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Eucalypt hybrids in south-west Western Australia

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

By Dr E.L. Barbour

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Foreword

A set of eucalypt hybrid trials has been established by the Forest Products Commission with a variety of partners across the south-west of Western Australia since 1996. The Joint Venture Agroforestry Program provided the opportunity to do two field measurements of these trials in the summer of 2000/2001 and 2002/2003 and to collate the outcomes of these assessments in this report. The project aimed to optimise direct returns from tree products whilst maintaining the environmental benefits that tree crops can provide. It is hoped that this report will provide valuable information to tree farmers assessing the economic value of the Eucalypt hybrids in comparison with the often utilised, *Eucalyptus globulus*.

This project was funded by 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 principally funded by the Australian Government.

This report, a new addition to RIRDC's diverse range of over 1000 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Simon Hearn

Managing Director

Rural Industries Research and Development Corporation

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Richard Mazanec and Mathew Williams, Department of Conservation and Land Management conducted the statistical analysis of the trial data.

Mr. and Mrs. Gordon of Boyup Brook, Mr. and Mrs. Ryan of Darkan, Mr. Winton of Gingin, Dr. Gary Inions of Plantations International, Toyota Australia, Mr and Mrs. Coffey of Kojonup and Mr and Mrs Howell of Mt. Barker permitted the use of their land to establish these trials.

Waters and Rivers Commission supported the cost of land preparation at the Kojonup site.

The three-way cross hybrid seedling material used in the Albany trial was donated by Mr. Keith Orme, an agreement was negotiated with Queensland Forestry Exports to clone and test the *E. grandis* x *E. camaldulensis* and *E. grandis* x *E. urophylla* clones in south-west Western Australia, and Saltgrow provided their material for testing at two of the trial sites.

Abbreviations

B	Branching
Dbh	Breast height diameter
FPC	Forest Products Commission
Ht	Height
Stem	Stem form
Vol	Wood volume

Contents

Foreword	iii
Acknowledgments.....	iv
Abbreviations.....	iv
Executive Summary	vi
1. Introduction	1
2. Objectives.....	2
3. Methodology	3
3.1 Trial sites	3
3.2 Source of trial material	4
3.3 Production of trial material.....	4
3.4 Trial assessment	5
4. Results	6
4.1 HB01 – Grimwade (Kirup) - P96	6
4.2 HB02 - Gordon’s (Boyup Brook) - P97	7
4.3 HB03 - Ryan’s (Darkan) – P98	9
4.4 HB04 – Plantations International – (Albany) – P98.....	10
4.5 HB05 - Winton’s (Gingin) – P98	12
4.6 HB06 – Pimelia (Pemberton) – P99	13
4.7 HB07 – Toyota (Collie) – P99	15
4.8 HB09 – Coffey (Kojonup) – P2000.....	16
4.9 HB11 – Howell (Mt Barker) - 2002	16
4.10 HB12 – Coffey (Kojonup) - 2002	17
5. Discussion of Results	18
6. Implications.....	20
7. Recommendations	21
8. References	22

Executive Summary

The project assessed the wood production performance of a range of Eucalypt hybrids in the southwest of Western Australia, to determine if an advantage can be gained using a Eucalypt hybrid in the low *Eucalyptus globulus* productivity areas. Since 1996, the Forest Products Commission (FPC) has established a range of trials across the tree planting areas in the southwest. The main focus was on *E. globulus* hybrids with *E. grandis* and *E. camaldulensis*, and *E. grandis* with *E. camaldulensis*, although other eucalypt hybrid material has been included.

Five of the trials were measured in 1999 and this measurement showed that *E. globulus* out-performed all the hybrids tested at all sites except for the low rainfall (534 mm) and high evaporation (1175 mm) site at Darkan where the *E. globulus* x *E. grandis* hybrid showed potential. Additionally, clones of *E. grandis* x *E. camaldulensis* at the Gingin site (rainfall 676 mm with evaporation rate of 1850 mm) had potential.

This project completed a further two assessments of these trials which, by the final measurement, had grown in number to ten. The assessments were made in the summer of 2000-2001 and 2002-2003, drought years in this region. Assessment of the trials showed that at the sites considered typical for *E. globulus*, *E. globulus* seedling growth was superior to that of the hybrid cuttings in a pulpwood rotation. However, at the sites that were not typical *E. globulus* pulpwood production sites, other hybrid material showed potential to produce a more productive tree crop. This material needs to be further tested in clonal blocks to monitor inter-tree relationships.

The discussion highlights the impact of the low rainfall conditions, parrot attack and deployment method on the performance of these trials.

1. Introduction

The clearing of land for agriculture has resulted in widespread degradation through forces such as rising ground water levels, wind and water erosion, and soil structure decline. It has been suggested that to reverse, or at least retard, this degradation, there must be a reintroduction of perennial species into the landscape. Tree planting in these areas has been widely promoted and recognised as a necessary tool in the fight against spreading salinity, for carbon sequestration, maintaining soil structure and ensuring water quality. The total cost of perennial establishment is high and any cost supplementation will accelerate the planting rate and thus land rehabilitation. Tree projects can be a source of revenue whilst providing the necessary environmental benefits to maintain soil, air and water quality. To date these projects have been confined to high rainfall areas with many hard lessons being learnt when species have been pushed beyond their range.

Eucalyptus globulus is a favoured eucalypt for tree farm projects in south-west Western Australia. Analysis of *E. globulus* performance indicates that rainfall, annual evaporation and soil fertility can predict performance, with lower productivity being related to decreasing rainfall and increasing evaporation (Harper et al. 1999). Additionally, the species performs poorly on shallow, saline soils and deep sands. Thus it is in these areas of low *E. globulus* productivity that a hybrid or an alternate species may have a role to improve performance.

Initial interest focused on a *E. globulus* hybrid rather than a new species, as markets prefer species they are familiar with, and hybrids offer this familiarity whilst potentially providing the opportunity to access needed environmental benefits. In this context a eucalypt hybrid could have a role in three potential scenarios. On the one hand, by manipulating the species mix within a tree farm, depending on site characteristics (saline, shallow soils, deep sands), the overall productivity of a planting could be improved. Basically it has been shown that *E. globulus* has little control over its water use and its “drought death” is usually the result of over-heating. Other eucalypt species have a range of drought avoidance mechanisms, *E. camaldulensis* being a species of note (Gibson et al., 1995). This approach will provide a greater genetic diversity against pests and diseases. Secondly, additional land could be added to the tree farm project by extending into high evaporation areas, covering a greater land area for land rehabilitation and provide an economic return to a greater number of landowners. The last alternative involves the re-planting of tree farms. There is evidence that the first rotation of *E. globulus* can dry the root-zone (Crombie, 1999) so that any stored water that was being utilised by the first rotation is either much reduced or depleted for the second rotation. This could result in a decline in productivity of *E. globulus* during the second rotation, which a hybrid might solve.

Since 1996, the Forest Products Commission (FPC) has established a series of trials to search for suitable eucalypt hybrids (Table 1). Some of the trials are in high rainfall areas where growth can be accelerated to assess tree form. Most are in areas of low rainfall and high evaporation, that is, the target area for expansion of the plantation projects. The range of hybrids has expanded as material has been developed within the Forest Products Commission (FPC) or been made available by other organisations.

Hybrid production and breeding is tightly linked to the system of deployment. Worldwide, hybrids have been deployed as clones. Generally, the approach has been to cross the best selection of one species with the best selection of another species to make hybrid seed. This seed has been grown and either planted directly in the field for assessment or it has been multiplied so that replicated trials can be established for hybrid clonal assessment. The advantage of the first approach is that the hybrid is tested to a degree before the expense of creating the vegetative propagation system. The second approach tests the propagation ability of the hybrid first, which can be a stumbling block to deploying a hybrid. Some hybrids are difficult to propagate and the vegetative propagation system can alter the field-performance of the hybrid.

To establish this series of trials, the initial approach was to screen for the vegetative propagation ability before field-testing, but nursery space became limiting as the amount of hybrid material increased. Thus the recent trend has been to plant hybrid seedlings directly into the field with no vegetative propagation screening.

A major change during the life of this project has been a move from high density pulpwood plantings to sawlog rotations. Trees used to be planted at 1250 stems per hectare and left at this density until clearfall at 10 years, whereas in a sawlog rotation, establishment is reduced to 1000 stems per hectare with two thinnings thereafter before clearfall at 20 years. Currently, the sawlog rotation consists of two thinnings, the first after 3 years growth to 300 stems per hectare and the second at year 6 to a final crop of 150 stems per hectare. This approach is to produce 'fat logs' by allowing trees to grow at their maximum rate with little water-stress. The debate ensuing is whether to leave more stems so that a pulpwood and sawlog product can be attained from the same site.

Silvicultural management of tree density to control water-use from a site is of great environmental value in fighting salinity and improving the water quality in a catchment. This approach opens the opportunity to produce a solid wood product in lower rainfall areas and thus assist with the financing of land rehabilitation. With this alternative focus on a sawlog, the parameters for judging species or hybrids alter. Greater emphasis is placed on tree form, and the stresses within the tree.

The question arises as to why the final stocking of 150 trees per hectare is not planted from the start, especially if a hybrid clone can be identified that can produce all of the necessary wood attributes. A higher density of trees can lower the water table for greater environmental benefits. Additionally, the surrounding trees may provide protection for the final crop. In the south-west of Western Australia, parrots, particularly the Port Lincoln or Ringneck parrot, attack the stem of the trees damaging their form. A greater density of trees can alleviate the damage on the final crop of trees. Early stocking also has major implications for stem form and branching.

This project provides wood production information in the south-west Western Australia for the three main eucalypt hybrids, *E. globulus* x *E. grandis*, *E. globulus* x *E. camaldulensis* and *E. camaldulensis* x *E. grandis* in the south-west Western Australia. Material has been propagated and sent to eastern Australia for the establishment of three plantings by two private companies. Additionally this project connects with the Saltgrow project, which resulted from the "Xylonova" project of Forbio. This project provides the public with some information on which to assess the merits of Eucalypt hybrids.

2. Objectives

To identify eucalypt hybrids that have a greater productivity than *E. globulus* on low rainfall, high evaporation sites in the south-west Western Australia by assessing ten field trials.

3. Methodology

3.1 Trial sites

The trial sites are listed in Table 1 together with their planting date and the average rainfall and evaporation of the site. In Western Australia, adaptability of species is dependent on their ability to survive the summer drought. The south-west of Western Australia has been undergoing a drought cycle during the life of these trials. Thus, whilst the average annual rainfalls are recorded in the table, active rainfall has generally been lower.

Table 1: A list of the sites with their planting date, the rainfall and evaporation data from the nearest weather station to the site and a summary of the material included at each site.

Site	Plant -ing date	Average Rainfall	Annual evaporation	Trial material
HB01: Grimwade (Kirup)	July 1996	880 mm	1150 mm	<i>E. globulus</i> x <i>E. grandis</i> seedlings and cuttings
HB02: Gordon's (Boyup Brook)	July 1997	835 mm	1175 mm	<i>E. globulus</i> x <i>E. grandis</i> cuttings <i>E. globulus</i> seed orchard seedlings <i>E. grandis</i> seed orchard seedlings
HB03: Ryan's (Darkan)	July 1998	534 mm	1175 mm	<i>E. grandis</i> x <i>E. globulus</i> cuttings <i>E. globulus</i> seed orchard seedlings
HB04: Plantation International (Albany)	July 1998	739 mm	940 mm	<i>E. globulus</i> x <i>E. grandis</i> cuttings <i>E. grandis</i> x <i>E. urophylla</i> cuttings (<i>E. globulus</i> x <i>E. nitens</i>) x <i>E. globulus</i> seedlings (<i>E. nitens</i> x <i>E. cordata</i>) x <i>E. globulus</i> seedlings (<i>E. globulus</i> x <i>E. gunnii</i>) x <i>E. globulus</i> seedlings <i>E. globulus</i> control cross seedlings
HB05: Winton's (Gingin)	July 1998	767 mm	1850 mm	<i>E. globulus</i> x <i>E. camaldulensis</i> seedlings <i>E. camaldulensis</i> tissue cultured plantlets <i>E. camaldulensis</i> seedlings <i>E. grandis</i> x <i>E. camaldulensis</i> cuttings
HB06: Pimelia (Pemberton)	July 1999	1200 mm	950 mm	<i>E. globulus</i> x <i>E. grandis</i> cuttings <i>E. grandis</i> x <i>E. camaldulensis</i> cuttings <i>E. globulus</i> x <i>E. camaldulensis</i> cuttings <i>E. globulus</i> seed orchard seedlings <i>E. grandis</i> seedlings <i>E. camaldulensis</i> seedlings
HB07: Toyota (Darkan)	July 1999	650 mm	1270 mm	<i>E. globulus</i> x <i>E. grandis</i> cuttings <i>E. grandis</i> x <i>E. camaldulensis</i> cuttings <i>E. grandis</i> x <i>E. urophylla</i> cuttings, <i>E. globulus</i> x <i>E. camaldulensis</i> cuttings <i>E. globulus</i> seed orchard seedlings <i>E. grandis</i> seedlings <i>E. camaldulensis</i> seedlings
HB09: Coffey (Kojonup)	August 2000	534 mm		<i>E. globulus</i> x <i>E. camaldulensis</i> cuttings <i>E. grandis</i> x <i>E. camaldulensis</i> cuttings <i>E. globulus</i> seedlings <i>E. grandis</i> seedlings <i>E. camaldulensis</i> seedlings
HB11: Howell (Mt Barker)	August 2002	737 mm		<i>E. globulus</i> x <i>E. camaldulensis</i> cuttings <i>E. grandis</i> x <i>E. camaldulensis</i> cuttings <i>E. globulus</i> seedlings <i>E. grandis</i> seedlings <i>E. camaldulensis</i> seedlings
HB12: Coffey (Kojonup)	August 2002	534 mm		<i>E. globulus</i> x <i>E. camaldulensis</i> seedlings <i>E. globulus</i> <i>E. grandis</i> <i>E. camaldulensis</i>

The sites cover a wide range of conditions, with high rainfall sites being included so that rapid assessment of tree form could be made. All sites were ripped and mounded and fertilised except for Grimwade and each site had a degree of weed control.

Twelve trials in all were established but two were lost, the first to severe insect damage and the second to sheep grazing. The first site was not re-established but the second was secured and re-established the following year. HB05 at Gingin had a threat of fire in 2001 but measurement in 2003 could not detect any severe damage to the trees.

The research program has been plagued by parrot attack of the trees. Some sites were attacked more than others and this will be noted in the results at each of the sites.

The emphasis changed from a pulpwood product to a sawlog product during the life of this project. HB07 Toyota (Darkan), at 3 years old, was pruned after its final assessment so that this aspect could be taken into account. HB01 was to be assessed for sawlog potential, but Timber Technology (a section of the FPC) advised that better sawlog information would be gained if the site was thinned, pruned and fertilised and the assessment delayed until the trial was 10 years old.

3.2 Source of trial material

The *E. globulus* x *E. grandis* hybrid was made through collaboration between a South African forestry company and FPC, with FPC supplying the *E. globulus* pollen. In 1995, 1,825 seeds were received with 553 seedlings germinating to be established as mother plants of 9 families represented as A (7 clones), B (112 clones), C (104 clones), D (76 clones), E (111 clones), F (106 clones), G (8 clones) H (28 clones) and I (1 clone). Obviously deformed individuals were discarded together with a number of seedlings that did not adapt to the mother plant system, and others were removed due to their poor propagation ability. The remaining mother plants were cloned as rooted cuttings for trial establishment.

The *E. grandis* x *E. camaldulensis* and *E. grandis* x *E. urophylla* hybrid seed was received from South Africa in 1997. Seventy seed of *E. grandis* x *E. camaldulensis* from three families were sown but only 24 mother plants were successfully established represented by A (4 clones), B (5 clones) and C (15 clones). Seventy-five seed of the *E. grandis* x *E. urophylla* from 5 families were also sown with one family lost during germination and the remaining 4 families represented by A (2 clones), B (3 clones), C (6 clones) and D (6 clones). All successful individuals were established as mother plants and were cloned for trial establishment.

Three hybrid seed lots, (*E. globulus* x *E. nitens*) x *E. globulus*, (*E. nitens* x *E. cordata*) x *E. globulus*, (*E. globulus* x *E. gunnii*) x *E. globulus*, were received from Mr. Keith Orme for testing in Western Australia in 1997. All three hybrids were established as seedlings.

Saltgrow approached the FPC to test their material in south-west Western Australia. Two trials covering a range of their *E. globulus* x *E. camaldulensis* and *E. grandis* x *E. camaldulensis* material have been established and are assessed in this report.

3.3 Production of trial material

Material was propagated by the FPC, except for the material supplied by Saltgrow for HB09 and HB11. Seedlings and cuttings were produced at facilities in Perth. The seedlings were raised in a 60:40 (composted sawdust: sand mix) with a pre-mix fertiliser mix in the Colmax 64 tray. The seed was sown in December and fertilised regularly to be ready for planting in June. The cutting material was selected from mother plants raised from seedlings in a 1.5 litre pot. The cuttings were trimmed to 2 node cuttings with the leaves cut in half and set in inserts containing vermiculite. The cuttings were placed under mist until rooting and then transferred to a shade house for further development and hardening-off for the June planting. The original insert was a square 50 ml container but this was superseded in the P99 season with an air-pruning insert imported from South Africa.

Additionally, under-heating was added to the misting house to accelerate rooting in 1998 for the 1999 season.

3.4 Trial assessment

Each of the trials was visited twice during the project, in the summer 2000/2001 and 2002/2003. In some of the older trials, measurements had occurred prior to the start of the project. This information is included.

The assessment used was the standard FPC tree breeding assessment of trials:

- Dominance, where 0 is a missing tree, 1 a dead tree, 2 a runt, 3 a sub-dominant, 4 a co-dominant and 5 a dominant tree. Trees that were scored 0, 1 or 2 had no further assessment.
- Straight stem on a scale of 1 – 6 where 6 is a very straight stem.
- Crown quality on a scale of 1 – 6 where 6 is when the branches are small and evenly spaced on the tree.
- Malformation, where 6 is a single straight stem with no malformation, 5 has a few ramicorns (1-2), 4 has many ramicorns (>2), 3 has a minor fork with or without ramicorns, 2 has major multiple forks, 1 is shrubby.
- Health, where 6 is a healthy tree, 5 has a nutrient disorder, 4 has insect damage, 3 multiple damage, 2 is drought affected and 1 is a drought-killed tree.
- Flowering where c defines caps, b buds and f flowering.

The data were entered into a spreadsheet and analysed using SAS and other statistical tools that were applicable.

4. Results

4.1 HB01 – Grimwade (Kirup) - P96

The site allocated for this trial had been cleared of *Pinus radiata*. Whilst standard land preparation was conducted prior to planting, no fertiliser was given to the plants after planting. Some initial death was thought to be due to spray drift from surrounding pine plantations but there was no parrot damage at this site.

Table 2: HB01 Trial analysis at 20, 42, 60 and 80 months. Height is measured in meters, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

		20 mnths	42 mnths	60 months					80 months	
Hybrid	family	Ht	Ht	Dbh	Ht	Vol	Stem	B	Dbh	Stem
E.globulus x E.grandis	A	2.06	3.69	10.30	8.30	0.0231	5.00	3.00	14.00	6.00
	B	2.35	4.80	10.20	8.32	0.0362	3.57	3.13	16.77	4.74
	C	2.17	4.05	10.55	8.07	0.0367	3.57	3.21	16.58	4.92
	D	2.42	4.23	8.77	8.21	0.0229	3.68	3.21	15.34	5.00
	E	1.55	3.19	6.85	8.25	0.0112	3.50	2.50	10.33	4.50
	F	2.97	5.16	9.68	7.75	0.02846	4.11	3.22	14.46	5.44
	G									
	H	2.36	3.37	5.85	5.60	0.0068	2.50	2.50		
	Avg.	2.35	4.34	9.60	8.03	0.03	3.66	3.14	15.73	4.97

A total of 258 *E. globulus* x *E. grandis* seedlings (mother plants rejected from the program due to their poor propagation ability) and cuttings representing 8 families were planted at random. Initial survival was poor but this altered little by the second measurement. Family ranking of tree height after 20 and 42 months of growth indicates that the superior families are F, B, and D respectively. This family order changed as the trial matured so that when the trial was 60 months, the family producing the greatest wood volume was C closely followed by B. In the final measurement at 80 months, family B dominated followed by C and then D. Insect attack under the bark of some clones was observed in families B, C and D, with D also suffering a nutrient disorder expressed by a distinct yellowing of the leaves. This may account for the change in order of the families over time. The two largest clones had a breast height diameter of 338 mm (family C) and 253 mm (family B) and were healthy. It was proposed to clear fell this trial for a sawlog study, but on the recommendation of FPC Timber Technology, the trial is to be tidied up and fertilised and the wood taken at year 10.

The malformation score changed very little from the 60 month assessment to the 80 month assessment. 69% of those trees that survived after 60 months were regarded as a single straight stem. This proportion of single straight stems increased to 84% by 80 months.

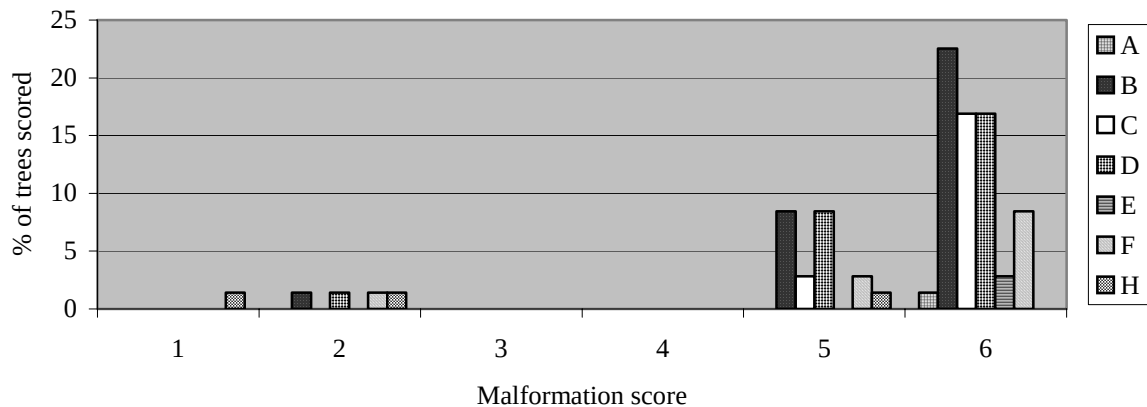


Figure 1: Malformation is scored such that 6 is a single straight stem with no malformation, 5 has a few ramicornis (1-2), 4 has many ramicornis (>2), 3 has a minor fork with or without ramicornis, 2 has major multiple forks, 1 is shrubby. The graph shows the percentage of trees within each species or hybrid with the noted malformation scores after 60 months of growth.

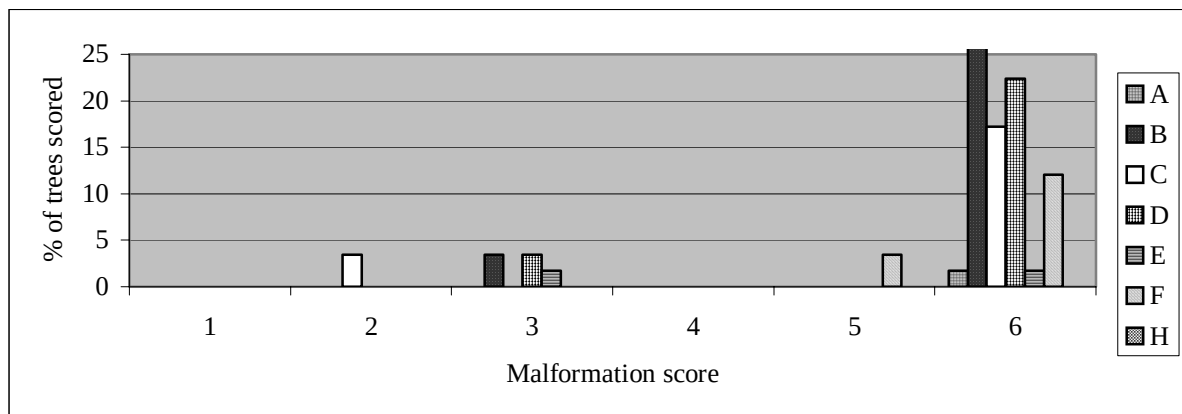


Figure 2: Malformation is scored such that 6 is a single straight stem with no malformation, 5 has a few ramicornis (1-2), 4 has many ramicornis (>2), 3 has a minor fork with or without ramicornis, 2 has major multiple forks, 1 is shrubby. The graph shows the percentage of trees within each species or hybrid with the noted malformation scores after 80 months of growth.

4.2 HB02 - Gordon's (Boyup Brook) - P97

The site was on the edge of an *E. globulus* plantation establishment due to its shallow soil depth. The site was ripped and mounded and sprayed clear of weeds prior to planting. No further silvicultural management has occurred to date. Parrot damage began to occur after the trial was two years old.

Thirty two treatments of the *E. globulus* x *E. grandis* hybrid with an *E. globulus* and *E. grandis* seed orchard seedling control were planted in a 4 tree row plot and replicated 5 times. Trial survival at 10 months was 68.1%, which had declined after 30 months to 65.6 %. This survival declined further in the last measurement of the trial, at 66 months, to 56.6%. Survival of *E. grandis* was the highest, followed by *E. globulus* with the hybrid having the lowest survival. One family of the hybrid, family H, had survival above the trial average. These deaths appeared to be due to drought.

Table 3: HB02 trial survival (%) at 10, 30, 41 and 66 months.

Species	family	10 months	30 months	41 months	66 months
<i>E.globulus</i>		75.0	75.0	75.0	65.0
<i>E. globulus</i> x <i>E.grandis</i>	A	42.6	40.0	40.0	36.5
	B	50.0	50.0	50.0	50.0
	C	61.8	59.2	59.2	50.0
	E	66.3	60.0	60.0	47.5
	F	74.2	71.7	71.7	55.0
	H	83.5	82.0	82.0	74.8
	Average	66.1	63.4	63.4	54.2
<i>E.grandis</i>		87.0	84.8	84.8	78.3
Average		68.1	65.6	65.6	56.6

Of the 8 possible families of the *E. globulus* x *E. grandis* hybrid, only 6 were represented in this trial. Family ranking of tree height after 30 months of growth indicates that the superior families are B, F, and C. In relation to the two controls of *E. globulus* and *E. grandis* seedlings, the only *E. globulus* x *E. grandis* family to perform similarly was family B.

After 41 months of growth, *E. globulus* was showing the greatest growth followed by *E. grandis* and then the hybrids. Stem form and branching rated higher in the hybrids compared to both *E. globulus* and *E.grandis*. The wood volume superiority of the pure species, *E. globulus* followed by *E.grandis*, became more pronounced by 65 months and any form advantage that the hybrids initially had, had been lost.

Table 4: Trial analysis at 10, 30, 41 and 65 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

	F a m	10	30	41 months					65 months				
Species		Ht	Ht	Dbh	Vol	Ht	S	B	Ht	Dbh	Vol	S	B
<i>E.globulus</i>		1.63	6.20	10.71	1.41	9.85	4.4	4.4	11.50	16.97	90.64	2.83	2.33
<i>E. globulus</i> x <i>E.grandis</i>	A	0.90	4.74	8.68	1.14	8.80	5.7	5.6	9.37	12.36	41.12	3.14	2.85
	B	1.35	5.81	10.33	1.34	9.05	5.2	4.6	8.83	13.87	45.24	2.50	2.75
	C	0.98	5.07	8.13	1.07	8.52	4.6	4.7	8.72	12.01	34.66	3.16	2.96
	E	0.90	4.52	8.83	1.07	8.47	5.6	5.0	8.37	12.74	37.91	2.72	2.92
	F	1.01	5.31	8.57	1.13	8.73	5.5	5.2	9.07	11.87	35.97	2.95	2.80
	H	0.98	4.62	7.77	1.00	8.38	5.7	5.6	8.81	11.73	34.29	3.01	2.86
	Avg.	1.02	4.92	8.72	1.13	8.66	5.3	5.1	8.86	12.43	38.20	2.92	2.85
<i>E.grandis</i>		1.36	5.63	9.94	1.31	9.30	4.9	4.4	10.28	13.65	52.73	2.89	2.92

A clearer view of the change in tree form can be seen through the malformation information. Tree malformation altered little for *E. globulus* and *E. grandis* from 41 months to 65 months. The hybrid, on the other hand, had 57.2 % of the trial trees with a single straight stem at 41 months, which declined to 42.8 % 21 months later.

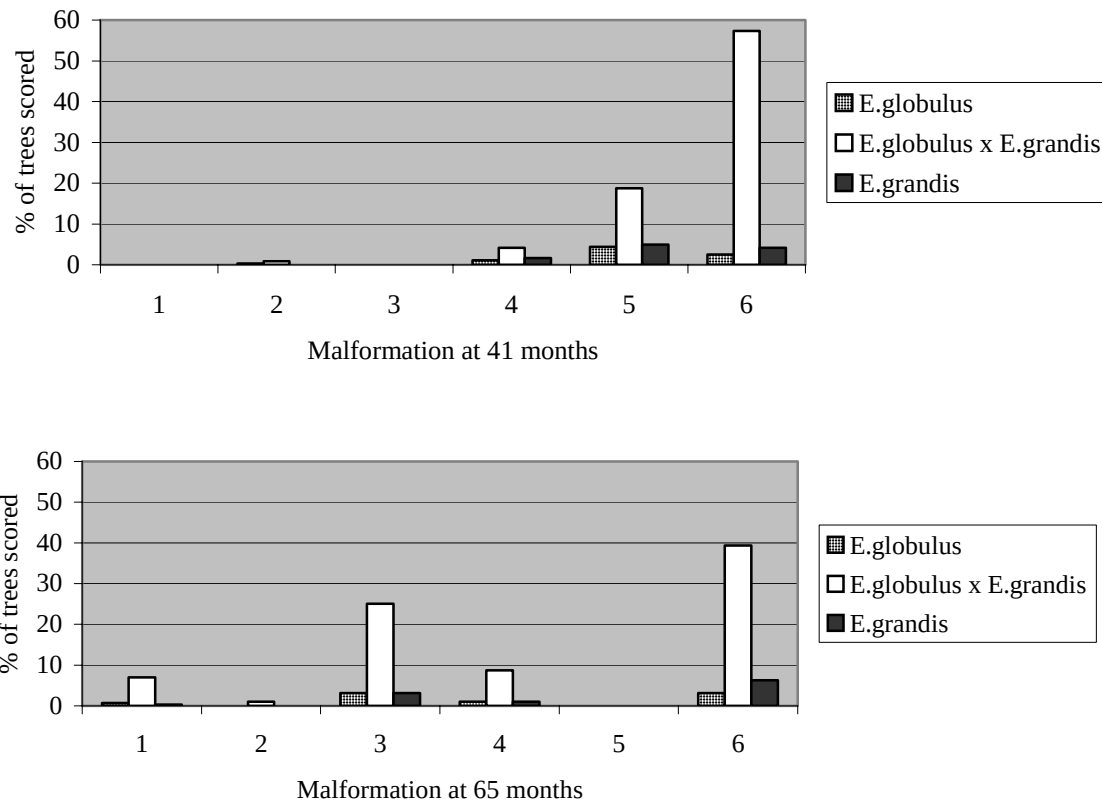


Figure 3: Malformation is scored such that 6 is a single straight stem with no malformation, 5 has a few ramicorns (1-2), 4 has many ramicorns (>2), 3 has a minor fork with or without ramicorns, 2 has major multiple forks, 1 is shrubby. The graph shows the percentage of trees within each species or hybrid with the noted malformation scores after 41 and 65 months of growth.

4.3 HB03 - Ryan's (Darkan) – P98

Clonal lines of *E. globulus* x *E. grandis* family hybrid material were planted at random in July 1998. Trial survival after 38 months of growth was 78.5 %, with the hybrid cuttings showing 81.1% survival and *E. globulus* seedlings 43.4 %.

Although initially *E. globulus* was out-performed by family A, B, C, D, E and F at 38 months of growth, by the time the trial was 56 months old, of the trees that had survived *E. globulus* was out-performing the hybrids. It should be noted that by this time, only 23% of the *E. globulus* were surviving whereas 81% of the *E. globulus* x *E. grandis* hybrid were alive.

Table 5: HB03 trial survival (%) after 38 and 56 months.

	Family	Survival at 38 months	Survival at 56 months
<i>E.globulus</i>		43.4	23.2
<i>E. globulus</i> x <i>E.grandis</i>	A	68.3	67.0
	B	87.1	88.2
	C	84.0	84.0
	D	95.1	93.8
	E	90.5	90.5
	F	89.9	90.5
	G	50.0	50.0
	H	77.5	78.0
	Average	81.1	81.0
Trial average		78.5	77.0

Table 6: HB03 trial analysis at 18, 38 and 56 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6

Species	Family	18 mnth	38 months					56 months		
		Ht	Ht	Dbh	Vol	Stem	B	Dbh	Stem	B
<i>E.globulus</i>		3.02	3.02					8.35	3.25	3.58
<i>E. globulus</i> x <i>E.grandis</i>	A	3.40	3.40	3.34	0.0000	3.54	103	7.11	3.04	3.23
	B	4.02	4.01	3.97	0.0014	3.04	73	7.23	3.05	3.60
	C	3.78	3.78	3.77	0.0019	3.36	58	6.78	2.94	3.52
	D	4.28	4.27	4.91	0.0035	2.84	31	7.57	3.04	3.60
	E	3.40	3.39	4.83	0.0031	3.67	9	7.92	3.30	2.80
	F	3.90	3.90	3.87	0.0021	2.94	51	7.97	2.82	3.39
	G	3.34	3.34	3.12	0.0009	3.00	3	6.50	2.67	3.33
	H	3.32	3.32	3.30	0.0012	2.98	47	6.61	2.92	3.05
	Avg	3.73	3.72			3.20	376	7.17	2.97	3.41
Grand Average		3.70	3.62	3.89	0.0017	3.20	376	7.19	2.98	3.41

4.4 HB04 – Plantations International – (Albany) – P98

The site was established in July 1998 with 7 replicates of 36 treatments in a 3 tree row plot and was first assessed after 18 months growth. The trial included a range of hybrids (Table 1), which are compared with 5 control cross-pollinated *E. globulus* family seedlings.

The overall survival at this site after 56 months of growth is 90.1 %. The highest survival at species level was achieved by *E. globulus* (99%), with the poorest being with a hybrid, *E. globulus* x (*E. nitens* x *E.cordata*). One *E. grandis* x *E.urophylla* family had 100% survival but this was in contrast to another family, which only had 28.6 % indicating wide range of variance within the hybrid.

After 18 months, the trial showed that *E. globulus* was the superior species compared to all hybrid material tested at this site and this trend dominated until the final measurement at 56 months. The *E. globulus* x (*E. nitens* x *E. cordata*) eventually all died by the last measurement at 56 months.

Table 7: HB04 trial survival (%) after 18, 30 and 56 months

Species	Family	Survival 18 months	Survival 30 months	Survival 56 months
E.globulus		99.0	99.0	99.0
E. globulus x (E. globulus x E. gunnii)		90.5	90.5	85.7
E. globulus x (E. globulus x E. nitens)		95.0	95.0	95.0
E. globulus x E.grandis	A	89.5	89.5	89.5
	B	95.2	95.2	95.2
	C	95.1	94.5	94.5
	D	95.2	95.2	95.2
	E	95.2	95.2	95.2
	F	93.7	93.7	93.7
	H	86.9	86.9	86.9
		92.5	92.3	92.3
E. globulus x (E. nitens x E.cordata)		38.1	42.9	19.0
E. grandis x E.urophylla	J	85.7	28.6	28.6
	K	87.0	87.0	87.0
	L	100.0	100.0	100.0
	M	76.2	76.2	76
	Average	87.0	81.2	81.2
Trial average		91.4	90.9	90.1

Table 8: HB04 trial analysis at 18, 30 and 56 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

		18 mnths	30 months					56 months		
Species	Fam	Ht	Ht	Vol	Dbh	S	B	Dbh	S	B
E.globulus		4.09	7.56	0.0203	9.66	3.2	3.7	13.93	3.2	4.2
E. globulus x (E. globulus x E. gunnii)		3.32	6.33	0.0128	8.77	2.6	3.0	12.69	2.9	3.8
E. globulus x (E. globulus x E. nitens)		2.56	5.05	0.0060	6.26	3.1	3.0	11.33	2.8	2.9
E. globulus x E.grandis	A	2.03	5.03	0.0051	5.73	3.2	3.2	8.88	3.6	3.1
	B	2.31	5.18	0.0059	6.04	3.0	3.3	8.85	3.0	3.1
	C	2.17	5.46	0.0069	6.46	2.9	3.0	9.61	3.3	3.4
	D	2.27	5.35	0.0053	5.88	3.0	3.2	9.30	3.2	3.4
	E	2.12	5.42	0.0069	6.51	3.1	2.9	10.55	3.5	4.0
	F	2.36	5.76	0.0075	6.66	2.9	3.2	10.19	3.5	3.4
	H	2.12	5.53	0.0071	6.43	3.1	3.2	8.67	3.4	3.1
	Avg	2.20	5.39	0.0064	6.24	3.0	3.1	9.43	3.4	3.4
E. globulus x (E. nitens x E.cordata)		1.16	3.09	0.0001	2.96	3.1	3.0			
E. grandis x E.urophylla	J	0.53	6.33	0.0114	8.17	2.9	3.0	10.40	3.0	2.0
	K	2.53	5.68	0.0066	6.39	3.0	2.8	9.20	3.3	2.9
	L	1.90	5.45	0.0062	6.24	3.0	3.0	8.97	3.3	3.0
	M	2.00	4.78	0.0040	5.11	2.8	3.0	8.18	3.1	2.8
	Avg	1.67	5.56	0.0071	6.48	2.9	3.0	9.19	3.2	2.7

The malformation assessment shows that tree form has declined from 30 months to 56 months. Most of this damage is due to parrot attack.

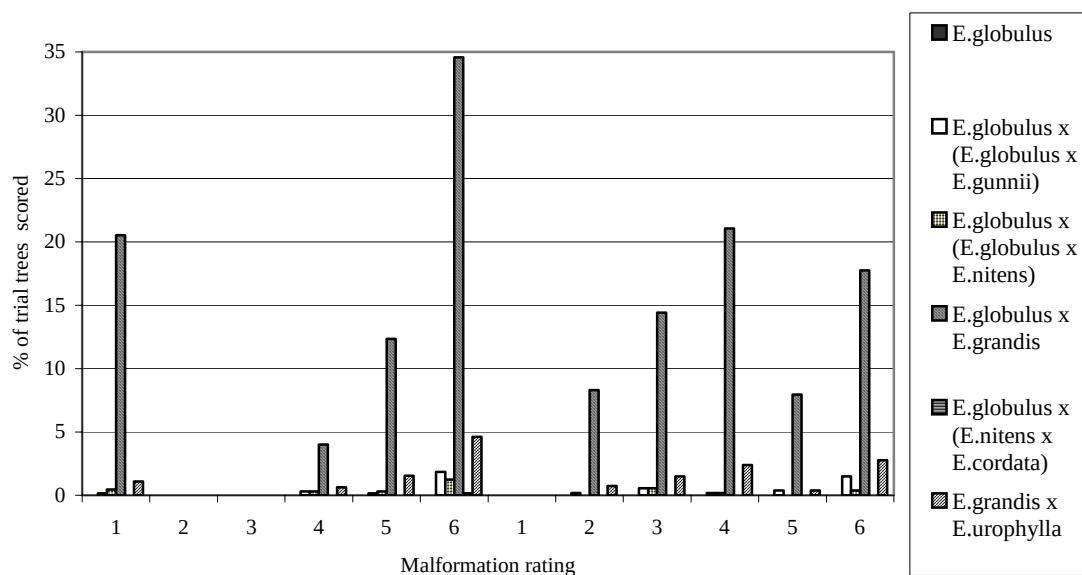


Figure 4: Malformation is scored such that 6 is a single straight stem with no malformation, 5 has a few ramicorns (1-2), 4 has many ramicorns (>2), 3 has a minor fork with or without ramicorns, 2 has major multiple forks, 1 is shrubby. The graph shows the percentage of trees within each species or hybrid with the noted malformation scores after 30 months (left) and 56 months (right) of growth.

4.5 HB05 - Winton's (Gingin) – P98

This trial was planted on the deep white sands north of Perth, a site that would be typical for *Pinus pinaster*, a species that surrounds the trial. The site was threatened by fire during the 2001 summer although by the time the trial was measured early 2003, there was no evidence of any damage. Parrot damage was severe from an early age.

The material included in the trial is mostly *E. camaldulensis* or a hybrid of this species with *E. grandis* and the pure species *E.globulus*. The *E. globulus* x *E. camaldulensis* all died soon after planting and were in-filled (Table 1). The material was designed into 7 replicates of 20 treatments in a 3 tree row plot and was planted in July 1998. Measurement of the trial after 18 months showed 84.4% survival. The best performing treatments were *E.globulus*, the control cross-pollinated *E. camaldulensis* and family C of the *E. grandis* x *E. camaldulensis* hybrid (Table XX). However, whilst not statistically significant due to low numbers (5 individuals), two *E. grandis* x *E. camaldulensis* clones out-performed *E. globulus* with heights of 239.6 cm and 175.2 cm. There was no statistical difference between the different crossings within the *E. camaldulensis* that is open pollinated, control out-cross pollinated and self-pollinated.

When the trial was measured at 30 months, *E. globulus* out-performed *E. camaldulensis* and the *E. camaldulensis* x *E. grandis* hybrid. However, by 56 months, one family of the hybrid *E. grandis* x *E. camaldulensis*, family A was out-performing the *E. globulus* at breast height diameter but its form was not assessed as highly as *E.globulus*. There was still no statistical difference between the performance of the different pollination crossing types of the *E. camaldulensis*.

Table 9: The survival and average tree height of the surviving trees at the Winton's site (Gingin) measured at 18 months. Means with the same letter are not significantly different.

Trial material	Family	# clones	Survival	Tree height
<i>E. grandis</i> x <i>E. camaldulensis</i> cuttings	A	4	91.6	133.4 cd
	B	5	95.7 ab	135.4 bc
	C	15	80.0 cd	146.7 abc
<i>E. globulus</i> x <i>E. camaldulensis</i> seedlings	A		75.0 cd	97.9 e
<i>E. globulus</i> seedlings			100.0 a	167.8 a
<i>E. camaldulensis</i> control pollinated seedlings			79.2 bcd	145.3 abc
<i>E. camaldulensis</i> open pollinated seedlings			79.2 cd	131.0 cd
<i>E. camaldulensis</i> self pollinated seedlings			79.2 bcd	131.4 cd
<i>E. camaldulensis</i> tissue culture	A	2	100.0 a	164.1 ab
	B	6	95.8 ab	104.9 de
	C	11	84.7 bcd	101.1 e
	D	5	71.7 d	93.9 e
	E	5	90.2 abc	140.5 abc

Table 10: HB04 trial analysis at 30 and 56 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

		30 months					56 months		
Species	Fam/mat	Dbh	Ht	Vol	Stem	B	Dbh	Stem	B
<i>E. globulus</i>	seedlings	5.86	5.31	0.0054	3.08	3.29	9.57	4.48	4.91
<i>E. grandis</i> x <i>E. camaldulensis</i>	A	5.7	5.26	0.0052	2.78	2.78	10.05	3.14	2.5
	B	5.5	5.31	0.0049	3.3	3.4	7.34	4.12	3.0
	C	5.2	4.95	0.0040	3.35	3.05	7.48	3.7	2.89
	Average	5.45	5.15	0.0048	3.16	3.07	8.15	2.82	4.55
<i>E. camaldulensis</i>	CP seedling	4.64	4.28	0.0026	2.27	2.27	6.72	3.69	3.94
	OP seedling	4.31	4.44	0.0025	2.79	2.79	5.47	3.82	4.35
	Self seedling	4.87	4.63	0.0031	2.67	2.27	7.25	3.40	4.00
	Tissue cult	4.52	4.06	0.0027	2.65	2.51	6.50	4.01	3.56
	Average	4.54	4.14	0.0027	2.63	2.49	6.49	3.93	3.67
Trial average		4.82	4.38	0.0033	2.76	2.66	6.98	3.79	3.89

4.6 HB06 – Pimelia (Pemberton) – P99

The site was cleared of *Pinus radiata* with the stumps removed and the site stick-raked. The karri loam soil was then ripped and mounded. The material (Table 1) was designed into 4 replicates of 81 treatments in a 3 tree row plot and was planted in July 1999.

After 41 months of growth, the pure species, *E. globulus* and *E. camaldulensis* had the best survival but when crossed to make the hybrid, the hybrid had significantly the poorest survival (Table 11). This variation of survival for the *E. globulus* x *E. camaldulensis* cross can be seen within the family crosses (Table 11) with family FC only dying after 41 months whilst FD died mostly at planting and then after 30 months. Family LF had good initial survival and then rapidly declined to 24.2%. The only other family to show this type of trend in *E. globulus* x *E. grandis* was family G, all the others had fairly good survival. The *E. grandis* x *E. camaldulensis* generally had good survival.

At 29 months, *E. globulus* was the tallest species and wood production of *E. globulus* dominated when the trial was 40 months old. The only other material of note was an *E. globulus* x *E. grandis* family, F, and an *E. grandis* x *E. camaldulensis* family C.

Table 11: HB06 trial survival (%) after 7, 30 and 41 months

Species	Family	Survival at 7 months	Survival at 30 months	Survival at 41 months
E.globulus		97.2	94.4	94.4
E. globulus x E.grandis	A	93.6	95.7	93.6
	C	98.3	96.7	83.3
	E	100.0	100.0	83.8
	F	93.3	90.0	75.0
	G	83.3	75.0	33.3
	H	100.0	93.1	81.9
	Average	96.5	93.8	80.9
E. globulus x E. camaldulensis	FC	95.8	83.3	50.0
	FD	66.7	54.2	37.5
	LF	93.3	54.6	24.2
	Average	91.3	56.9	27.4
E.grandis		100.0	97.2	75.0
E. grandis x E. camaldulensis	A	100.0	100.0	91.7
	B	97.9	95.8	77.1
	C	99.5	99.5	89.2
	Average	99.3	99.0	87.5
E. camaldulensis		100.0	100.0	94.4
Trial average		96.1	84.8	67.8

Table 12: HB06 trial analysis at 29 and 40 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

Species	Family	7 months	29 months	40 months				
		Ht	Ht	Ht	Dbh	Vol	S	B
E.globulus		0.34	3.06	8.79	8.19	17.29	4.67	2.8
E. globulus x E.grandis	A	0.40	2.12	6.28	7.62	10.84	4.98	4.47
	C	0.41	2.26	5.81	6.98	8.43	3.86	3.08
	E	0.39	1.87	5.40	7.08	8.27	4.96	4.00
	F	0.39	2.04	6.71	8.10	13.13	4.12	3.93
	G	0.26	0.83					
	H	0.39	1.80	5.29	6.45	6.18	4.02	3.57
	Average	0.38	1.82	5.90	7.24	9.37	4.39	3.81
E. globulus x E. camaldulensis	FC	0.53	2.71	5.95	6.11	6.03	3.92	3.00
	FD	0.34	1.76	5.04	6.28	4.82	5.02	1.88
	LF	0.31	2.08	5.83	5.93	5.75	3.16	2.09
	Average	0.39	2.18	5.61	6.11	5.54	4.09	2.32
E.grandis		0.50	2.01	6.06	7.67	10.40	4.56	3.56
E. grandis x E. camaldulensis	A	0.54	2.66	5.50	6.37	6.30	3.79	2.23
	B	0.49	2.58	6.00	7.12	8.60	4.53	3.45
	C	0.50	2.33	7.32	7.59	12.25	3.99	3.29
	Average	0.51	2.52	6.27	7.02	9.05	4.09	2.99
E. camaldulensis		0.43	1.99	4.82	6.21	4.98	4.42	3.74

4.7 HB07 – Toyota (Collie) – P99

The trial was designed into 6 replications of 8 treatments per replicate with each plot being a 5 x 5 tree plot (25 tree block). Replicate 1 and 2 have an additional treatment to add the *E. grandis* x *E. urophylla* hybrid. Family data could not be statistically extrapolated as the clones and families were randomised within each treatment. The site was ex- pasture land planted in July 1998.

Table 13: HB07 trial survival (%) after 6, 12, 24 and 37 months

Species	Survival 6 months	Survival 12 months	Survival 24 months	Survival 37 months
<i>E. globulus</i>	94.3	94.3	93.0	93.0
<i>E. globulus</i> x <i>E. grandis</i>	88.0	86.3	85.7	85.0
<i>E. globulus</i> x <i>E. camaldulensis</i>	76.3	73.7	54.0	54.0
<i>E. grandis</i>	96.0	96.0	96.0	96.0
<i>E. grandis</i> x <i>E. camaldulensis</i>	94.7	95.3	94.7	94.7
<i>E. grandis</i> x <i>E. urophylla</i>	98.0	98.0	98.0	96.0
<i>E. camaldulensis</i>	98.7	98.7	98.7	97.3
Grand Total	89.0	88.1	82.8	82.5

Overall survival over the 37 months declined to 82.5 % with the *E. globulus* x *E. camaldulensis* being the poorest performer.

Table 14: HB07 trial analysis at 6, 11, 29 and 36 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

	6 months	11 months	29 months					36 months
Species	Ht	Ht	Ht	Dbh	Vol	S	B	Dbh
<i>E. globulus</i>	1.40	2.27	5.4	5.40	5.50	3.96	3.98	8.82
<i>E. globulus</i> x <i>E. grandis</i>	1.10	1.70	4.4	4.40	2.28	3.45	2.74	7.25
<i>E. globulus</i> x <i>E. camaldulensis</i>	1.09	1.42	4.65	4.65	3.90	2.40	2.24	7.67
<i>E. grandis</i>	1.32	2.11	4.71	4.71	2.92	3.19	2.70	7.29
<i>E. grandis</i> x <i>E. camaldulensis</i>	1.48	2.34	4.85	4.85	2.73	3.12	2.48	6.82
<i>E. grandis</i> x <i>E. urophylla</i>	1.21	1.81	4.04	4.04	1.81	3.17	2.17	6.49
<i>E. camaldulensis</i>	1.20	1.55	3.43	3.43	0.96	2.07	1.94	5.16

E. globulus has out-performed all of the other species and hybrids at this site when compared on wood production and form. The next best hybrid was *E. camaldulensis* x *E. globulus* for wood production and this was due to the death of a number of abnormal clones and the dominance of two outstanding clones.

4.8 HB09 – Coffey (Kojonup) – P2000

The trial is established on ex-pasture site, which was visibly suffering the effects of salinity on the lower slope of the trial. The trial was planted as 5 replicates of 38 treatments in a 4 tree row plot. Only four replicates were used in the statistical analysis as the 5th replicate could not be fully planted. This trial has had severe parrot damage since the first assessment. Being a waterlogged site, the weeds were more difficult to control.

Overall survival is good with 93.3 % after 31 months of growth. The most affected is the *E. grandis* at 87.5 % with *E. camaldulensis* still showing 100 % survival. There was no significant difference in height growth after 9 months and similarly no growth differences were evident when the breast height diameter was measured after 31 months of growth. *E. globulus* was significantly straighter than the other species but only the hybrid *E. globulus* x *E. camaldulensis* showed significantly smaller branches than the other material in the trial. The *E. grandis* x *E. camaldulensis* hybrids were noted for their very heavy crown in this trial but this could be due to parrot attack.

Table 15: HB09 trial survival (%) after 9 and 31 months

Species	Survival 9 months	Survival 31 months
<i>E. globulus</i>	100.0	94.1
<i>E. globulus</i> x <i>E. camaldulensis</i>	95.8	94.9
<i>E. grandis</i>	93.8	87.5
<i>E. grandis</i> x <i>E. camaldulensis</i>	93.2	90.3
<i>E. camaldulensis</i>	100.0	100.0
Trial total	95.1	93.3

Table 16: HB09 trial analysis at 9 and 31 months. Height is measured in metres, breast height diameter (Dbh) in centimeters, volume (Vol) in dm³, stem form (Stem) and branching (B) are graded on a scale of 1-6.

	9 months	31 months		
Species	Ht	Dbh	S	B
<i>E. globulus</i>	91.6	1.64	3.75	3.02
<i>E. globulus</i> x <i>E. camaldulensis</i>	98.0	1.62	2.44	3.35
<i>E. grandis</i>	102.0	1.69	2.50	3.00
<i>E. grandis</i> x <i>E. camaldulensis</i>	113.9	1.65	2.41	2.50
<i>E. camaldulensis</i>	116.6	1.61	1.83	3.17

4.9 HB11 – Howell (Mt Barker) - 2002

The material was divided into 5 replicates of ten treatments planted into a four tree row plots. It was planted in August 2003 and thus only 7 month heights and survival could be measured. At this stage the *E. grandis* x *E. camaldulensis* were taller.

Table 17: HB11 trial assessment after 7 months. Height (Ht) is measured in centimeters and survival is expressed as a percentage.

Material	Ht	Survival
<i>E. grandis</i> x <i>E. camaldulensis</i>	118.19	97.8
<i>E. globulus</i> x <i>E. camaldulensis</i>	86.29	99.8
Trial average	102.24	98.8

4.10 HB12 – Coffey (Kojonup) - 2002

In this trial, hybrid seedling material from *E. globulus* x *E. camaldulensis* crosses was planted directly in the field without the stage of multiplication. The trial was not statistically designed but the hybrids randomized between the controls so that there was a row of *E. camaldulensis*, 2 rows of hybrids, a row of *E. grandis*, 2 rows of hybrids and a row of *E. globulus*. This was repeated across the site.

Unfortunately there was heavy insect damage over the summer setting back the growth of the seedlings.

Table 18: HB12 trial analysis after 7 months. Height (Ht) is measured in centimeters and survival is expressed as a percentage.

Material	Ht	Survival
<i>E. globulus</i>	50.5	91.8
<i>E. globulus</i> x <i>E. camaldulensis</i>	39.2	80.6
<i>E. grandis</i>	38.7	60.7
<i>E. camaldulensis</i>	36.3	94.1
Trial average	41.18	81.9

5. Discussion of Results

At the beginning of this research, it was debated whether vegetatively propagated material of both the hybrids and *E. globulus* should be compared. *E. globulus* seedling material was eventually used as this is the chosen deployment system for *E. globulus* in southwest Western Australia.

The deployment of eucalypt hybrid material has many challenges. It is assumed that an identical copy of a hybrid clone is produced every time, but this is not always possible with the propagation techniques available. The impact of producing an adventitious rooting system from a tap or true root system can affect growth. Furthermore, ageing of the material can change the root structure in that the number of roots is reduced and, more importantly, the type of root produced. Older mother plant stock loses the ability to produce fine feeder roots and has a dominance of thick roots. These anatomical changes have physiological effects that complicate the interpretation of the growth performance of hybrid material. The resulting growth performance may be due to the propagation method rather than the genetic expression of the hybrid. The more juvenile the propagation material, and thus closer to true root formation, the less the propagation effect on hybrid performance. The race to attain a somatic embryogenesis tissue culture system for eucalypts is a testimony to this concern.

The seasonality of the cutting production system in southwest Western Australia also created some challenges. In this climatic zone, field planting occurs within the months of June to August and can be shortened if the rain is late. Cuttings are set from late November through to early February to be of a quality acceptable for establishment. The mother plants must be maintained for the rest of the year.

A number of cells and media types was experimented with during the course of this research. A single insert was favoured as there was a high level of sorting of the cuttings, firstly disposing of cuttings that did not root, then sizing the cuttings according to their growth rate and the final sort was into the trial design. It was observed that an insert that had a length over 12 cm was needed to accommodate the setting depth of the cutting. It was felt that air-pruning slits added no value to the insert. As cuttings were in a high humidity for a length of time, the early rooting clones roots broke through the slits and made the cutting difficult to extract in the field. Media was equally a challenge. In the misting house, pure vermiculite was favoured for good rooting success but once out of that environment and the cuttings had grown, the cuttings were difficult to manage as the media had little water-holding capacity. Thus a higher air filled porosity media was used that had an acceptable water-holding capacity for the hardening-off stage.

The ranking of *E. globulus* tree performance in breeding trials can be predicted after 2.5 years when water availability is unlimiting (T. Butcher, pers. comm.). However as tree canopy size is related to available water (Specht and Specht 1989), the trees need to mature further before water-limiting situations may arise and highlight the drought-tolerance mechanisms between the species and hybrids. Depending on the site characteristics (Harper et al. 1999), signs of droughting in *E. globulus* have been observed as early as 4 years in the southwest Western Australia. Thus the initial measurements prior to this project were interesting in terms of survival and initial growth, but the trees had not matured sufficiently to prediction full rotation performance.

Water-limiting conditions appeared to affect the trials with some trees responding by coppicing from the base of the tree and in others by the natural death lowering the overall survival of the trial. Not all survival was related to drought. Some trees were so abnormal (especially the *E. globulus* x *E. camaldulensis* hybrid) that death appeared due to the abnormality rather than an environmental factor. However, it was thus clear that, for the trials to remain useful, a thinning to sawlog rotation would be required. To test if any of these hybrids could become an alternative pulp source to *E. globulus* on lower rainfall or saline sites, block plantings of a single clone are required. This would then test their ability to control their water uptake at commercial planting densities.

Parrots plagued the form assessment of these trials. Some sites were more severely attacked than others and this appeared to be related to the openness of the trial. The more exposed the trial (in the middle of an agriculture field) the more attacked by parrots. Generally the pattern was initially for the taller trees to be attacked and then all the trees were sequentially attacked to varying degrees. What was of interest was the ability of a species or hybrid to recover its apical dominance after such an attack and maintain a single stem rather than become a multi-ramicorn bush. Where there was no parrot attack (HB01, Grimwade) the percentage of trees with a single straight stem increased (Figure 1 and 2). In the parrot attacked sites (HB02, Boyup Brook; HB04, Albany), the higher malformation scores declined (Figure 3 and 4). The greatest decline in malformation score in HB02 (Boyup brook) was with the *E. globulus* x *E. grandis* hybrid (22.25 %) whereas the form improved in *E. grandis* (19.6%) and in *E. globulus* (9.13 %). In HB04 the *E. grandis* x *E. globulus* declined (42.35%) with *E. globulus* declining but not to the same degree (11.77%).

Assessment of the trials through this project period showed that, on the sites that were considered *E. globulus* sites, HB02 (Boyup Brook), HB04 Albany, HB06 (Pemberton), HB07 (Collie) and HB12 (Kojonup), *E. globulus* seedling growth was superior to that of the hybrid cuttings in a pulpwood rotation. However, on the sites that were not typical *E. globulus* pulpwood production sites, HB03 (Darkan), HB05 (Gingin), HB09 (Kojonup and saline) and HB11 (Mt Barker and saline), other hybrid material showed potential to produce a more productive tree crop.

In HB03 (Darkan) family F of the *E. globulus* x *E. grandis* hybrid showed 90.5% survival and had the largest breast height of this hybrid (7.97 cm). Whilst *E. globulus* had a larger breast height diameter (8.35 cm) survival was only 23.2% and the wide spacing would have allowed for this increase in growth. Until this low survival, *E. globulus* had been one of the poorer performers (Table 6).

HB05 (Gingin) only contained *E. grandis* x *E. camaldulensis* hybrids and family A in the last measurement was showing signs of out-performing *E. globulus* (Table 10). Of concern in the family is the poor form performance of the family but this is due to parrot attack.

In HB09 (Kojonup and saline), the first hybrid trial to be tested for saline tolerance, there is little difference between the material at 31 months. Whilst *E. grandis* has the greatest breast height diameter (1.69 cm) this is not statistically significant from the rest of the species and hybrids (Table 16). Of note is that the best form was measured in *E. globulus* even under severe parrot attack. HB11 (Mt Barker and saline) is too young for any far-reaching conclusions.

This project has shown that finding superior hybrids is an intensive exercise of making the hybrids, testing them at a number of levels and improving the deployment system before they can be reliably marketed. Starting with material that is crossed with best selections from species adapted to the local environment greatly enhances the level of success.

6. Implications

This project has not been able to show a hybrid family that has better growth performance than *E. globulus* on a typical *E. globulus* site. A small number of clones have shown potential but these have to be further tested in bulk plantings so that inter-tree interactions are tested. Where *E. globulus* is included in trials that are not typical *E. globulus* sites, the deep sands of Gingin or low rainfall sites or saline sites, the hybrids appear to show more promise at the family level.

The project further indicates that in lower rainfall areas, hybrids may not be able to meet growth expectations at high pulp market stockings (1250 stems per hectare). A level of water use control through silviculture may have to be implemented and thus the greater value of the primary product being solid wood perhaps should be considered.

The question of the propagation technique and the effects of ageing are of a concern as more experience is gained in this field. Mother plant ageing prior to the setting of the cuttings can have major growth retardation effects. This ageing concern was not quantified in this project.

7. Recommendations

1. Re-visit deployment systems for temperate hybrid eucalypts.

Eucalypt hybrid forestry developed in the tropics and has continued with hybrids that vegetatively propagate easily. The hybrid species chosen coppice easily from a stump, the tissue is rejuvenated and thus rooting is a relatively easy task. As a result, eucalypt hybrids have always been deployed at a clonal level.

There are many advantages to implementing clonal hybrid forestry in tropical climates compared with temperate climates. Firstly, there is a larger planting window so the system can and is run on a year-round basis in most countries. This adds greatly to the cost-efficiency of the system. Additionally for establishment in tropical regions, rain falls in the summer when evaporation is high and declines in the winter when little evaporation occurs. As a result the plants undergo lower levels of stress compared to a winter rainfall cycle as seen here in the southwest of Western Australia. Mediterranean climates demand the cuttings to survive summers of between 3 – 6 months of no rain. The root system is of greater importance to tree survival and growth. The ultimate vegetative propagation system is somatic embryogenesis where the tissue is the most juvenile and the roots produced are true roots. The somatic embryogenesis system is attaining commerciality with softwoods and research is nearing a positive result with eucalypts. Large pulpwood companies with plantation holdings that can justify this level of expenditure can afford this type of research.

Seedling deployment of hybrids has been avoided. Hybrid research has always focussed on clones because clonal forestry has been attainable. Seedling forestry involves a dilution, or reduction in genetic gain. However, certainly in a Mediterranean climate, the advantages of having a true root system compared to an adventitious root system together with the possibility of an ageing effect could negate any genetic advantage of clonal forestry. When two hybrids are crossed, segregation is expected. If all seedlings were to be kept to final rotation, as for a pulp market, then this would be a significant consideration. However, for a saw log rotation where only 15 % of the crop is kept to final rotation, is this of concern? For a pulpwood rotation, mass control pollination systems to make hybrids could be developed with some crosses. A recommendation is to re-visit the deployment of hybrids through seedlings to re-value the system.

2. Present trials are managed on a sawlog rotation.

The present trials are a mixture of hybrid material; some are hybrids that could be used for a higher density planting, others that would excel in a sawlog rotation with greater moisture availability. This latter selection of material will be lost if the trials are kept at their present density. Furthermore, the parrot damage has created larger canopies that would normally occur. These trees need to be removed or pruned if they can be saved.

3. Superior hybrids are further assessed in block planting field trials

The superior hybrids need to be tested in clonal blocks so that the interaction between trees can be assessed for large scale deployment.

4. Wood quality assessment of superior hybrids

Those hybrids that show promise in the block plantings should be further assessed for their wood quality both for pulpwood and for sawlog.

8. References

- Harper R.J., Edwards J.G., McGrath J.F., Reilly T.J. and Ward S.L. (1999). Performance of *Eucalyptus globulus* plantations in southwestern Australia in relation to soils and climate. In 'Balancing productivity and drought risk in blue gum plantations'. A Plantation Management workshop. November 9th 1999. Pemberton, Western Australia.
- Specht R.L. and Specht A. (1989). Canopy structure in *Eucalyptus*-dominated communities in Australia along climatic gradients. *Acta Ecologica/Ecologia Plantarum* 10, 191-213.