DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

OF

WESTERN AUSTRALIA

EUCALYPTUS GLOBULUS PLANTATIONS

IN

S.W. WESTERN AUSTRALIA

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Eucalyptus globulus at Sprent in northern Tasmania
Planted in 1943, unthinned, MAI 18m3/ha./yr.

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1. TERMS OF REFERENCE

As per instructions in the letter dated 1st. October 1987 from Dr. S. Shea, Executive Director of the W.A. Department of Conservation and Land Management to R. K. Orme

1. To organise a seed collection of up to 75kg. of *E. globulus* seed from NE Tasmania to be delivered to Perth by late December.

2. To commence planning to provide superior grafted stock for a seed orchard to be planted in W.A.

3. From field observations and discussions concerning the seed orchard to provide a report giving a critical technical review of the proposed project and specifically of the planning of seed supply and its genetic quality.

2. SUMMARY

This report looks into the technical aspects of the large-scale plantations of Eucalyptus globulus which is proposed by C.A.L.M. to overcome two major environmental problems in S.W. Western Australia: the salinity of the water courses and the eutrophication of coastal estuaries. It has been written based on a week's visit made to the proposed areas and discussions with various members of C.A.L.M. who kindly acted as guides.

The proposal is both feasible and innovative, will provide an increasing supply of high quality wood and give the farming community an alternative crop, albeit a longer term one. Growth rates predicted for the project are attainable with good silvicultural practice and an average yield of 15m3/ha./yr is a reasonable estimate for economic analyses.

Existing trials demonstrate that a number of provenances grow well under W.A. conditions and those from Bass Strait, King Is. Otways and Flinders Is. should form the major component of the proposed project. To supply suitable seed for the project as soon as possible a clonal production seed orchard has been proposed. This will result in a 30% gain in wood production as well improvement in quality. Because of a doubt about early flowering it may be necessary to plant part of this orchard in another climate.

There is need for the future development of this species under W.A. conditions and a tree improvement programme is proposed which would use both selections made from W.A. trials together with additional material from better provenances such King Island.

The general silvicultural requirements, management options and the possibility for clonal plantation forestry with this species are discussed.

Research requirements to provide better knowledge about certain aspects of E. globulus plantation forestry in W.A. have been listed.

3. INTRODUCTION

3.1 General

The Western Australian Department of Conservation and Land Management proposes a major afforestation scheme for the south-western part of W.A. to combat two major problems caused by past and present agriculture practice:

1. eutrophication, or the fouling, of rivers, lakes and estuaries of the sandy coastal plain which fringes the Darling Plateau, in particular the Peel-Harvey catchment. This is caused by the leaching of phosphates applied to the agricultural soils into the water drainage systems.

2. the salinization of the Darling Plateau agricultural soils, streams and water supplies caused by the removal of the native forests and woodlands, and their replacement by pasture grasses which have allowed the water tables to rise bringing soil salts to the surface.

The project will involve the large scale planting of all affected areas which are listed in table 1. This will, in time, solve these problems. As well the project would provide a substantial source of high grade eucalypt pulpwood which would be valued at $120 million annually at current prices on the world market for every 100,000 hectares of plantation established.

Such a large resource of high grade plantation grown wood would allow for the establishment of a large-scale pulp and paper industry in W.A. within a decade or so. This wood would have a minimum pulp yield of 55% (Soda pulping) which is 25-30% better in quality than the karri-marri pulpwood which is currently being exported from W.A. to Japan. Plantation grown wood is amenable to several pulping processes, some of which are more attractive from environmental considerations.

TABLE 1 LIST OF PRIVATE PROPERTY AREAS IN C.A.L.M. PROPOSAL

PRIVATE PROPERTY AREAS

	Coastal	HRZ	IRZ	LRZ	<LRZ	TOTAL
A Bunbury cell						
1 Peel	103.1					103.1
2 Bunbury coastal	261.9					261.9
3 Northern forest		58.0	2.3	40.1		100.4
4 Wellington		6.0	10.9	45.3	41.6	103.8
5 Central forest		9.4	83.8	79.6		172.8
CELL TOTAL	365.0	73.4	97.0	165.0	41.6	742.0
B Manjimup cell						
1 Manjimup coast	12.9					12.9
2 Southern forest		52.2	44.4	80.7	101.5	274.8
CELL TOTAL	12.9	52.2	44.4	80.7	101.5	291.7
C Albany cell						
1 Albany coast	44.4					44.4
2 Albany		26.3	38.8	144.7	73.8	283.6
3 King/Kalgan	119.6					119.6
4 East of Kalgan	41.2					41.2
CELL TOTAL	205.2	26.3	38.8	144.7	73.8	488.8
TOTAL	583.1	151.9	180.2	390.4	216.9	1522.5

Note: - In 1000s of hectares.

- Coastal category includes all areas off the Darling Plateau i.e. mostly coastal plains with soils formed over recent sandy sediments.

- HRZ, IRZ and LRZ are rainfall zones delineated as follows:

  - HRZ high rainfall zone > 1100 mm pa
  - IRZ intermediate rainfall zone 1100 - 900 mm pa
  - LRZ low rainfall zone 900 - 700 mm pa
  - <LRZ less than 700 mm rainfall extending out to catchment boundary

3.2 Consultant's view on project.

At the onset the proposed project is innovative since it will not only will solve the eutrophication and salinity problems, but at the same time will provide a large of resource of high value pulpwood which could either be exported, or processed in W.A. Although eucalypt plantation forestry is well established in countries like Brazil, it is only by commencing similar schemes that Australia will be able to compete in the international markets in the long-term and W.A. would reap the benefit of such foresight. Reliance on traditional silviculture regimes as practiced in Australia is not an efficient way of producing wood. The amount of wood produced by 250,000 hectares of such plantation would exceed the total annual wood production of 3.8 million m3 from Tasmania's 2,000,000 hectares of productive forest.

The size of the plantation project of around 10,000 hectares annually is quite substantial by Australian standards, but by no means unattainable if sufficient resources are allocated and two to three years are allowed to build-up the scale of the operation.

From the plantations visited by the consultant throughout the range of sites to be included in the project there is little doubt that the proposed scheme is feasible. Probably it could even be extended out into slightly dryer areas down to the 600mm. isohyet, especially if one considers that most E. globulus grown in W.A. comes from the colder and higher rainfall areas of southern Tasmania (1200mm.) and not from the warmer dryer regions of the north-eastern coast, nor from the Bass Strait Islands (700-800mm.) Growth rates of the trial plots and plantations visited were higher than would have been predicted without the benefit of observation and plot data. With good establishment techniques and good genetic stock there is no reason that a mean growth rate of 15m3/ha./yr. could not be attained, and as seed orchard seed becomes available and plantation techniques improve with experience this could be substantially improved up to 25m3/ha/yr.

As well as the proposed areas there are substantial areas of "die-back" affected jarrah forest which could be rehabilitated into aesthetically pleasing and productive forest by expanding the scale of this proposal at some stage.

E. globulus plantation at Stoodley in N. Tasmania
Planted 1941, unthinned until 1981, MAI 22m3/ha/yr.

4. E. GLOBULUS IN WORLD FORESTRY

Plantation forestry with eucalypts is a well developed practice in many parts of the world and there have been substantial increases in areas planted over the past two decades, particularly in sub-tropical climates. These plantations supply wood for many purposes varying from fuel and poles for local consumption up to the production of pulp and paper for world markets. Brazilian developments have been on the largest scale with very large plantations of mainly E. grandis, E. urophylla (Timor) and more recently various hybrids. Substantial improvements have been made by the Aracruz company by changing from seedlings to very high yielding clones in plantations.

E. globulus is more suited to temperate climates and is widely planted in the mediterranean region; in particular, Spain and Portugal, where it is used more or less solely for the production of pulp and paper. The species is quite adaptable and is used on both the northern Iberian coast on good granitic soils and high rainfall as well as in the far hotter, dryer parts of southern Spain and Portugal between Seville and the southern and south-western coasts. There is a large area of about 10,000 ha. planted south-east of Huelva which is very similar to the swampy coastal sands of W.A., at least superficially.

As well this species is used in the African highlands and in the Nilgiri Hills of S. India. In South America E. globulus grows in plantations going from southern Argentina and Chile through the high plains of the Andes in Peru, Bolivia, and Ecuador up to northern Colombia where it is grown between the 2000m. and 3000m. levels. In fact it is the only tree species to be seen growing on the altiplano of these countries. Here, the wood is mainly used for local consumption, poles, charcoal, fuelwood etc. However, sawn timber from Chile is finding a ready market in Europe where it is competing successfully against both "Tasmanian Oak" (regnans, delegatensis, obliqua) and American White Oak for the furniture market. This wood is coming from older plantations which where planted in the 1920's and are owned by the Forestal Colcura S.A. company which is based in Lota. There will be commencing shortly a 200,000 tonne p.a. wood-chip export operation to Japan based on the thinnings of these plantations in order to up-grade this resource for timber production.

Estimates of the total area of E. globulus plantation in the world in 1973 were over 800,000 ha., but it is likely that this figure could have doubled by now (FAO,1981).

The original source of E. globulus for these plantations is thought to be from southern Tasmania, probably near Bruny Is. and Recherche Bay since the French explorers Baudin and D'Entrecasteaux, as well as Captain Cook, spent most of their time in Tasmania in this area. One can only assume that this material was transferred to Europe, probably via Maritius, since the introduction of exotic species was a terribly popular pastime amongst society of the time.

In view of the commercial importance of the species one wonders why so little interest was shown in the provenance variation and genetic improvement of this species until recently. It is pertinent to point out that the majority of these plantations are suffering some depressed productivity due to inbreeding. The Portuguese are now showing considerable interest and have commissioned new seed collections in Australia, more or less along the sames lines as the Brazilians did with E. grandis nearly a decade ago when it was realised their local "land-race" of E. grandis was inbred.

It is very doubtful that many of the overseas plantations would have originated from the Bass Strait island populations since the writer undertook the first known collections only in 1976.

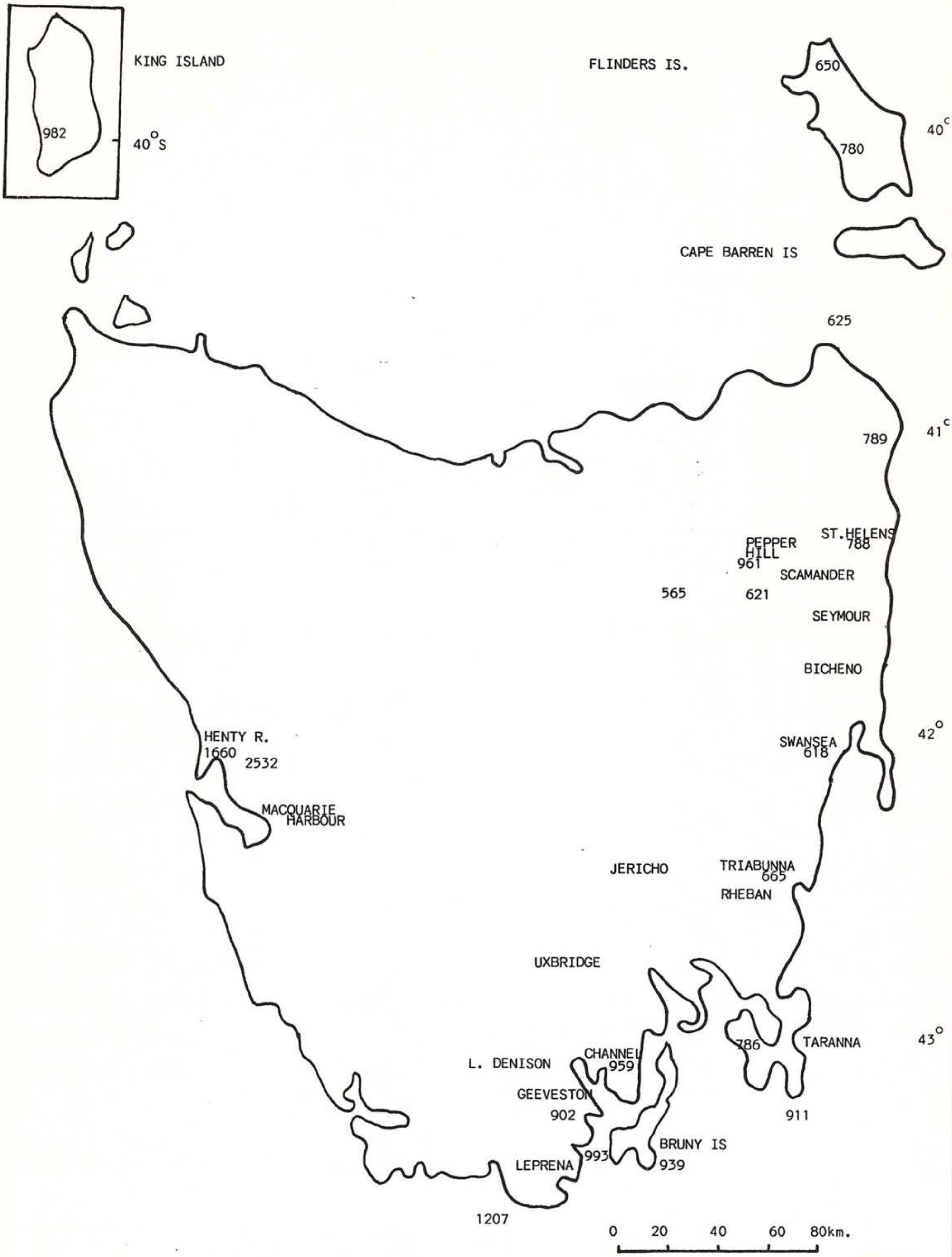

FIGURE 1 LOCATION OF PROVENANCES OF E. GLOBULUS IN TASMANIA AND ANNUAL RAINFALL (mm.)

5. PROVENANCE VARIATION

5.1 General

The initial study into the provenance variation of this species was undertaken by the writer in late 1975 (Orme,1977). This resulted in a wide range of collections being made throughout the range of globulus and the closely-related species bicostata, maidenii, and pseudoglobulus. These seed collections were distributed widely and now there are many provenance trials established in many countries as far apart as Uruguay and Nepal. Unfortunately results from all these trials are not known, nor likely to be, but there are sufficient to suggest that a large number of the provenances have been successful in many parts of the world.

The pattern emerging from the better known of these trials is that the Bass Strait provenances are just as good performers as the southern provenances, and in some trials they occupy the top positions. As well, it appears that family variation is considerable and this may have masked variation due to provenance in many of the trials since the designs were not sophisticated.

5.2 W.A. Trials

Inspection of the two provenance trials, at Baudin near Busselton and at the Manjimup nursery, confirm the general trend of other trials: that globulus has performed better than maidenii and bicostata, and that the Bass Strait provenances (King Island, Flinders Is., Otways and pseudoglobulus) have grown well, but there are little significant differences apparent between most provenances of globulus and pseudoglobulus.

A two year old trial retaining family identity has been established on the Huntley mine rehabilitation area. The results of this illustrate quite well the significance of family variation within the various provenances.

The 73 families from this trial have been divided into three groups representing the top, middle and lowest thirds based on the recent height measurement.

Table 2. Numbers of families at the Huntley Trial ranked by height at age 2 and Provenance.

Provenance	Top 1/3	Middle 1/3	Lower 1/3	Total
Eastern	7	6	11	24
Bass St.	6	1	2	9
Southern	12	8	5	25
Western	-	6	2	8
Other	-	3	3	6
Totals	25	24	24	73

It is noteworthy that the southern and Bass Strait provenances occupy the top ranks of this particular trial, but there are good families from other areas as well and these should not be excluded from the future breeding programme, especially since some families are good, e.g. S2, whilst many are untested.

5.3 Wood Quality

Wood samples were taken from the original collection and the results from the pulping tests showed there were zones of very high pulp yields (Henty River, Macquarie Harbour, King Island and some southern provenances). The highest individual was Tree no. 2 from the Henty River (western Tas.) with a 60% pulp yield; the lowest yields were around 35% (fig.2).

Several seedling seed orchards were established in Tasmania based on the top 40 families of this collection selected on the basis of pulp yield, in fact trees with pulp yields over 52.5%. This sample was heavily biased in favour of the southern provenances and families since they were, on average, those with the highest pulp yields.

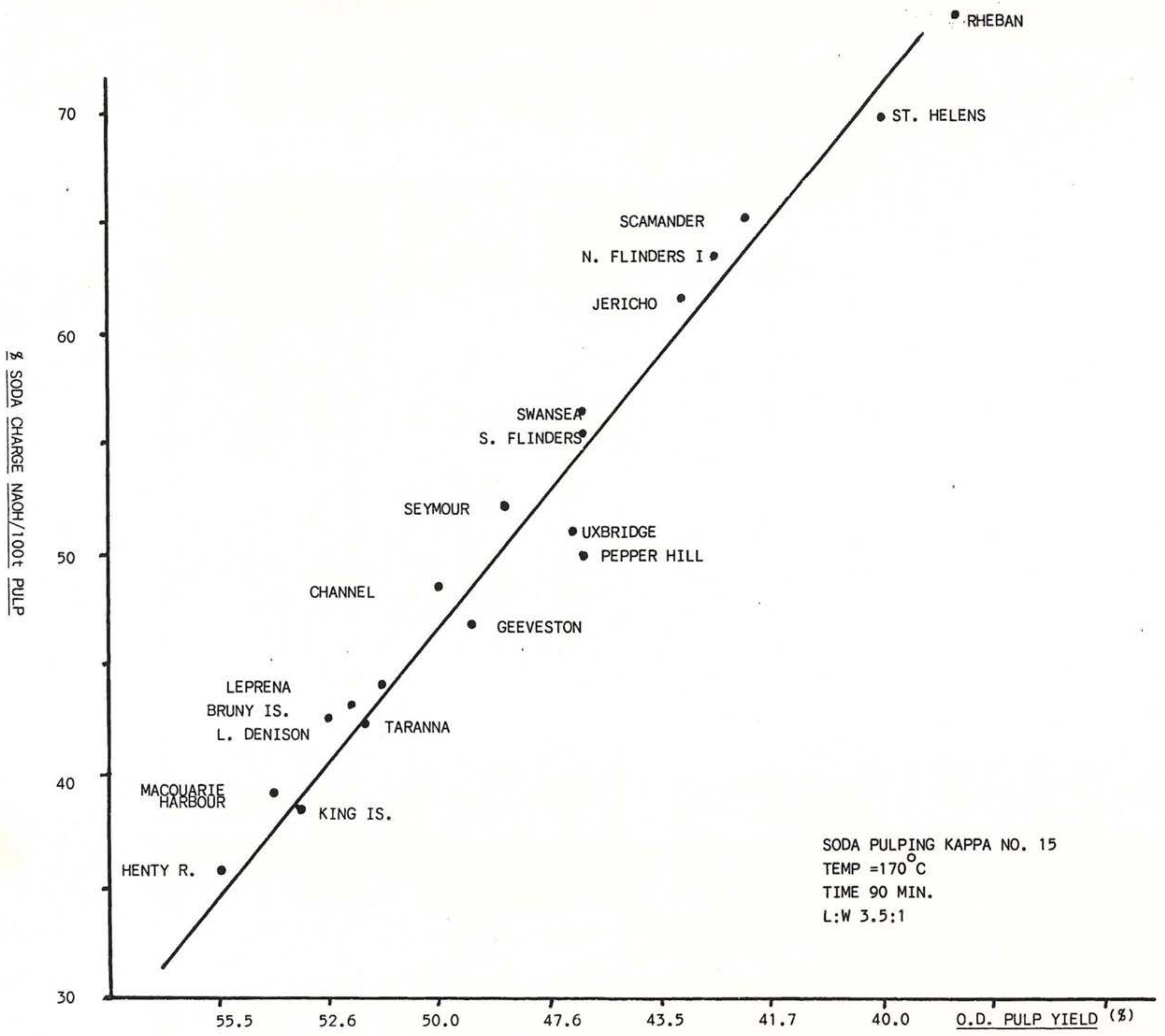

FIG 2 MEAN PULPING YIELDS FOR E. GLOBULUS PROVENANCES FROM PARENT TREES SAMPLED FROM NATIVE STANDS

The seed orchard at Woolnorth in NW Tasmania has been well cared for since its establishment in 1980 and recently has been assessed for both pulping yields and growth data. In general the Bass St. families provided individual trees with the fastest rates of growth. However, when pulping data are also considered the best families overall tended to be those from the southern provenances.

The families in the Woolnorth seed orchard have been assessed according to the following index:

Growth rate	3 points
Basic Density	4 points
Dry Matter	4 points
Bark thick.	10 points
Pulp Yield	10 points

Families were given values from 0.00 to 1.00 for each of various characteristics assessed. Then a weighted value for the selection index was calculated for each family and the indices for the top twenty families have been listed in table 3.

E. globulus seedling seed orchard at Woolnorth at age 5 years. Seed production commenced at 6 years.

Table 3 The Top 20* families in the Woolnorth Seed Orchard.

Family	Index	Provenance
G9	77	Southern
C5	76	S
B10	75	S
T10	71	S
B4	69	S
NF2	67	Bass St.
G10	66	S
O4	65	B
L8	63	S
L6	62	S
G6	62	S
C3	58	S
T9	57	S
C4	57	S
MH2	57	Western
KI5	56	B
T1	56	S
SF8	54	B
MH1	53	W
S2	53	Eastern
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.		
.		
.		
.		
H5	22	W

* out of 48 families

Overall the pulp yields for the various individuals of these families also varied somewhat, but the majority of trees tested gave pulp yields in the range of 54% to 55%. The highest yield was 57% for one member of the L8 family (Leprena, southern Tas.).

One point of considerable significance coming out of this work is that there was little relationship between the pulp yields of the parent trees coming from different environments and their progeny when grown at the one site.

5.4 Conclusion

Based on the current information (which should not be cited until published) there is a large amount of genetic variation occuring between individuals within families, between families, and between provenances of E. globulus, especially from the point of view of growth rates and pulping properties.

This means that:

1. there is a lot of scope for improving the productivity of this species by genetic improvement, since plantations in W.A. are currently based on virtually unknown material from southern Tasmania.

2. that the improvement programme should be based on a very wide initial genetic base which will allow for heavy culling in later stages of the programme without the fear of inbreeding.

The other main point arising from this work is that the pulping characteristics should probably play a greater role in an improvement programme than just straight growth rate and tree form alone since pulpwood is the desired end product. The desirable characteristics of the ideal pulping tree are:

1. Good form with small branchs
2. Fast growth rate
3. High pulp yield
4. Basic Density 500 to 550
5. Thin bark
6. Low moisture content

6. GENETIC IMPROVEMENT PROGRAMME FOR E. GLOBULUS

6.1 General

The results from the provenance trials demonstrate:
1. that many provenances have performed well under W.A. conditions and,
2. there is also considerable within and between family variation.

Therefore, the general aim of the improvement programme is to commence the breeding work with the widest possible genetic base. This can be accomplished by selecting material from the majority of the provenances in the W.A. trials and supplementing this with additional material from selected areas in Tasmania.

This material is put into a breeding seed orchard where all the associated testing work, controlled pollinations and so on can be done. A four hectare site will be required for this and will contain two replicates of the 300 clones listed in table 4.

6.2 Breeding Clonal Orchard Composition

1. Selections from W.A. Provenance Trials

Make two selections per provenance of all *globulus* and *pseudoglobulus* provenances from the trials situated at Baudin and Manjimup. *E. pseudoglobulus* is to be included but not to be treated any differently from *E. globulus* at this stage since they will cross readily. These selections should be made on the basis of form, diameter, height, bark thickness and wood properties if possible.

Since most provenances were represented by a mixture of 10 parent trees the chances of making four selections from the one family are not high.

2. W.A. Family Trial at Huntley

This is a very useful trial for your improvement programme since it is possible to make selections knowing the complete background of the various families. There should be one selection made from the top half of the families in the trial. The family K13 should also be selected despite its position near the bottom of the ranking; it is likely that the progeny of this particular family are due to selfing because this selection was an isolated tree on King Island. In fact I am surprised that any progeny grew at all.

3. Tasmanian Seed Orchards

As mentioned previously several seed orchards were established during 1980 and 1981 in Tasmania. These have been measured, pulp tested and culled. Therefore it is proposed to obtain material from the top individuals of the best 20 families for inclusion in the W.A. improvement programme. Perusal of the Huntley trial data reveals that there are only 3 families in common with these families from the Tasmanian orchards, Channel Tree No. 5, Seymour Tree No. 2 and Channel Tree No. 3 which rank, respectively, 2, 20 and 12 out of 48 (table 2).

4.Additional Field Collections

Because of fairly limited sampling in the better provenances it is recommended that further selections be made.

The numbers and provenances proposed are:

1. King Island	50 trees
2. Flinders Island	25 trees
3. N.E. Tas.	25 trees
4. Southern Tas.	25 trees
5. Otways	25 trees

These would be selected in the field over the next few months and grafted ready for planting into the W.A. orchard(s) in late Autumn next year. As well as field collections from the original forest areas some selections would be also taken from plantations of known provenance.

A summary of the proposed composition of the future seed orchard is given in table 4.

TABLE 4 COMPOSITION AND ORIGIN OF GENETIC MATERIAL FOR IMPROVEMENT PROGRAMME OF EUCALYPTUS GLOBULUS IN W.A.

Locality	Huntley Trial	Manjimup Trial	Baudin Trial	Tas. S.O.	Tas. Forest	Total	%
Bass Strait	8	12	12	4	100	136	46%
Eastern Tas.	8	12	12	1	25	58	20%
Southern Tas.	16	12	12	12	25	78	27%
Western Tas.	5	4	4	2	-	15	5%
Other	1	2	2	-	-	5	2%
Totals	38	42	42	20	150	292	

Figures are the numbers of individual clones proposed.

6.3 Breeding strategy for *E. globulus*

The proposed strategy for this species follows the classical approach; the selection of elite material, interbreeding, testing of progeny, new selections, interbreeding, testing of progeny and so on.

1988

Make 300 selections from the best available material and establish a breeding seed orchard.

1992-93

When all the clones are flowering well undertake cross pollinations of one representative of each clone with a broadly based standard pollen mix to obtain uniform seed for a progeny test. Establish the progeny test as soon as possible. The alternative approach to cross pollination would be just to use open-pollinated seed from the orchard for the progeny test which is a less costly, but satisfactory approach if the flowering is fairly uniform. Select material from the G-E tests and add to the breeding seed orchard.

1997

Undertake an assessement of the progeny test both for growth data and wood qualities, and on the basis of this test cull out at least half, perhaps two thirds of the clones in the programme. By this stage it is likely that the heritabilities of the various growth and pulping characteristics will have been established for *E. globulus* and future planning of the orchards will be far more precise than is possible at the moment.

1998

Based on the above information set-up new production seed orchards incorporating the best 20-30 clones. By this stage data on the G-E tests will be available, and perhaps several production orchards maybe required for the various areas using a different selection of clones. Commence a large scale controlled crossing programme between the majority of the remaining 100-150 clones (plus the G-E test selections) in the breeding orchard to develop new material for future advanced plantations.

1999
Set-up progeny trials with the seed from the controlled crosses.

2003
Assess these progeny trials and make selections to establish a new breeding orchard.

2008
Undertake another crossing programme when the new breeding orchard is flowering and set-up the next set of progeny trials.

2013
Assess these progeny trials and set-up new production seed orchards based on the results.

6.4 Alternative Strategy

Rather than introduce a lot of new clones into W.A. next year the important point with this strategy is to set-up the production seed orchards, which will contain 20-30 clones of known performance, as quickly as practicable. When these are flowering (1992-3) then introduce a large range of new material into the programme by the transfer of pollen and cross it with the established clones in the production orchards.

Basically the difference in strategies is that the genetic transfer will be by pollen rather than by grafts and cuttings. The only disadvantage of this strategy is that the maternal effect of the introduced material cannot be assessed immediately.The subtle difference between the strategies is that although the paternal effects of the new material can be assessed, the maternal effects cannot be until the progeny have flowered and they in turn have been progeny-tested some 10 years later.

It is a more economical approach to the breeding programme and would only result in the loss of a generation in time (4-5 years) in the worst possible case and with no loss in the best.

6.5 Benefit of Genetically Improved Seed

Currently the project has to be based on available seed sources. However, the benefits of genetically improved seed are considerable and could increase plantation productivity by up to 30% when the production seed orchards are producing, since one would be going straight from bush seed to selected clones for the production seed orchards. The first gain in productivity is due to the out crossing of slightly inbred material as collected from the native forests. The probability of seed collected from two adjacent trees being related is fairly high because of common ancestry. This effect is removed completely when totally unrelated material is put together in a seed orchard. There is also a likely gain to be made by the crossing of widely different provenances of the same species e.g. King Island x Channel. Estimates of the benefit of improved seed are given in table 5.

Table 5. Productivity Gains of Various Seed Sources

Source	%Gain	M.A.I. (m3/ha./yr)
Overseas seed	-30%	10
Tasmanian forests	0%	15
Selected Provenances	10%	16.5
Seed Production Stands	15%	19
Early Seed Orchards	15%	19
Culled Seed Orchards	15%	22
Advanced Seed Orchards	20%	25
Clonal Plantations	20-30%	30-40

7. OVERALL STRATEGY FOR SEED SUPPLY

7.1 General

The major constraint of the current proposal is a lack of a suitable supply of seed both in terms of quantity and genetic quality.

Possible sources are:

1. Seed wholesalers
2. Private Tasmanian Collectors
3. Tasmanian Forestry Commission

In the short-term the project will have to be based on seed collected from the native forests in Tasmania. Because of the current good flowering there will be a good seed crop available in late October 1988 and the majority of your seed requirements for the first 3 to 4 years of the programme, before improved seed becomes available, should be purchased then.

In the long-term it is best to cater for your own requirements as soon as it is practicable since plantation productivity can be greatly enhanced, and secondly with such a large programme it would be wise not to base so much investment on an unreliable supply from the Tasmanian forests. Imported eucalypt seed is now banned because of quarantine restrictions, but it is really unsuitable for this project with yields only reaching 50% of King Island material in one 14 year old trial.

The three alternatives for seed production in W.A. are:

1. Conversion of plantation into seed production stands
2. Seedling seed orchards
3. Clonal orchards

7.2 Seed Production Stands

Both the Baudin and Manjimup provenance trials could be converted to seed production areas. This would provide a good mixture of selected provenances which are proven under W.A. conditions. However, the trials are probably too old to be converted at this stage, except by coppicing, and they are also too small to have much impact on seed supply. Therefore, they are probably best left as a source of genetic material for the proposed clonal orchards.

The Bannister and Huntley trials are much younger and could be converted to seed production areas. The Huntley trial really amounts to a seedling seed orchard since family identity has been retained. Again they provide a good mixture of provenances, but they are probably too small to worry about and will provide a useful source of selections for the clonal orchards.

The best area seen for conversion to seed production was at the Tallings farm area. Since the whole plantation will be used for experimental purposes next year it would be best to make selections for seed production now prior to falling allowing a 10m x 10m. spacing between selections. After coppicing the shoots should be thinned down to 3 or 4 per stump and the other residual stumps killed. Reversion to adult foliage is fairly quick and this stand would provide seed in 4 to 5 years time. The provenance of this plantation was not known, but I would assume that it was from southern Tasmania. There maybe other similar plantations existing that could be similarly treated, but it is only an interim measure since clonal orchards will provide seed of better genetic quality within the same time span.

7.3 Seedling Seed Orchards

Most current seed orchards of E. globulus are seedling orchards since this was a necessary part of the improvement programme, and now such orchards should only be used as a back-up to clonal orchards. There is a need to determine the genotype-environment interaction for this species under W.A. conditions. Do the same provenances or families perform equally well on all sites or not? In order to find this out there is need for a minimum of three types of sites to be tested and these site/family/provenance tests could be converted to seedling orchards. Such trials will also provide new material for introduction into the breeding programme at a later stage. Seed production with seedling orchards takes from 6 to 7 years and there is wide variation in flowering times and seed production of the different trees.

7.4 Clonal seed orchards

This is the best way of obtaining improved seed quickly with seed being produced within 3 to 4 years after establishment. It is possible to control the exact composition of the orchard which is the great disadvantage of a seedling orchard. Grafted clones flower earlier than cuttings, but graft incompatibility is a problem and losses of 20-25% of grafted clones must be anticipated. Cuttings are better proposition, however, not all clones can be produced this way. So one would have to use a mixture of both types. With one of my clones 71-250 (King Is.) (see photograph) flowering occurred only two and a half years after planting so one can be fairly optimistic that commercial seed production would occur within 4 years. Another cutting of the same clone has just started to initiate buds 18 months after planting. The number of clones that are available as cuttings is a limiting factor at this stage, but they could be built up quickly to establish a production clonal orchard of 20-30 clones.

1. Production clonal orchard(s)

This orchard would contain a mixture of grafts and cuttings of 20-30 selected clones which are genetically superior and with a good balance of provenances. 25 hectares of this type of orchard would be necessary to achieve sufficiency of improved seed by 1993. The Tasmanian seed orchards and trials are the obvious source of these clones. As well the clones in this orchard(s) would have to flower at the same time to maintain a good mixture of pollen. The other point about these clones is that they have to be heavy seed bearers. One will have to select the best producing individuals of the superior families. This orchard would provide improved seed for the project from 1992 until 2002 by which time better genetic material would have been developed.

2. Breeding clonal orchard

This orchard would contain the future genetic base of E. globulus for its continued development, or some 300 clones as recommended in chapter 6. Four hectares of orchard would allow for two replicates of each clone. The two clonal orchards maybe contiguous, or separate, whatever is convenient since pollen contamination is not really a problem.

Clone 71-250, King Island origin, a dominant tree selected in 1984 when aged 11 years(1/50) Planted March 1985, Flowering October 1987.

7.5 Siting of Seed Orchards

This perhaps the most important factor controlling seed production and it is a point of some concern. Although early flowering was looked for in all trials and plantations visited there was very little to be seen in the older provenance trials at Baudin and Manjimup and in the many 6-7 year old plantations visited. Seed was noticed on the trees in the older trials, at Hull Rd. near Walpole and in the sandpit just north of Manjimup on Palgarup Rd., as well as on the large specimen in front of the Dwellingup Hotel. There is no doubt that flowering will occur within a decade, but this is not a reliable enough estimate to base the project on. Therefore, very serious consideration must be given to siting part of your main seed orchard in a proven climate, such as Tasmania, as a safeguard.

The two factors which seem to control the flowering of E. globulus are proximity to the sea and plenty of light. I spent last week collecting pollen samples from southern Tasmania and flowering was very evident alongside the beaches, as well as in the open farmland up to 15 Km. from the sea; whereas there was very little flowering in the actual forest.

Since more flowering was noticed on the southern coast around Walpole and Denmark, and because this area is more climatically similar to Tasmania I would recommend that your main seed orchard(s) be planted fairly close to the sea on a reasonable soil type in this general area.

The timing of flowering seems to be much the same as occurs in Tasmania from early September through to late November. The seed is ripe ready for collecting by October of the following year. It is also possible to predict the extent of next season's flowering since the bud initials are evident on the new growth by the completion of flowering.

7.6 Seed Strategy for the plantation programme

Taking into account the project requirement of 10 million seedlings annually and the various types of seed orchards and trials proposed in this report an overall strategy has been developed which is given in table 6.

Seedling seed orchard of E. globulus at Golconda in N. Tas Although 7 years old little seed production due to poor site.

TABLE 6 SEED STRATEGY FOR E. GLOBULUS PLANTATION PROGRAMME IN W.A. FOR NEXT DECADE

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Seedling requirements	2 m.	6.5 m.	10 m.	10 m.	10 m.	10 m.	10 m.	10 m.	10 m.	10m.
Tas. Forest	100kg.	325kg.	500kg.	500kg.	180kg.	55kg.				
Seed Production Stands(3ha.)	-	-	-	-	30kg.	30kg.	30kg.	30kg.	30kg.	30kg.
Seedling Seed Orchards (8 ha.)	-	-	-	-	-	-	80kg.	80kg.	80kg.	80kg.
Clonal Production S. Orchards (25ha.)	-	-	-	-	250kg.	375kg.	375kg.	375kg.	375kg.	375kg.
Breeding S. Orchards (4ha.)	-	-	-	-	40kg.	40kg.	40kg.	40kg.	40kg.	40kg.
Totals	100kg.	325kg.	500kg.	500kg.	500kg.	500kg.	525kg.	525kg.	525kg.	525kg.

Calculations based on 20,000 seedlings produced per kg. of natural seed which contains on average about 45,000 germinating seed per kg. With seed orchard seed viability should increase and the amount of seed required perhaps be reduced to 400kg. annually.
Seed orchard yields will vary between 10 to 15kg. of seed/ha./yr. depending on the type of orchard. Both good and bad years must be anticipated at the onset and the 25kg. surplus and reduction in quantity due increased viability must be considered as a safety margin

Flinders Is. Provenance in Lone Star Provenance Trial
Age 10 years MAI 25m3/ha. yr

8. SILVICULTURE OF E. GLOBULUS

8.1 General

E. globulus plantations are normally grown as short-term coppice crops of 10-12 years for the production of fuel or pulpwood. It is a vigorous species and coppices rapidly after harvesting. The coppice shoots are allowed to grow to 2m. before being thinned down to 2-3 stems per stump for the next harvest. After three crops the plantations are replanted since there is a significant loss of stumps (about 10% at each harvest). However, older plantations of this species are used in Chile for sawnwood production and it is also grown for electricity poles in Colombia. Interestingly enough it is globulus, not the traditional eastern state ash species, which are showing up well in the Young Eucalypt Programme sawing trials, and its potential for sawlog production and sliced veneerwood, especially if low stress clones are developed, is promising.

8.2 Nursery Techniques

The species is normally grown as container stock in a variety of containers, jiffy pots, paper pots etc. Seedlings are pricked out of seedling trays at the two leaf stage and with favourable conditions a crop of trees can be produced in two and a half months during the spring and autumn period. It can also be grown as "bare-rooted" stock with a root-pruning regime similar to that used for radiata pine; the advantage of such stock is that they tend to be more resistant to damage by native game.

8.3 Establishment

Good preparation of plantation areas is crucial to obtaining fast initial growth of eucalypts. Usual preparations after clearing of forest areas are: ripping and the mound-ploughing of planting lines followed by spraying with a combined knockdown and residual herbicide (Roundup/Atrazine). On pasture sites application of appropriate herbicide is essential to success. Planting is carried out in the late winter to early spring when soil moisture is adequate. An initial application of fertilizer (100-150 g. per tree) is usually applied three to four weeks after planting. Inter-row cultiviation is beneficial if practicable.

8.4 Plantation Spacing

The maximum production will be given by a close spacing of 2 x 2m. However, such regimes are only suited to high rainfall areas on good soil types. Recommended spacings for the W.A. programme are:

High rainfall areas	3 x 2m	1666 stems/ha.
Medium rainfall areas	4 x 2.5m.	1000 stems/ha.
Low rainfall areas	4 x 4 m.	625 stems/ha.

If sawlog production is contemplated then it would be best to set aside certain plantations for this. More than 50% of the total production of a sawlog plantation will be pulpwood from thinnings.

Proposed sawlog regime

Age	Stems/ha.
1	1000
12	475
17	298
22	193
27	117
32	71
37	clearfall

To minimize growth stress it is important to thin sawlog plantations regularly.

8.5 Insect Pests

Being a native species globulus is readily attacked by numerous natural predators. Two species in particular can cause severe damage to juvenile foliage: the leaf skeletoniser, *Uraba lugens*, and the Autumn gum moth, *Mnesampela privata*. Chrysomelid beetles can cause severe damage to adult foliage on occasions. With intensive plantations insect outbreaks would have to be controlled; synthetic pyrethroides are suitable insecticides.

However, very little sign of insect attack was seen during the inspection of the various trials in the S.W. and once the plantations attain adult foliage insects should only be a minor problem.

8.6 Clonal Forestry with E. globulus

Clonal forestry has been developed in the Congo initially, and later in Brazil for various sub-tropical species grandis, urophylla, and tereticornis. Cuttings are produced from basal coppice shoots which have been treated with hormone, usually IBA, and kept in constant humidity for about a month by which time a good root system has developed. The cuttings are then weaned, sorted and put outside ready for planting. The writer has been successful in propagating the temperate eucalypts, including E. globulus, but not as successful as other workers have been with the sub-tropical eucalypts in a warmer and more humid climates (Orme, 1983). It appears that it is possible to grow E. globulus by rooted cuttings commercially, but it will be another 2-3 years before sufficient development has taken place to undertaken large scale clonal plantations. E. globulus can also be grown successfully by micro-propagation, but without means of mass production at this stage, its cost would be too high to do so on a commercial basis and cuttings seem to be more promising. In the future this may change. Clonal forestry offers the possibility to produce a high quality uniform product quickly

8.7 Hybridisation

Hybridisation is actively being researched overseas as one means of increasing yield. The evidence from the Congo is that hybrids seem to have greater site adaptability than the pure species. They have commercial plantations of E.PF1 which is a hybrid of E.tereticornis and E. urophylla

E. globulus hybridises readily with most members of the sub-genus Symphyomyrtus and possibly some useful hybrids could be developed.

e.g. x brookerana for swampy sites
x grandis for faster growth
x viminalis for dryer areas
x camaldulensis for increased rooting capacity of cuttings as well as for greater drought tolerance.

It is best to use globulus as the male parent since pollens from smaller flowers will not fertilize globulus flowers unless the style has been shortened.

F1 hybrids are generally intermediate between their parents, but in the F2 and back-cross some useful individuals are found.

8.8 Other Species

As well as E. globulus there are some other species which could play some role in the plantation programme. Small plots of these should be planted with the G-E trials. These are:

E. grandis

This was seen growing well in one bluegum windbreak in the Peel catchment and several provenances including E. saligna should be tried.

E. viminalis

The natural range of this species is large and several provenances should be tested. In the WACAP trial near Manjimup and also in the Wellington catchment plantings of several provenances were growing well. Edaphically it is probably more tolerant than globulus.

E. brookerana

This was formerly classified with E.ovata, but is the tall forest form; it grows on swampy sites in the far NW of Tas. and perhaps could be useful.

E. morrisybi

This is a Tasmanian endemic species that is only found in two localities near South Arm near Hobart. The sites are particulary dry and sandy. It is no more than an outsider, but would hybridise with E. globulus easily.

9. RESEARCH AND DEVELOPMENT

The four main areas where knowledge is incomplete about E. globulus plantation forestry in Australia, apart from the tree improvement field are:

1. The Genotype-Environment interaction
2. Growth data
3. Fertilizer requirements
4. Stand management

9.1 Genotype-Environment Interaction

The established trials visited are not sufficient to determine if there is a significant G-E interaction i.e. do specific genotypes, be they individuals, families, or provenances, perform differently on different sites or not? There appear to be four types of sites to be included in the project where different provenances of E. globulus could probably be used to advantage, and if this is so it would have to be accommodated for in the breeding strategy.

The main areas are:

1. the western coastal country including the Peel-Harvey catchment
2. The higher rainfall and more fertile sites around Pemberton and Manjimup.
3. The dryer inland country northwards from Mt. Barker.
4. The southern coastal swampy areas.

To test for a G-E interaction I would use a range of twenty families from each of the following provenances:

1. King Island
2. Flinders Is.
3. N.E. Tas.
4. S. Tas.
5. Otways

G-E Trial

Provenances	5
Families	20
Replications/family	4
Sites	4

Allowing for a 5 tree line plot per family and a spacing of 4 x 2.5m. this trial would require 2 hectares to establish at each site.

As well as establishing if there is a significant G-E interaction, or not, these trials will also provide new material for the breeding programme at a later stage. After assessment at age four selections could be made and transferred by grafting to the main breeding orchard, and the whole trial thinned and converted into a production seed orchard.

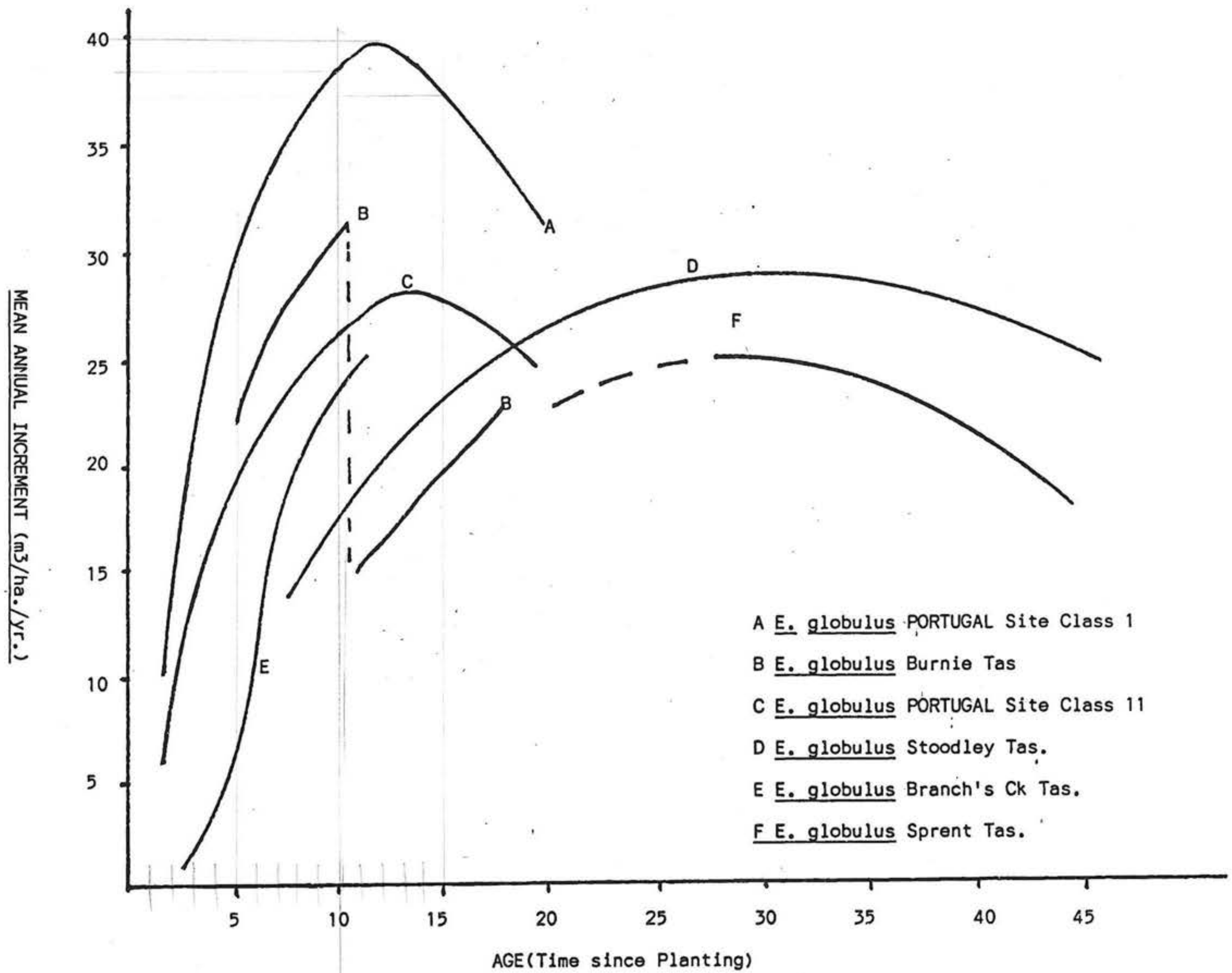
9.2 Growth Data

Because of little interest in eucalypt plantation forestry in Australia there are few data available for any species and basically one has either to adapt data from other countries, or establish your own data base.

The growth figures that were quoted for the plots visited were in my experience quite acceptable varying from around 15 to 25 m3/ha./yr. Volume calculation using various formulae, such as Opie's, are satisfactory for the moment, but in the longterm there will be need for a comprehensive set of yield and volume tables. My experience with the Opie formulae is that it gives a 10% to 15% over-estimate in 10 to 12 year E. globulus plantation and personally I prefer to use the formula of a cone which gives an under-estimate. However, I strongly recommend that representative samples of some of the plantations up to 12 year old be sampled by stem analysis to verify if the predicted yields of gross volume are being obtained.

The other point about growth rates of eucalypt plantation is that they bear little relationship to those in native forests, and any extrapolation should be avoided. Some data for E. globulus has been published for Tasmania but the relevance of these data from a neglected 40 year old plantation to your situation is not a lot (Goodwin, 1982). The yield curves from the Branch's Creek plot are probably more indicative of the W.A. situation (Orme, 1985).

FIG 3 YIELD DATA FOR E. GLOBULUS PLANTATIONS IN TASMANIA AND PORTUGAL



I would recommend that the Portuguese yield tables for their site 111 quality be used as a general guide for the project, and for the Pemberton situation the site 11 curve would seem more appropriate (FAO, 1981)

9.3 Fertilizer Studies

It is crucial that eucalypt plantations are given a good start as they are far more susceptible to competition than radiata pine. General experience is that an initial application of 100-150 gm. per tree of an NP fertilizer is highly beneficial. The results of studies done in Tasmania showed large differences between any fertilizer treatment and the control, but little difference between fertilizer treatments. The best general establishment procedure seems to be to rip and mound plough, spray with both knock-down and residual herbicide, plant and fertilize.

There is need for a lot of research work to establish what are the appropriate levels of soil nutrients for E. globulus plantation on the various soil types, especially at the lower end of the fertility range. Experience appears to be if there are certain deficiencies present it is best to rectify these in the initial year because secondary fertilization doesn't seem to work very well.

There will be need for longterm studies into the fertilizer requirements of these plantations after coppicing; on what soil types is it required and how much fertilizer should be applied? Some work on this subject has been done in southern Spain.

9.4 Plantation Management

E. globulus is grown overseas as a short-term coppice crop with two to three rotations of ten to twelve years. Economically this is the only way to grow this species for pulpwood production as there is little point in leaving the plantations once they attain a merchantable size. With rapid improvement in the genetic quality of E. globulus coppicing may be of less importance, but this is a decision for the future.

Because such management is new to Australia there is need to establish if this type of management will work under W.A. conditions. Climatically W.A. is similar to Spain and Portugal so I really don't forsee any difficulties with coppicing. In these two countries harvesting operations continue throughout most of the year.

The cut plantations will coppice when soil moisture is sufficient and the temperature high enough to encourage growth. Basically trees that are cut in the winter and spring will coppice in the late spring whilst those cut in the summer will not coppice until the following spring. There is a 10% loss of stumps at each harvest.

A study into the coppicing ability of E. camaldulensis was undertaken in Morocco and this showed that there was no significant difference between the time of cutting and the quantity and size of the coppice shoots after twelve months (Riedacker, 1973).

However, there is a need to undertake to establish a series of coppicing trials under W.A. conditions to verify if Iberian experience is applicable or not.

<u>E. globulus</u> stump ready for thinning of coppice shoots

Bud initials on clone 250 after recent flowering

10. APPENDICES

1. References 43

2. Yield table for Site Q111 Portugal 44

3. Details of Production Seed Orchard 45

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YIELD TABLE FOR E. GLOBULUS IN NORTHERN PORTUGAL
QUALITY CLASS 111, DOMINANT HEIGHT AT AGE 10 IS 19m.

AGE	H.DOM	MEAN DIA	VOL.	B.A.	MAI
yrs.	m.	cm.	m3/ha	m2/ha	m3/ha/yr
2	6.4	5.6	6	2.7	3.0
3	9.0	6.7	14	3.9	4.7
4	11	8.5	28	6.2	7.0
5	12.8	10	46	8.7	9.2
6	14.2	11.3	66	11.1	11.0
7	15.6	12.6	90	13.7	12.9
8	17.0	13.9	120	16.7	12.0
9	18.0	14.6	140	18.3	15.6
10	19.0	15.1	160	19.8	16.0
11	20.0	15.8	185	21.6	16.8
12	21	16.4	210	23.3	17.5
13	22.0	16.8	230	24.3	17.7
15	23.6	17.5	270	26.6	18.0
16	24.2	17.9	288	27.6	18.0
17	24.8	18.1	304	28.4	17.9
18	25.2	18.4	318	29.2	17.6
19	25.6	18.6	330	29.8	17.4
20	26.0	18.7	340	30.2	17.0

Source FAO, 1981

PRODUCTION CLONAL ORCHARD

Aim

To provide large quantities of genetically improved seed as quickly as possible for the plantation project with the emphasis on seed production.

Area required: 25ha.

Production

15 kg. /ha/yr. once established and producing; large variation in crops are to be anticipated and storage of seed will be required. Production life of orchard 1993 until at least 2002

Location

Because of doubt about early flowering in W.A. part of the orchard may be established in Tasmania; the balance near Walpole, or Denmark, but not an inland site.

Establishment

Minimum cultivation is ploughing of planting lines, pegging and spraying of tree sites in late Autumn.

Fencing: Winter 1988

Planting:late Winter 1988

Fertilizer: 150g. per tree after planting, another 250g per tree in the late spring and another 250g. per tree the following Autumn.

Spacing

Rows 10m. apart and 7m between trees (approx 150/ha.) Some losses of grafts will occur but these would not be replaced.

Composition of orchard

Approximately 125 trees of 30 clones would be established in the orchard arranged in blocks of one hectare with five trees of each clone in a block. The clones to be used will come from a variety of sources; the majority to be used have already have demonstrated good potential for seed production as well having some other attribute such as belonging to one of the "20" better families, being a dominant tree in an exisiting trial, or a plantation selection of known provenanance. The majority of clones will come from progeny of the provenance collections undertaken by the writer in 1975, or more recent selections made by him.

Provisional list of clones and their origin(36)

Top "20" families[1]	Provenance	cutting/graft
T10*	Taranna	graft
NF2*	Flinders Is.	"
O4*	Otways	"
L8*	Leprena	"
G6*	Geeveston	"
G10*	Geeveston	"
S2*	Seymour	"
KI5*	King Island	"
Other families[1]		
NF8*	Flinders Is	"
03*	Otways	"
O5*	Otways	"
Other Material		
250	King Island	cutting & graft
257	King Island	"
400	King Island	graft
401	King Island	graft
309*	King Island	cutting
310*	Macquarie H.	"
293*	Uxbridge	"
266*	Macquarie H.	"
253*	Otways	graft/cutting?
254*	Seymour	"

Plus 4 clones to be selected and grafted from a 6 y.o. Otways plantation

* Denotes from original provenance collection

1. denotes that 2 selections would be made for each family.