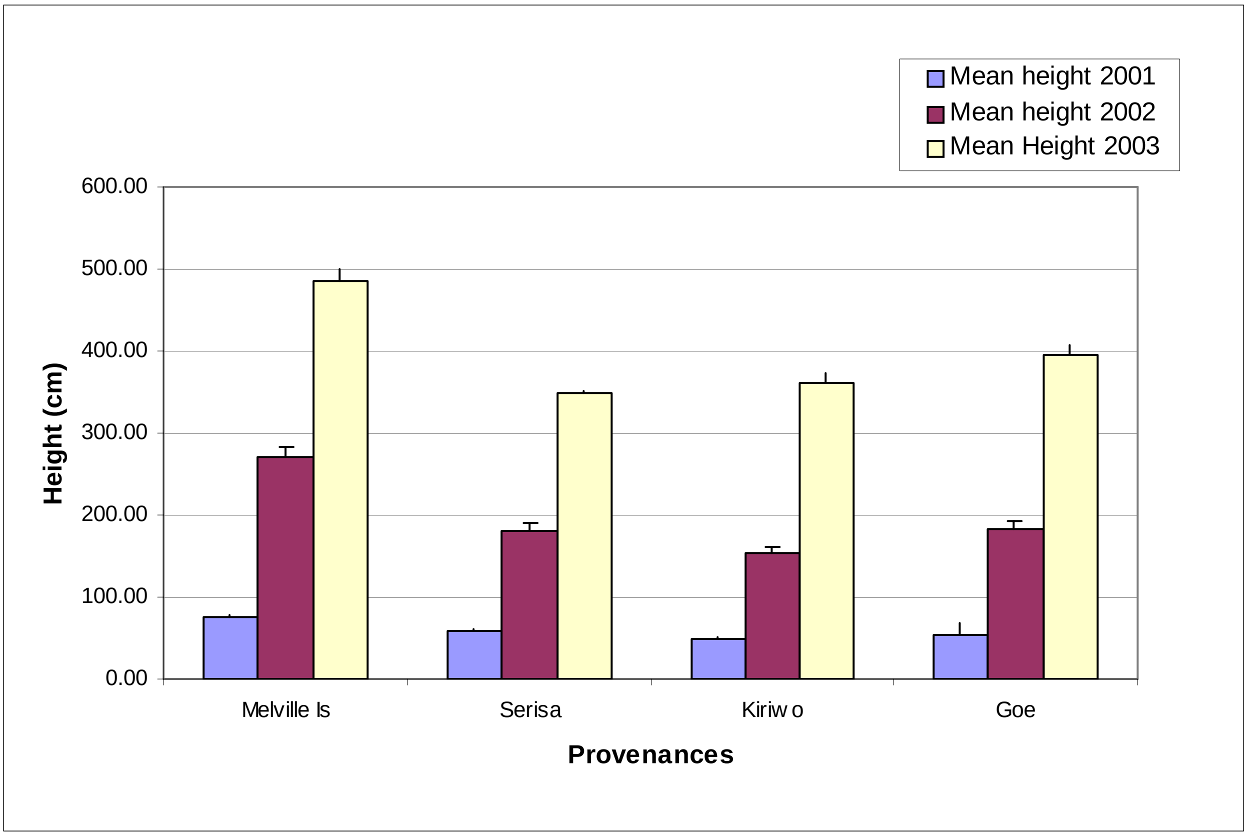


Figure 3.2. Relative height growth of *E. pellita* provenances in 2001, 2002 and 2003 at 4, 15 and 27 months respectively from planting in the Howard Springs seed production area (means of 7 blocks). Error bars indicate standard error.

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 Island 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 was 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. Such early planting is preferred over later planting in the Top End of the Northern Territory (and north Queensland). Based on experience, it normally provides maximum opportunity for seedlings to effectively establish themselves 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 Island versus Goe, it should be noted that the Melville Island provenance had higher and more consistently higher survival than any other provenance (Table 3.2, Appendices 3.6, 3.7). As well, this provenance had by far the smallest number of plots with < 50% survival (8 versus 18, 23 and 26 - Appendix 3.7). 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 shows that the second-generation Melville Island provenance 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, at the time of writing this report, there was still a substantial margin in heights between the Melville Island and Goe and Kiriwo provenances (89.6 cm and 122.3 cm respectively). Note, too, that the Melville Island provenance had the tallest individual trees at each measure (Figure 3.2).

Thus, the Melville Island provenance seems the most promising for growth and survival abased on 27 months data. Both these differences could be expected as the Melville Island 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 Island SSO, and because the seed parents were selected for phenotypic superiority and overall adaptability in the monsoonal tropics of Melville Island. The Serisa provenance seems the least promising for growth as its relative height fell to rank four by 27 months of age, and its 15-27 month increase in height was substantially lower than that of all other provenances.

This SPA comprises a diverse stand. Experience suggests that large, within-provenance variation in growth and other economic traits will result after final culling with 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 the 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 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 regarding whether the only other *E. pellita* seed source in the NT (Melville Island) 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. 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 Island population in the SPA indicates that, pending seed production on superior trees of the Howard Springs SPA, the Melville Island 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 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 spacing of trees within rows (2 m), and the great inequality of survivals in the blocks that are not measured (Appendix 3.7).

In 2003, the experiment plan recommended the following management schedules:

> Thinning schedule:
> 1) 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), depending on development over the remainder of the 2003 dry season. 2) The seven plots with less than 50% stocking would not be thinned. 3) 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. 4) A final stocking of 200 trees/ha seems appropriate in view of some of the present authors' experience 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.
>
> Seed production:
> 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 Island *E. pellita* SSO be encouraged to manage (if possible) and protect it as an interim seed source.

However due to a lack of funds and forestry staff, this schedule has not been undertaken between 2003 and 2007, although good weed control and maintenance has continued at the sites (D. Reilly pers. comm.). Seed was evident on trees in 2006 and flowering indicates a good crop in 2007. However thinning to remove inferior trees is necessary before seed is worth collecting. Further management and measurement of the trial is also warranted, and funds should be made available for this purpose.

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 has a very small but increasing market for forest products locally, and is far from other Australian and most overseas markets, but has opportunities in Asia. 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 in such a harsh environment, farm forestry as well as a plantation industry 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. That 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 three or four replications of 36-tree/49-tree, multi-row plots. Across these trials planted during 1971-1973, a total of 24 introduced provenances were used (21 from natural stands in 11 African countries and 3 from stands in New Caledonia; 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 was slightly reduced as some of the better trees were used for timber by the Prison Farm that was established in the area. These stands provided a resource for selections for the project reported here.

In more recent studies, *K 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.

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 has also been 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.

4.1.1 Weed risk assessment

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, for example Darwin, Howard Springs, Melville Island.

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 until about age 10 which is nearly halfway to the anticipated rotation age for commercial plantings (although ICRAF literature states 25 years, Australian trees have been observed to begin fruiting at 7-10 years of age; G. Nikles pers. comm.);
- the seed is not winged to aid dispersal;
- the large seed pods fall to the ground mainly 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 was 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 indicated that the species is “acceptable” and should not be regarded as a weed threat in the Top End.

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 germplasm and secure it against loss
- establish and manage a 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 prior seed orchards/seed sources of *K. senegalensis* had been established in the NT or in Queensland. 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.

Establishing a CSO with a large number of clones (around 100) from trees selected within the Gunn Point provenance trials and 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 sub-setting of the species caused by different provenances flowering at different times throughout the year.

The clonal seed orchard (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 in 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-years), un-thinned 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 m), 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 Territory[4]

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 Republic	x	x	

[4] 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
S9368	Sudan		x	
S9687	Sudan	x	x	
D500	Ghana	x		x
D411	Togo		x	

Phenotypic selection of superior trees

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 five months after planting, the finger indicating the position of the graft union.

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

Collection and grafting of scions

The scions comprised tips of vigorous shoots as high in the canopy as could be reached safely with climbing ladders. 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 six ramets per ortet (to provide four of each clone for the CSO, and two 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 two weeks and then put out under partial shade for another three 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*, eg S*wietenia 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 *E. 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^o 28" 17/18' S
	721500E	Longitude 131^o 02" 15' E
AMG COORDINATES CCB:	8624000N	Latitude 12^o 26' 34" S
	709050E	Longitude 130^0 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. Rainfall 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-tyned 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 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 a spacing of 5 m x 6 m (333 trees/ha). It 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 a spacing of 4.37 m x 5 m (457 trees/ha). It 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 the total number of clones that were established as grafts to ninety-eight.

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 same method was used at the CCB established at Berrimah Farm to replace 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 application

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

Table 4.3. Amount of each element within the fertiliser applied per hectare (kg) at the two stocking rates when 100 grams 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

As above under 'collection and grafting of scions', the informal testing of different grafting techniques began on 25 July 2001 and the overall success rate was 85% . The highly successful planting was mentioned 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-year-old selected trees, grafting and planting of the CSO and CCB, and 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[5]) 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.

The achievements are:

- Establishment of an alternative site with a genetic resource of the best clones of *K. senegalensis* in a clonal conservation bank and CSO
- Establishment of a future resource for flowering and breeding observations and seed production.

4.6 Implications

The successful establishment of the CSO means that, within several years, farm forestry and industry stakeholders in the NT 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 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 other sources ie. 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 with this species in the NT and elsewhere. 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 managed.

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.

[5] First flowering of the clones occurred at 18 months of age, and a few trees have flowered since in 2005 and 2006. 2007 will hopefully be the first general flowering, suitable for subsequent pod collection (D. Reilly pers. comm.).

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 improve 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. 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

Ongoing 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 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 a predicted increase in the demand for hardwood timbers, 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 – these 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, with a mean annual rainfall (MAR) for Darwin of 1800 mm, decreasing in the south of this region to Katherine that has MAR of 1050 mm.

The first of the taxa trials was established at Berry Springs in December 2000 (see chapter 2 of this report). The aim of the second trial was to replicate the earlier trial at a different site to gain a better understanding of the species performance 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. The testing of pure species taxa is important to provide growth performance data for the provenances of tested dryland species. It is also for comparing pure species growth and survival to that of the performances of the hybrid species.

Results from Queensland research assisted with the design of this sub-project, which included trials of hybrid seed recommended by QFRI. 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 dryland 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.

5.2 Objectives

- to assess and compare the growth of a number of 'best bet' dryland species
- 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
- evaluate the growth of a suite of species when applying lime to acid soils

5.3 Methodology

The main components for the second trial were:

- A series of trials spread across key regions established in the 900-1800 mm MAR zone in the Darwin region of NT. These replicated trials compare imported eucalypt hybrids and 'best bet' local species as well as dry zone exotic hardwoods.
- good silviculture with maintenance of weed free conditions in the first year (and this has been maintained subsequently, D. Reilly pers. comm.).
- lime applied to two of four replicates so as to raise the pH of the soil to an acceptable level for plant growth
- In the future, superior hybrid trees identified in trials will be propagated clonally for further testing.

Location

The Howard Springs Forestry reserve was chosen for the establishment of the second taxa trial. This provided security of land tenure and a location relatively close to the base of project staff (Berrimah). The site is 30 km southeast of Darwin and approximately 15 km from the Berrimah administration office.

Original Vegetation

This comprised open, mixed eucalypt forest with the predominant species being *Eucalyptus tetrodonta* 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. Appendix 5.1 and 5.2 give results of soil analysis.

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	12° 28″ 17/18' S
	721500E	131° 02' 15' E

Table 5.1. Climate data for 2002 for Darwin airport (20 km NW of Howard Springs)

2002	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max(C^o)	34.5	33.9	34.5	35.8	35.3	33.9	33.0	34.1	34.7	36.2	35.9	35.3
Min (C^o)	22.5	21.2	21.9	22.6	16.2	15.4	14.6	13.9	19.9	20.4	21.6	20.8
Rainfall (mm)	147.6	407.4	247.4	55.8	44.2	0.0	0.0	0.2	26.6	9.0	181.4	94.8

Site Preparation

Cultivation consisted of deep ripping lines at 4.0 metre intervals to a depth of 50 cm 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 and other site management details can be seen in the 'Performance table' at Appendix 5.3.

Genetic Material

'Best bet' species were used in the treatments. This is species and provenances that are more than likely to be successful in northern monsoonal areas of less that 1000-1800 mm annual rainfall. These species/provenances were allocated to eight 'taxa treatments', as follows:

1. *Eucalyptus pellita*

This species was established on Melville Island 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)

2. *Acacia crassicarpa* and *E. camaldulensis*

A. crassicarpa

This acacia has been planted in trials both on Melville Island (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. 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 SO (20383)

3. Eucalypt hybrid clones

The *E. grandis* x E. *camaldulensis* (G x C) – 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

4. 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:

- *E. urophylla* x *E. grandis* hybrid clone 58
- *E. urophylla* x *E. grandis* hybrid clone 59
- *E. urophylla* x *E. grandis* hybrid clone 60
- *E. urophylla* x *E. grandis* hybrid clone 61

5. *Corymbia* hybrid complex

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

- ct2-2 x cv2-6

6. Exotic dryland hardwoods

Khaya senegalensis

This species is an exotic cabinet quality timber tree and has shown great potential in trial plantings in a number of regions in the Top End, including the recent NHT funded Farm Forestry project conducted from 1998 to 2001. The main problem appears to be short bole length, but his 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 *K. senegalensis* but usually has a much better form and grows into a large tree. It requires more moisture and 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*) it grows in an area having a similar climate (dry season) to the Top End. 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 1960s of the closely related species *C. velutina* indicated good early survival and form, but poor growth after two years.

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

7. 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)

P. 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)

P. 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 1960s. It propagates readily from seed and striplings.

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

P. 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 1970s.

8. Other eucalypts and mixed hardwoods

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. tetrodonta

Darwin Stringybark is found only in north Queensland, northern NT and in the Kimberley region of WA on a range of soil types, but it 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 types, 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 40 m, is generally of excellent form and the timber has deep red heartwood that is hard, strong and durable, and 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, 93 cm^3 volume per cell) on 6 to 13 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 *Eucalyptus* 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 *P. santalinus* and *P. indicus* were dug up from under existing plots at Howard Springs plantation and potted on into forestry pots. The *P. 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/m^3. All seedlings were transferred from 60% shade to direct sun six weeks after germination. The overall quality of the seedlings was good and height ranged to 45 cm. 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 November 2002 and from previous experience, their uncontrolled activity in the nursery results in most plants being completely defoliated; in some cases plants died. To avoid a repeat of the situation, an application of Rogor, (Dimethoate) at one millilitre per litre was sprayed over all plants in the nursery on 28 November 2002. 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 die and fall off. Within two weeks most plants had begun to recover and new growth was evident. 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 slowed growth, and in some cases retarded growth and development of plants. By the time of planting, most plants had grown through the setback and the few that had not 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 *E. grandis* x *E. 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 eight 'taxa treatments' referred to above were established as a replicated trial. The design was a randomised complete block with 4 replications. Plot size is 24 trees, comprising 4 rows x 6 trees. Spacing is 4 metres between rows and 2 metres between trees. This realises a stocking of 1250 stems per 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*): had four provenances, therefore each row within the plot was randomly be allocated to each provenance.
- Treatment 2 *A. crassicarpa* with two provenances, and *E. camaldulensis* with two provenances therefore each row within the plot was randomly allocated to each provenance.
- Treatment 3 (G x C Hybrid clones): there were four different clones within this treatment, therefore each seedlot was randomly allocated a single row within each plot.
- Treatment 4 (U x G hybrids): there were four seedlots within this treatment, so allocation is the same for treatment 3.
- Treatment 5 (*Corymbia* hybrid complex): had only one treatment, therefore no within plot randomisation was required. All rows within a plot were planted with the same hybrid complex.
- Treatment 6 (Exotic dryland hardwoods): there were four seedlots within this treatment, therefore each seedlot was randomly allocated a single row within each plot.
- Treatment 7 (Rosewoods): there were four different seedlots so allocation was 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 from 31 December 2002 to 2 January 2003. 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 at 9l/ha and Round-up at 3l/ha using a one metre boom spray delivering 300l/ha.

Fertiliser application

An application of NPK Fertiliser (6:14:14:2) at 35 kg P /ha as an Individual Tree Application (ITA) of 200 grams was made on 6 January 2003. The fertiliser was placed in pockets approximately 20 cm each side of the trees. Fertiliser was again applied 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 50 kg of P/ha for the trees planted at 1250 stems per ha. This resulted 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 – established December 2002

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

Lime Application

The amount of lime required was calculated using the known amount of calcium in the soil as determined by the soil test. This amount was then subtracted from a figure considered the minimum adequate amount 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 were controls for the liming treatment. The total area of the trial was 6,144 square metres and each replicate covered 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 replicates 1 and 3 only. After a period of about three 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 January 2003 with some re-filling where required. A health assessment was undertaken on the trial on the 13 February 2003, where any deaths were replaced.

Tending

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

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 April 2003 to determine plant survival and height. Plant survival at age four months (April 2003) was acceptable (83-100%) with the exception of the Corymbia complex treatment (67%) and *E. argophloia* (17%). Mean height measurements ranged from *P. indicus* (150 cm), *A. crassicarpa*, Fiji SO (148.5 cm) to S. *humilis* (31.5 cm) and *E. tetrodonta* and *E. argophloia* (45 cm) (see figure 5.1). Due to the very young age of the trial at time of writing, further statistical analysis was not possible.

Some trends appear to be evident in the lime versus the un-limed 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 5.6).

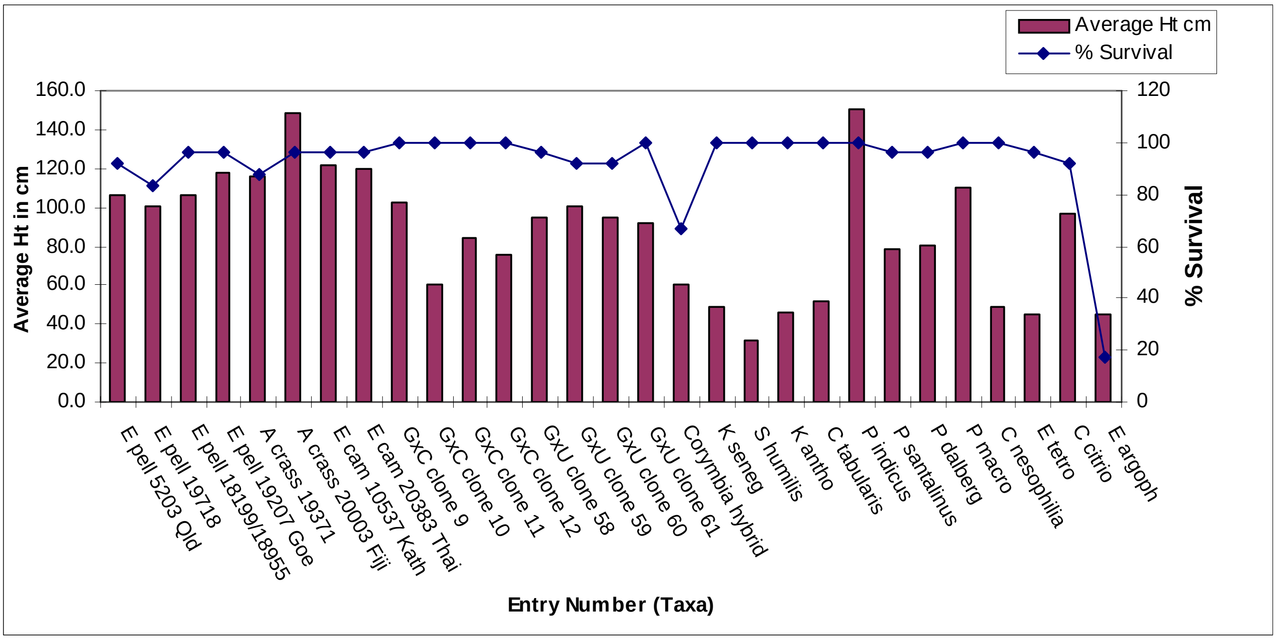


Figure 5.1 Howard Springs taxa trial age four months. (Note G x U should read U x G.)

Plant health

Post-planting observations during health assessment on 13 February 2003 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 may be responsible for inhibiting zinc or iron uptake, but the chloritic symtoms 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 indicated that the plants were growing through the problem as new growth and shoots looked healthy and the new leaves were 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), dryzone mahogany grown in north Queensland is susceptible to zinc deficiency that maybe easily remedied with a foliar spray of zinc.

5.6 Implications

The taxa trial at Howard Springs is the second of two taxa evaluations undertaken 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 had an additional treatment of lime applied to determine the impact of raising pH on plant performance. This experiment should be viewed as a valuable resource for the ongoing evaluation of the better performing species in this trial and for the Top End. 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 trialling eucalypt hybrids as part of its Research and Development program to evaluate fast growing acacias and eucalypts for its fibre project.

5.7 Recommendations for future management

The recommendations for future management of this trial are:
The next stage of this project is to begin thinning where necessary to allow the remaining trees to express their full growth potential (Haines 1986). Ideally this work would be undertaken in the dry season of 2005 or 2006[6]. 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] Thinning not yet undertaken (D. Reilly pers. comm. June 2007).

6. Summary and conclusion

In the Northern Territory, climatic factors and soil deficiencies have generally led to a low level of natural productivity associated with vegetation. Native forest is made up of tropical eucalypts and acacias that have low productivity, which therefore precluded any major timber industry development. Much of northern Australia's agricultural environment comprises pastures in woodland ecosystems, ie savannas. This markedly different to the situation in southern Australia where much of the agricultural landscape has been cleared of trees (Turvey and Larson 2001).

The Top End has a dry monsoon climate. The average rainfall is highest in the north on Melville Island where up to 1800 mm 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 mean monthly maximum temperature falls within the 30^0C (dry season) to 34^0C (wet season). Mean monthly relative humidity changes from moderately high (62%) to high (80%) from the dry season to the wet.

This low soil fertility and extreme climatic conditions, especially the long annual dry period from May to October, are the major limiting factors to tree establishment and survival. Therefore it is essential for thorough evaluation of new species, provenances and hybrids to be undertaken to determine their potential in the climatic environment of the Top End. Observations at measurement times have also noted where specific species are showing susceptibility to insect damage or where termites have been active.

The taxa trial established at Berry Springs was the first of two taxa evaluations undertaken within this project. The second, established at Howard Springs two years later, sought to evaluate the same suite of species and hybrids at a different site with an additional treatment of lime applied to two of the four replicated blocks. Only one measure has been reported on this second trial – at four months old where survival and height growth were recorded. A trend appeared evident between the limed and un-limed blocks. The treatments with *Acacia* species are showing better growth in the un-limed treatments and the leguminous species are performing better where the lime was applied.

The two taxa trials established within this project have achieved the objective of comparing growth of inter-specific eucalypt hybrids with 'best bet' dryland species of eucalypts and exotic hardwoods. This experiment should be viewed as a valuable resource for the ongoing evaluation of the best performing species in these trials. Based on the preliminary results, there may be incentive for commercial interests to pursue plantation establishment of some of these species in the future.

Additional to the taxon evaluations, this project also sought to develop facilities for seed and vegetative production of key species and to improve the capacity for genetic development research activities in the NT. The first of these facilities was established at Howard Springs in 2000. A seed production area (SPA) was established for the very promising *Eucalyptus pellita* using three provenances from PNG and bulked seed from phenotypically-superior trees selected from a Melville Island provenance progeny trial. Initial results (measure at 27 months) have shown the Melville Island seed source to have superior growth to the other three provenances, but only significantly different to the poorer of the three, which was the Goe provenance from PNG. The analysis was undertaken on only seven refilled blocks after planting as survival in the remainder of the blocks was low due to poor rainfall after planting and a high incidence of termites (*Mastotermes darwiniensis*) over the site despite efforts to control them. Although termite damage has been extensive across all the provenances, there is still potential to realise the objective of producing seed best suited to the conditions of the NT. Certainly thinning operations can be reduced as there is less scope for selecting superior trees and culling the rest, but because the termite damage is across all provenances, there is still an even representation of the provenances across the site. The seven (of 36 planted) refilled blocks are being retained at the original stocking to compare the performances of the provenances. Growth measures have been recorded from these seven blocks only.

The second of the genetic improvement facilities was also established at the Howard Springs site, but a year later in the 2001-02 wet season, along with a back up site of a Clonal Conservation Bank at Berrimah Farm. These facilities have now successfully conserved the valuable germplasm of a range of provenances of *Khaya senegalensis* planted at Gunn Point in the early 1970s. The initial method of grafting scion material onto rootstock for clonal propagation proved to be most successful. It is anticipated that the facilities will, within 5-6 years, produce improved seed with a known broad and large genetic base that will be suitable for local plantings. (Small numbers of trees flowered in 2005 and 2006, and a general flowering is anticipated in 2007. Flowering and seeding is being recorded.) The facilities also provide a sound genetic base from which to undertake a genetic improvement program. The necessary follow-up action for genetic improvement will be focused on both selected seed and vegetative re-production using rooted cuttings and field grafting. It is envisaged that the improvement work undertaken within this project could have significant impact on forestry in the tropical north of Australia.

There is increased industry interest in hybrids, *E. pellita* and *K. senegalensis* in northern Australia, and the research trials established within this project form a valuable basis for selecting improved material for plantations. Subsequent to establishing these trials, research effort has concentrated on the *Khaya* trials in collaboration with Queensland DPI&F, section Horticulture and Forestry Science. However attention to the taxa evaluation and *E. pellita* trials is also warranted, in particular to measure tree growth and thin stands in the near future, and to collect subsequent improved seed. Further funding is warranted to support continued management of the trials, in order to realise the prior investment.

7. 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

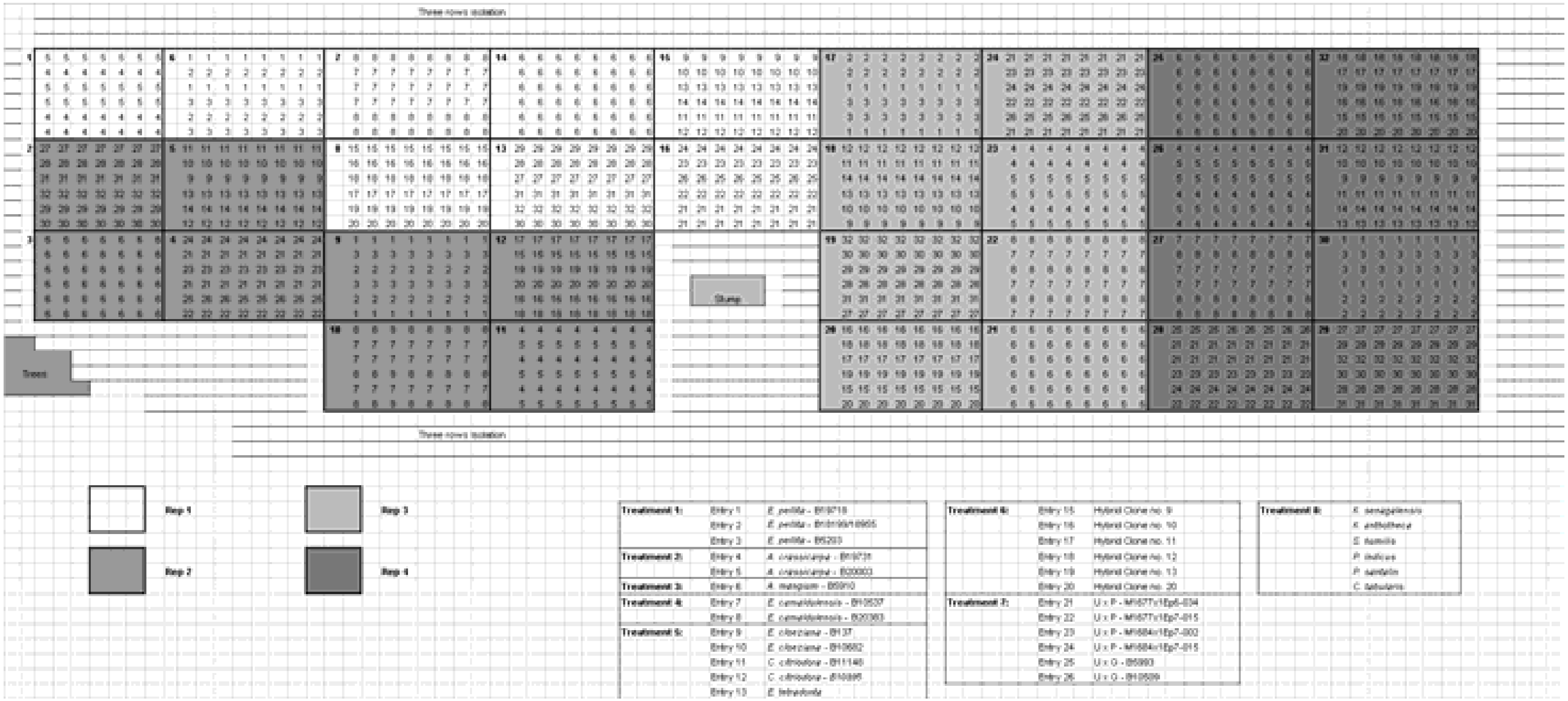
Appendix 2.2

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
(c) 1	0-10	5.6	40	210	70	<25	<5	4.1	0.13	3.4	1.2	6.4
(c) 2	10-25	7.1	<25	80	40	<25	<5	4.7	0.07	0.5	0.7	1.9
(c) 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



Appendix 2.4

Performance table for dryland taxa trial in the Northern Territory (expt. NT 516/2a HWD)

Task	Details	Date	Comments
Paddock Clearing	Cleared for grazing	1990	Details from Keitel
Tree removal	Excavator to remove trees	Nov/Oct' 2000	
Site Preparation	Deep rip & mound	5/12/00	Very wet
	No Round-up applied	No time	Bad move
	Slashing	Oct/Nov' 2000 Mar/April 2001	
Marking out	Paint planting sites	13/12/00	
Planting out	Natives only planted first	15/12/00	
	Exotics planted out	18/12/00	Trial area completed
	Surrounds planted	19&20/12/00	Site area completed
	Block of hybrids planted	15/1/01	Excess material planted
Fertiliser applied	346g/tree NPK plus Trace Element. 12:12:14:4	22/12/00	Too much in one hit spread on the surface
Health Assessment	Survival count	8&9/1/01	To determine replants
Replanting where deaths occurred		10-12/1/01	Survival % high (87%)
Spray Simazine	1m wide band along rows @ 4 -6l/ha	27/12/00	Only trial area sprayed
Weed control	Round-up spraying with knapsack @ 10ml/l	7&8/3/01	Planting rows sprayed between trees
	Hand weeding and Round-up spraying	5,6& 8/3/01 9,10/3/01	Planting rows sprayed between trees
	Verdict spraying @2l/ha in 400l H2O Post planting	12 & 13/3/01	Grass weed control only and effect reduced with late spraying
Pruning	Form pruning (where required)	31/5/01	
Termite control	Not required at this site		
Measure heights	Data collection on data sheets of trial trees only	18/4/01	Recorded only the trees in the trial area
Fire Incidence	Wildfire affected plots on southern side including Nos. 1,2,5,6,11,20&21	Early Aug.	Damage assessment on 25/9/01. No replants as yet!
Weed control	Glyphosate spraying @1.2l/ha on rows only Slashing interows	3/12/01 2/12/01	Grass control on all rows early in the season
Measure heights	Data collection on data sheets of trial trees only	18&19/4/02	Trees in trial area only were measured
Weed control	Glyphosate spraying @ 1% on rows between trees	23/4/02	Late spray to kill plants even though most have seeded. (needs slashing)
Slashing weeds	Slash between rows	11/3/03	
Weed control	Glyphosate spraying @ 1% on rows between trees	13/3/03	

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	Mar	Apr	May	Jun	Jul	Aug	Sep	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	Sep	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

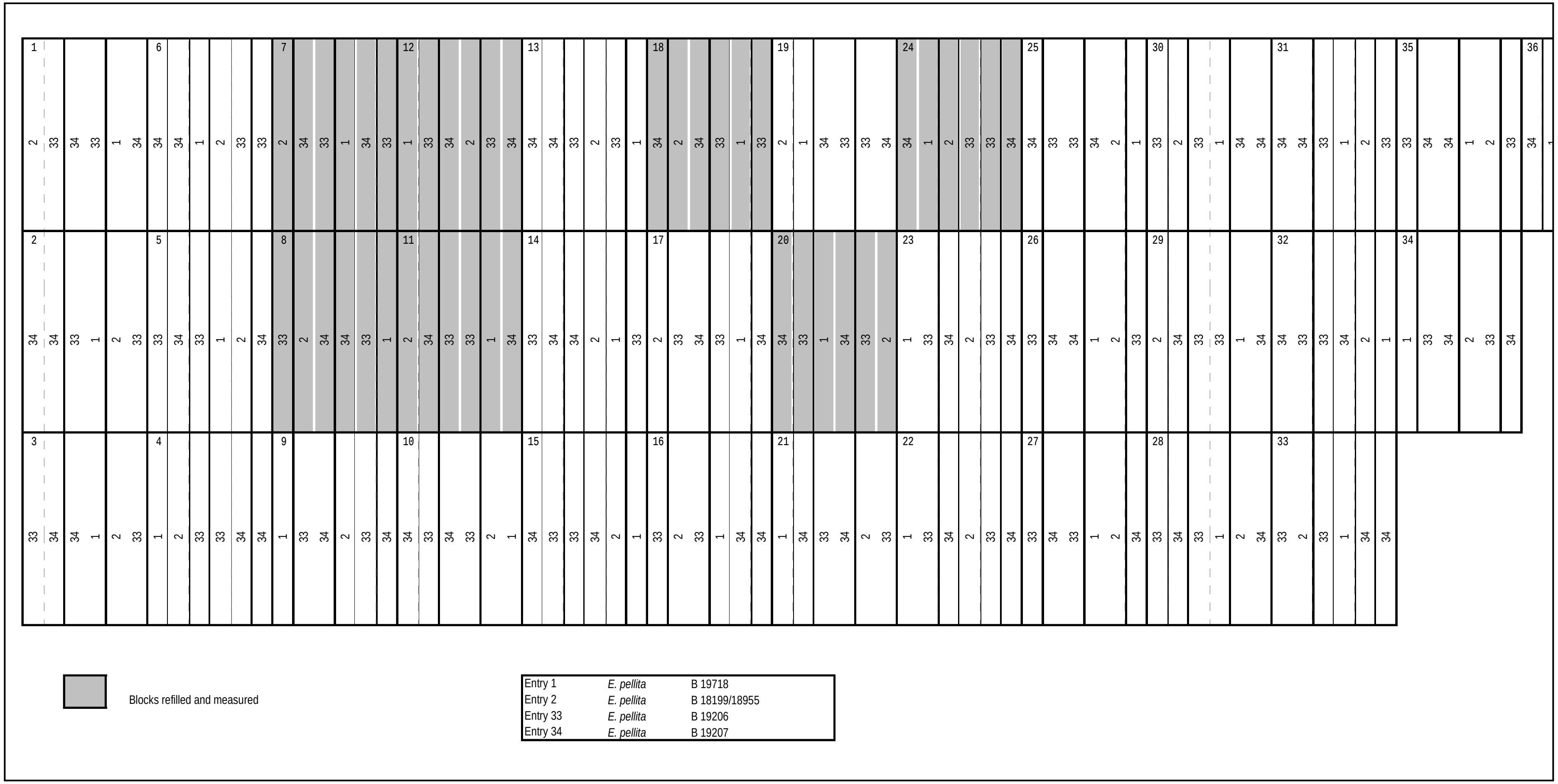
Monthly air temperature (C^0) 2000 to April 2003 for Darwin Airport

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	Max (C^o)	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^o)	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^o)	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^o)	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 maximum and mean minimum ^{o}C) for Darwin airport using data for 1941 - 2001

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	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 3.4.



Layout of the *E. pellita* seed production area at Howard Springs showing the 36 blocks, each with two rows of provenances 1 and 2 and two rows of provenances 33 and 34, and the seven blocks that were refilled (7, 8, 11, 12, 18, 20 and 24).

Appendix 3.5

Performance table NT 516/2b HWD
Eucalyptus pellita Provenance Seedling Seed Orchard (PSSO)

Task	**Details**	**Date**	**Comments**
Site Clearing	Dozing/stick rake	Sept. 2000	Bad windrows
	Windrows burnt	Early Oct 00	Ash heaps every where
Site Preparation	Deep rip/ mounding	25,26/10/00	Entire site incl. windrows
	Slashing interows	29/11/00, 19/1,11/4 &19/6/01	
	Spraying Round-up on rows @1/ha	29/11/00	Not many weeds germinated
Marking out	Painted plant sites	30/11/00	
Planting out	Biggest/ robust seedlings	11,12/12/00	Very dry conditions
Spray Simazine	1m band along rows @4-6l/ha	28/12/00	
Fertiliser applied	346g/tree NPK plus Trace Elements 12:12:14:4	28,29/12/00	Too much in one hit applied on the surface
Planting out	Smaller seedlings	27/12/00	All of trial done
Health assessment	Survival count	22/1/01	Low rate due to insects and dry conditions (57%)
Replanting where deaths occurred	Used small seedlings to replace	29-31/1/01	Concentrated on Blocks 7,8,11,12,18,20 & 24
Replanting	" " " '	6/2-9/2/01	
Weed control	Round-up spraying with knapsack @ 10ml/l	19,20 & 26/2/01	Too many weeds in rows despite simazine application
	Slash interows	5/3/01& 11/4/01	
	Round-up spraying with knapsack @10ml/l	28/3/01	Quick clean up
Measure heights	Data collection onto Husky Hunter & written	19/4/01	Only recorded blocks 7,8,11,12,18,20 & 24
Termite Control	Baiting (aggregating) initially in blocks 16 &23	29/6/01	
Termite treatment	Drums treated	13/8/01	Treated drums inspected on 14/9/01, no termites visible
Weed control Slashing	Glyphosate spraying with knapsack @ 10ml /l Between rows	28/11/01 27&28/11/01	Early grass control along tree rows
Weed control	Slash between rows	18 & 26/3/02	
Singling multi-stems	Pruned off multi-leaders	19/2 & 28/3/02	All trees in all blocks done
Weed control	Glyphosate @ 1% along rows between trees	19/2/02	All 36 blocks in trial done.
Measure heights	Data collection onto data sheets of trial trees only	16 & 17/4/02	Only recorded blocks Nos. 7, 8, 11, 12, 18, 20, &24
Termite control	Treating aggregated drums with Regent	?????	Entomology section testing new termite control method

Termite control	Directly injecting Regent into ground below affected trees with termites.	17/12/02	Some termite affected trees blown over with high winds and chance to directly apply Regent without need to aggregate termites in drums
Weed control	Slashing between rows	18/12/03	Early grass control

Appendix 3.6

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

Proven-ance →	Melville Island	Serisa PNG	Kiriwo PNG	Goe PNG	Mean
	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 3.7

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 Island 19719	Serisa PNG 18199/18955	Kiriwo PNG 19206	Goe PNG 19207	Mean
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 (‘performance table)

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

Task	Details	Date	Comments
Measure height at CSO and CSB	Assess growth performance	26 Aug 02	Rank performance
Health assessment CSB	Assess compatibility of grafts	6 Nov 02	Rankings given to indicate success
Measure height at CSO	Assess growth performance	28 Nov 02	Performance ranked
Measure height at CSB	Assess growth performance	2 Dec 02	
Weed control at CSB	Spot spraying Glyphosate at 10 ml/litre between trees	9 Dec 02	
Fertiliser applied	100 grams of NPK in pockets each side of trees	2 Dec 02 at CSB 11 Dec 02-CSO	NPKS ratio: 6%, 13.6%, 14%and 1.8%
Weed control	Slashing interows and Round-up spraying weeds	12 Feb 03	
Health assessment and height measurement	Assess growth performance	8 May 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

Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
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
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Tree

Row	21	22	23	24		
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	TKN %	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

Performance table for taxa trial 516 /(2d)

	Details	**Date**	**Comments**
Site Preparation	Ripped lines 50cm deep at 4 metre spacing	8/10/02	D7 Bulldozer used
Marking out	Marked out with pickets all plots	3/10/02	
Lime application	Applied Ag. Lime applied to reps 1 & 3 @ 3858 kg/ha	9 & 10/10/02	In rip lines only
Site Preparation	Off-set disc plough over rip lines	27/11/02	
Slashing	Slash grass between rows prior to spraying and planting	18/12/02	
Weed control	Sprayed Round up and Simazine along rip lines prior to planting with 1.0 metre boom sprayer delivering 300 litres per ha. Approx. 0.2 hectares sprayed (60 litres of water). One row missed (control)	24/12/02	Simazine @ 9l/ha and Round-up @ 3l/ha
Planting out	Trial area planted	31/12/02	Not much rain and very hot.
Planting out	Remainder of trial area planted and surround completed	2/1/03	Good rains
Fertilising trial	Fertiliser applied at 200 grams per tree of N, P, K, S. @ 6-14-14-2	6/1/03	100 grams placed each side of tree
First measure	All plants measured for starting height and assess need for re-plants	10/1/03	
Slashing	Slash grass between rows to reduce seed set and tidy area	12/2/03	
Health assessment	Assess trial for deaths and replace as necessary	13/2/03	

Appendix 5.4

Climate data (rainfall)
Monthly weather data 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

Climate data (mean maximum and minimum 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 5.5

Taxa trial layout at Howard Springs

516/2D Hwd Taxa Trial Howard Springs

N

With surround plantings

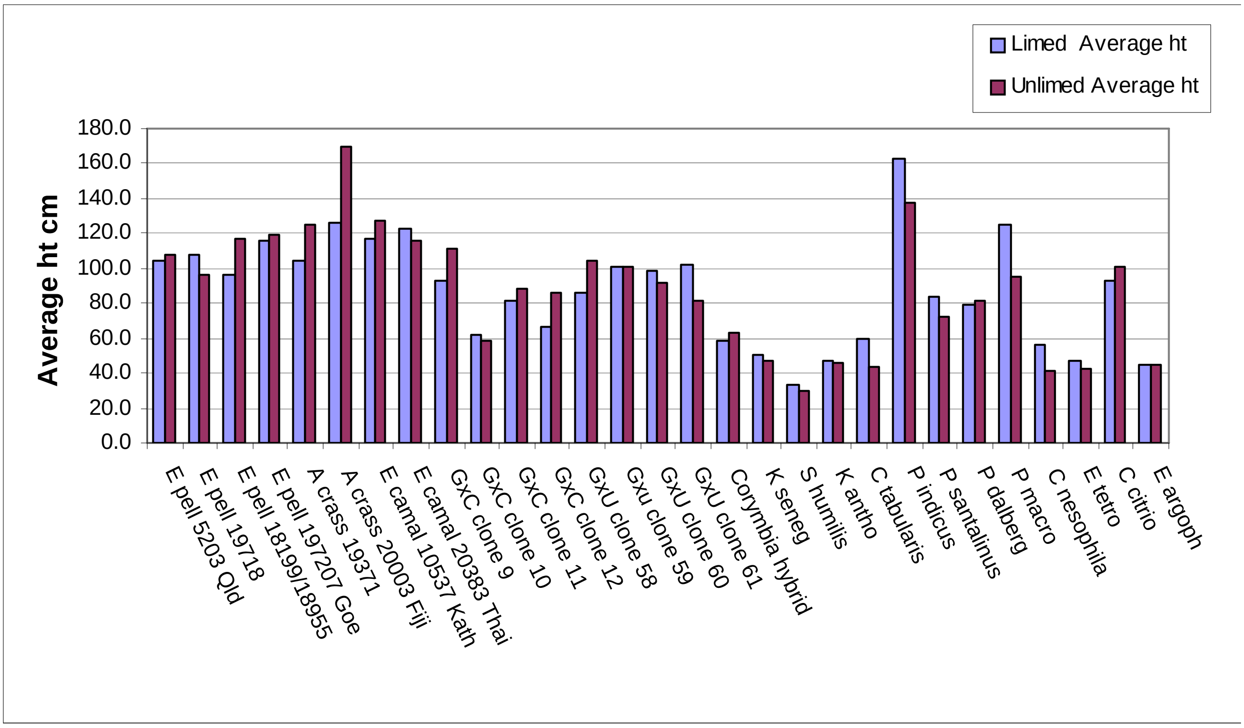
Planted 31/12/2002 and 2/1/2003

15	GxC 13	13	16	14																	
15	GxC 13	13	16	14	14																
15	GxC 13	13	16	14	14	GxC 13															
15	GxC 13	13	16	14	14	GxC 13	16														
15	GxC 13	13	16	14	14	GxC 13	16	13													
15	GxC 13	13	16	14	14	GxC 13	16	13													
15	GxC 13	13	16	14	14	GxC 13	16	13													
15	GxC 13	13	16	14	14	GxC 13	16	13	13												
15	**4** 15	13	16	14	**4** 14	15	16	13	13												
15	15	13	16	14	14	15	16	13	13												
15	15	13	16	14	14	15	16	13	13												
15	15	13	16	14	14	15	16	13	13	16											
15	15	13	16	14	14	15	16	13	13	16	16										
15	15	13	16	14	14	15	16	13	13	16	15	14	14								
17	**5** 17	17	17	17	**6** 21	18	20	19	**4** 13	16	15	14	14								
17	17	17	17	17	21	18	20	19	13	16	15	14	14								
17	17	17	17	17	21	18	20	19	13	16	15	14	14								
17	17	17	17	17	21	18	20	19	13	16	15	14	14								
17	17	17	17	17	21	18	20	19	13	16	15	14	14								
17	17	17	17	17	21	18	20	19	13	16	15	14	21	19	20	18	18				
19	**6** 19	21	20	18	**3** 9	12	10	11	**3** 10	12	9	11	**6** 21	19	20	18	18				
19	19	21	20	18	9	12	10	11	10	12	9	11	21	19	20	18	18				
19	19	21	20	18	9	12	10	11	10	12	9	11	21	19	20	18	18				
19	19	21	20	18	9	12	10	11	10	12	9	11	21	19	20	18	18				
19	19	21	20	18	9	12	10	11	10	12	9	11	21	19	20	18	18				
19	19	21	20	18	9	12	10	11	10	12	9	11	21	19	20	18	18				
24	**7** 24	25	23	22	**1** 4	2	3	1	**5** 17	17	17	17	**8** 26	27	28	29	29	K Granc	K Grand		
24	24	25	23	22	4	2	3	1	17	17	17	17	26	27	28	29	29	K Granc	K Grand		
24	24	25	23	22	4	2	3	1	17	17	17	17	26	27	28	29	29	K Granc	K Granc	K Grand	
24	24	25	23	22	4	2	3	1	17	17	17	17	26	27	28	29	29	K Granc	K Granc	K Grand	
24	24	25	23	22	4	2	3	1	17	17	17	17	26	27	28	29	29	K Granc	K Granc	K Grand	
24	24	25	23	22	4	2	3	1	17	17	17	17	26	27	28	29	25	22	24	23	25
4	**1** 4	2	3	1	**5** 17	17	17	17	**1** 1	2	4	3	**2** 8	5	7	6	**7** 25	22	24	23	25
4	4	2	3	1	17	17	17	17	1	2	4	3	8	5	7	6	25	22	24	23	25
4	4	2	3	1	17	17	17	17	1	2	4	3	8	5	7	6	25	22	24	23	23
4	4	2	3	1	17	17	17	17	1	2	4	3	8	5	7	6	25	22	24	23	23
4	4	2	3	1	17	17	17	17	1	2	4	3	8	5	7	6	25	22	24	23	23
4	4	2	3	1	17	17	17	17	1	2	4	3	8	5	7	6	25	22	24	23	23
11	**3** 11	10	12	9	**8** 27	28	26	29	**2** 7	6	5	8	**3** 10	11	12	9	**4** 15	13	14	16	16
11	11	10	12	9	27	28	26	29	7	6	5	8	10	11	12	9	15	13	14	16	16
11	11	10	12	9	27	28	26	29	7	6	5	8	10	11	12	9	15	13	14	16	16
11	11	10	12	9	27	28	26	29	7	6	5	8	10	11	12	9	15	13	14	16	16
11	11	10	12	9	27	28	26	29	7	6	5	8	10	11	12	9	15	13	14	16	16
11	11	10	12	9	27	28	26	29	7	6	5	8	10	11	12	9	15	13	14	16	16
26	**8** 26	27	28	29	**2** 8	5	6	7	**6** 21	19	18	20	**5** 17	17	17	17	**1** 1	3	4	2	2
26	26	27	28	29	8	5	6	7	21	19	18	20	17	17	17	17	1	3	4	2	2
26	26	27	28	29	8	5	6	7	21	19	18	20	17	17	17	17	1	3	4	2	2
26	26	27	28	29	8	5	6	7	21	19	18	20	17	17	17	17	1	3	4	2	2
26	26	27	28	29	8	5	6	7	21	19	18	20	17	17	17	17	1	3	4	2	2
26	26	27	28	29	8	5	6	7	21	19	18	20	17	17	17	17	1	3	4	2	2
6	**2** 6	5	7	8	**7** 22	24	25	23	**8** 27	26	29	28	**7** 22	23	25	24	1	3	4	2	2
6	6	5	7	8	22	24	25	23	27	26	29	28	22	23	25	24	24	GxU 14	GxU 13	GxC 13	
6	6	5	7	8	22	24	25	23	27	26	29	28	22	23	25	24	24	GxU 14	GxU 13	GxC 13	
6	6	5	7	8	22	24	25	23	27	26	29	28	22	23	25	24	24	GxU 14			
6	6	5	7	8	22	24	25	23	27	26	29	28	22	23	25	24	24	GxU 14			
6	6	5	7	8	22	24	25	23	27	26	29	28	22	23	25	24	24	GxU 14			
6	6	5	7	8	22	24	25	25	27	26	29	28	22	25	25	24	24				
	Rep 1				Rep 2				Rep 3								Rep 4				
			Split Plot 1								Split Plot 2										

T/ment	Entry No	
1	1	E pellita 5203 Nth Qld SO
	2	E pellita 19718 Melville Is SO
	3	E pellita 18199/18955 mix Serissa PNG natural stand
	4	E pellita 19207 Goe PNG natural stand
2	5	Acacia crassicarpa 19731 Oriomo Png
	6	Acacia crassicarpa 20003 Fiji SO
	7	E camaldulensis 10537 Katherine NT
	8	E camaldulensis 20383 Thai SO
3	9	GxC Hybrid clone 9
	10	GxC hybrid clone 10
	11	GxC hybrid clone 11
	12	GxC hybrid clone 12
4	13	GxU hybrid clone 58
	17	Corymbia hybrid complex
	18	Khaya senegalensis Tree No 118 Local
	19	Swietenia humilis Honduras
	20	Khaya anthotheca Local
	21	Chuckrassia tabularis 20035 Thanh Hoa Vietnam
	22	Pterocarp[us indicus Local
	23	Pterocarpus santalinus Local
	24	Pterocarpus dalbergioides 20235
	25	Pterocarpus macrocarpus ATSC
	26	C nesophilia Cape York Qld
	27	E tetrodonta Dry River stn NT
	28	C citriodora 10895 Glendon
	29	E argophloia Kingaroy Qld

Appendix 5.6

Results showing the difference in heights between limed and un-limed treatments



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