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ANALYSIS OF 1993 *E. GLOBULUS* PROVENANCE TRIAL

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REPORT NO. 26 MAY 1998

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INTRODUCTION TO *E.GLOBULUS*

There are four morphological-geographical groups in *Eucalyptus globulus* Labill. which have been recognised as subspecies. They are *E. globulus* Labill. *ssp. globulus*, *E. globulus* Labill. *ssp. pseudoglobulus* (Naudin ex Maiden) Kirkpatrick, *E. globulus* Labill. *ssp. maidenii* (F. Muell.) Kirkpatrick, and *E. globulus* Labill *ssp. bicostata* (Maiden *et al.*) Kirkpatrick. All of them are generically referred to as *E. globulus* or blue gum.

The natural distribution of *E. globulus* has been studied very thoroughly by Kirkpatrick (1975). The natural occurrence of *E. globulus* is restricted to Tasmania, Victoria and New South Wales. The species is mainly found in the coastal regions of eastern Tasmania, the islands of the Furneaux Group situated in Bass Strait, the Otway Ranges, South Gippsland, East Gippsland, South Coastal NSW, and inland in the foothills of the Great Dividing Range (Appendix 1). The four subspecies imperceptibly grade into one another through zones of contact.

The four subspecies of *E. globulus* have an extensive altitudinal range. Its lower limit is close to sea level and the maximal altitude where blue gum can be found is 1100m in the Snowy Mountains and Mount. Nullo.

The climatic conditions of the area of natural distribution are quite variable. Summers vary from mild to warm (mean maxima for the warmest month = 18 - 31°C) and winters from cool to mild (mean minima for the coldest month = 0 - 8°C). The winter average daily range varies from 6-8°C in coastal areas to 10-14°C inland, and the summer average daily range varies from 6-8°C to 14-17°C. The average number of days per annum with temperatures below freezing point varies from nil for coastal areas to over seventy at the altitudinal limit of blue gum on the mainland. Most occurrences of *E. globulus* are recorded between the isohyets of 600 to 1100 mm mean annual rainfall, and this species never occurs in areas with rainfall less than 500 mm. The distribution of precipitation over the year is variable from a marked summer maximum in South Coastal NSW to a marked winter maximum in the inland Victoria.

Blue gum grows under widely variable fertility conditions. *E. globulus* prefers deep soils with a loamy topsoil, clay subsoil and acidic reaction, but shows good adaptability to other conditions except for waterlogged or strongly alkaline soils.

Blue gums are seldom found in extensive pure stands. They are usually associated with at least one other species of eucalypt.

IMPORTANCE OF *E. GLOBULUS* WORLDWIDE AND IN NEW ZEALAND

E. globulus ssp. *globulus* has been highly ranked for growth and pulping qualities in Australia and worldwide (Cotterill and Brolin 1997).

In Australia *E. globulus* was traditionally used as structural timber, but only recently it has been extensively planted in its native habitat as an important pulpwood species (Potts and Savva 1989, Volker and Orme 1988)

E. globulus has been introduced in Europe, mainly in Spain and Portugal, but also in Italy and Greece, in African countries such as Zambia, Kenya, Congo, Ethiopia, Morocco and South Africa; in South America from Colombia, Equator, Bolivia, Peru, southern Brazil to Argentina, Chile and Uruguay, and in Asian countries such as India (Orme 1977).

Phytosanitary problems, such as its susceptibility to defoliating insects and to *Mycosphaerella* leaf disease, as well as susceptibility to frosting have been the main reasons why *E. globulus* has not been established in commercial plantations in New Zealand.

There is a need for a thorough literature review on the relative performance of different provenances of *E. globulus* ,and only a few references are presented in this report.

In 1987-1988 Gardiner and Crawford (CSIRO Tree Seed Centre) carried out an extensive collection of *E. globulus ssp. globulus* and populations intergrading with mainland subspecies. Provenance trials including the genetic material from this collection have been established in Australia and many other countries, and will constitute in most cases the base for *E .globulus* breeding populations (Potts and Jordan 1993).

Some 600 families from the Gardiner and Crawford collection were established in a trial at Burnie in the North coast of Tasmania (Volker and Orme 1988). Families were kept separate within provenances and sub-provenances. The trial was assessed at age 2 for growth. The top performing family was from King Island, but most of the 20 top families were either from South Gippsland or the Otway Ranges. Results indicated that high performing sub-provenances and families in this trial were concentrated in three main geographically isolated regions- the Otway Ranges, Jeeralang/Strezlecki Ranges, and South Greeveston in Southern Tasmania. The results of this trial were consistent with an older trial established in northern Tasmania. Results from other trials located further south in Tasmania, showed changes in the ranking of provenances across sites, indicating some degree of site x provenance interaction for growth traits.

Some 210 seedlots from the same collection were planted near Melbourne and every tree was irrigated with effluents. The trial was assessed at 23 months old for height, diameter and percentage of adult foliage. Lorne provenance performed better than average and King Island did not have the best growth rates as commonly believed (Spencer and Williams, 1993).

A trial including 28 provenances and 20 Jeeralang families planted across contrasting sites in Gippsland and assessed at ages 2 and 4 years for height and diameter, showed that provenance x site and family x site interaction were non-significant. The results indicated that *E. globulus ssp. bicostata* and *E. globulus ssp. maidenii* ranked poorly for diameter at age 20 months and 4 years, and the two *E. globulus ssp. pseudoglobulus* provenances ranked in the top six for growth (Woolaston *et al*,1991)

Eldridge *et al.* (1993) indicated that provenance trials of *E. globulus ssp. globulus* have not shown any single provenance to be consistently superior in growth rate and form, however, Geeveston, King Island and seedlots from Otway Ranges were among the best.

In Portugal, the experience of Stora Celbi in Quinta do Furadouro indicated that West Cape Otway and Flinders Island performed very well for stem volume at age 6 (Cotterill, pers.com) and in some cases certain locations within a provenance performed exceptionally well (eg. Parker Road or Holy Water Track).

There have been some studies on provenance variation in *E. globulus* to susceptibility to fungal diseases and insect pests.

Carnegie *et al.* (1994) found highly significant differences in *Mycosphaerella* leaf disease severity among provenances, with provenances from *E. globulus ssp. globulus* and *E. globulus ssp. bicostata* being the most severely affected, while provenances from *E. globulus ssp. maidenii* and *E. globulus spp. pseudoglobulus* were only slightly affected. There was also a highly significant difference among provenances within *E. globulus ssp. globulus* and *E. globulus ssp. pseudoglobulus*. However, the conclusions were based on only one provenance sample each of *E. globulus ssp. bicostata* and *ssp. maidenii*, and a larger sample would be needed to be able to draw definite conclusions.

In a plantation situated near Melbourne, Farrow *et al.* (1994) reported differences among provenances of *E. globulus* in their resistance to autumn gum moth (*Mnesampela privata*) and leafblister sawfly (*Phylacteophaga froggatti*). The King Island provenance was more resistant to both insects than provenances from other Bass Strait Islands, Tasmania and Victoria.

In South Africa, the King Island provenance showed more resistance to insects (Cotterill, pers.com).

SOME INFORMATION AVAILABLE ON THE PERFORMANCE OF *E. GLOBULUS* IN NEW ZEALAND

In New Zealand, there is some information available on the performance *of E. globulus* generated both from trials established by ***Forest Research*** and from experimental plantings carried out by industry. This section summarises some of that information.

a. Trial of coppicing Eucalypt species for short rotation fuelwood production

A joint trial between Hawkes Bay Catchment Board, Redcliff Nursery and ***Forest Research*** was established to evaluate a group of coppicing eucalypts as well as some non-coppicers (McConnochie 1989).

The Hawkes Bay Catchment Board provided a hectare of land near Clive, Hawkes Bay. Nursery stock was provided by Redcliff Nursery and the trial established by R. McConnochie of ***Forest Research*** in December 1987.

The trial consisted of two parts, (a) 20 unreplicated block planting of 48 trees per plot at 2 m x 1 m, (b) 8 replicates of 18-tree plots at 2.3m x 1 m. Twenty-two eucalyptus species were represented.

Inadequate weed control after establishment caused growth suppression and poor survival. Thus, the initial objective of coppice fuelwood production was abandoned and the trial was registered as a eucalypt species trial. Survival and diameter of the 3 largest trees per plot were measured in 3 replications at age 5. Measurements for species included in the 1993 *E. globulus* provenance trial are shown in Table 1.

E. globulus ssp. globulus and *E. globulus ssp. maidenii* were the best species for both growth and survival and showed very good crown health. The growth of *E. globulus ssp. bicostata* was poor as well as its survival. This trial demonstrated the growth potential of *E. globulus ssp. globulus and ssp. maidenii.*

This trial later provided information about wood density of the different species. *E. globulus ssp. maidenii* showed an average wood density of 543 Kg/m3, based on increment cores from 15 trees whereas *E. globulus ssp. globulus* was 440 kg/m. High wood density in *E. globulus ssp. maidenii* has been found in other trials (Jamieson 1997).

Table 1. Trial of coppicing Eucalyptus species. Hawkes Bay. Age 5 years.

Species	Provenance	Mean Diameter (mm)	Survival (%)
E. globulus ss.p globulus	Bruny Island, (Tas.)	153.0	81.5
E. globulus ssp. maidenii	--------	143.0	88.9
E. nitens (Cent. Vict)	Rubicon, Mt.Gwinear, Macalister (Vic.)	110.0	72.2
E. regnans	Tokoroa	101.3	38.9
E. nitens (NSW)	Badja, (NSW)	88.4	75.0
E. globulus ssp. bicostata	---------	85.0	61.1
E. fastigata	Cottonwood, Bendoc, (Vic)	45.0	51.9

b. *Eucalyptus species trial , Gallilee Property, Knudsen Road. South of Kaikohe*

This trial was planted in 1991 in a cubic lattice design with 3 replications. The trial included 27 species planted in 7 x 7-tree plots with the measurement plot being 5 x 5 trees. The trees suffered from an extremely dry summer and some weed problems during the first couple of years.

The trial was measured at age 5. A summary of the performance of *E. nitens* and *E. globulus* is presented in Table 2. These results have not been analysed statistically and therefore are inadequate to draw reliable conclusions, however *E. globulus* showed slower growth rate than *E. nitens.* In Northland, *E. globulus ssp. maidenii* had the highest density (518 kg/m^3) of the species represented. *E. globulus ssp.* globulus density was431 kg/m^3) whereas the density of *E. nitens* varied between 417 and 399 kg/m^3 for New South Wales and Central Victoria provenances respectively (Jamieson 1997).

Table 2. Summary of the Eucalypt species trial planted in 1991 at Knudsen Rd. Replication 3 at age 4, before thinning. Source: Carter Holt Harvey Ltd.

	Species and Provenance	Stems/ha	Height (m)	DBH (mm)
E. nitens	Toorongo	1932	14.7	150
	Rotoaira	2728	14.7	141
	Conners Plain	2273	14.9	138
	Rubicon	2841	14.2	134
	Brown Mt.	3069	13.3	123
	Badja	2614	13.8	123
	Macalister	2159	11.6	121
	Tallaganda	3182	10.6	110
	Errinundra	2728	11.6	108
E.globulus ssp. globulus	Huonville, Tasmania	2728	13.1	123
	Jeeralang North, Vic.	2841	11.8	109
E.globulus ssp. maidenii	Black Range, Eden	2841	13.1	111
	Bolaro Mt	2728	12.1	112

c. *E. globulus growth in Te Kapua*

A small area of *E. globulus* was established in 1994 together with other species of potential interest for Tasman Forest Industries at Te Kapua. This information derives from only one permanent sample plot and therefore is not statistically sound. This data was included in this section to give some indication of the growth of this seedlot at age 3 years. (Table 3).

Table 3. Performance of a plot of *E. globulus ssp. globulus* (Jeeralang North) at Te Kapua.

Species and provenance	Sph	MPH (m)	MPD (mm)	MTH (m)	MTD (mm)	MAI (m3)
E.globulus ssp. globulus - Jeeralang North (Vic)	975	7.7	92	9.2	128	6.7

Note: MPD = mean plot diameter is the mean diameter at breast height (1.4m) of all live plot trees, MPH= mean plot height, MTD= mean top diameter, MTH= mean top height
Source: Information provided by Tasman Forest Industries

1993 *E. GLOBULUS* PROVENANCE TRIAL

In New Zealand, *E. globulus* has seldom been included in trials to evaluate its performance. In an attempt to gain better understanding on the potential of this species, a provenance trial was established in 1993. The main objective was to examine the differences between 8 seedlots of *E. globulus ssp. globulus*, 1 seedlot of *E. globulus ssp. pseudoglobulus* and 1 seedlot of *E. globulus ssp. bicostata*, and to compare their performance with the eucalypt species currently in use or with recognised potential for forestry in New Zealand, *E. nitens* (NSW), *E nitens* (Victoria), *E. fastigata* and *E. regnans.*

MATERIAL AND METHODS

Field Design

The 1993 *E. globulus* Provenance Trial was established in two locations: Omataroa in the Bay of Plenty and Lillburn Valley in Southland. The 14 seedlots (Appendix 2) were planted in 20-tree-plots in a completely randomised design. At Omataroa, the compartment looked very homogeneous in spite of being traversed by a road. Most seedlots were represented in the trial by 3 plots, except for 2 seedlots represented only by 2 plots. The ground preparation was deep ripping and mounding. Seedlings were raised in root-trainers and planted at 3 x 4 m in November 1993.

The second site of this trial ,established in Southland, was abandoned in 1996 as a result of severe frost damage in the winter 1996.

Traits assessed

The present analysis was based on measurements of diameter at 1.4 m height (DBH), and a subjective assessment of straightness, form and health at age 4 years at Omataroa (Table 4).

Table 4. Scoring criteria for straightness, form and health

TRAIT	SCORING
Straightness	Scale 1 to 9, 1=crooked - 9= very straight
Form	Scale 1 to 9, 1= severe malformations - 9=no malformations
Health	Scale 1 to 3, 1= very unhealthy - 3= healthy

Data analysis

Analysis of variance was performed using SAS GLM Procedure (1990). Even though there were no reasons to suspect heterogeneity in the site at the time of planting, clear differences in growth were noticed between both sides of the road at the time of assessment. In consequence and for the analysis, the trial area was divided in two blocks according to their relative position to the road.

The linear model assumed included block, species and provenance within species as main effects. All effects were considered random. The analysis of variance was based on plot means.

$$Y_{ijkl} = \mu + B_i + S_j + P_{k(j)} + e_{ijkl}$$

Y_{ijkl} = the l^{th} individual of the k^{th} provenance in the j^{th} species

μ = overall mean

S_j = the effect of the j^{th} species

$P_{k(j)}$ = the effect of the k^{th} provenance within the j^{th} species

e_{ijkl} = the random error

The best estimates of the population marginal means, often called least squares means, were obtained within the SAS GLM Procedure (1990). The significance levels of the appropriate *t*-tests for comparing each population marginal mean to all other population marginal means within the same effect were obtained using the PDIFF option in the SAS GLM Procedure.

Results and discussion

Tree survival at age 4, which neglected dead trees and trees with DBH <100 mm, was very poor in some seedlots (particularly *E. regnans* - Tasmania Forestry Commission; *E. globulus ssp. pseudoglobulus* - Wiebens Hill, and *E. globulus ssp. globulus* - Flinders Island). The poor survival of those seedlots cannot be attributed to any particular factor. (Table 5).

Table 5. Percentage survival of seedlots at Omataroa.

Seedlot	Species	Origin	%Survival at age 4
1	*E.globulus ssp. pseudoglobulus*	Wiebens hill via Orbovic, Vic.	55
2	*E.globulus ssp. bicostata*	Nullo Mtn S.F. Erylston NSW	78.3
3	*E. globulus ssp. globulus*	Strathblane, Tas.	61.6
4	*E. globulus ssp. globulus*	Orford, Tas.	90
5	*E. globulus ssp. globulus*	Lorne Po. Vic.	75
6	*E. globulus ssp. globulus*	Moogara, Tas.	71.6
7	*E. globulus ssp. globulus*	St. Marys, Tas.	60
8	*E. globulus ssp. globulus*	King Island	70
9	*E. globulus ssp. globulus*	Flinders Island, Tas.	56.6
10	*E. globulus ssp. globulus*	Jeeralang North, Vic.	76.7
11	*E. nitens*	Toorongo Plateau, Vic.	73.3
12	*E. nitens*	Tallaganda S.F., NSW	98.3
13	*E. regnans*	Tas. For. Comm.	30
14	*E. fastigata*	Badja Mtn. NSW.	65

Analysis of variance

The analysis of variance is shown in Table 6. Block effect was highly significant for DBH and form, significant for straightness and non-significant for health. Species effect was significant for DBH and straightness, and non-significant for form and health. There were significant differences between provenance means within species only for DBH and straightness.

Table 6. Analysis of variance for diameter at 1.40 m (DBH); straightness (STR), form (FOR), and health (HTH).

		DBH		STR		FOR.		HTH	
Source of variation	df	Type III SS	F value	Type III SS	F value	Type III SS	F value	Type III SS	F value
Block	1	991.54	11.90**	2.29	5.29*	4.85	9.72**	0.0002	0.01 ns
Species	3	1057.43	4.23*	5.02	3.86*	3.61	2.41 ns	0.0358	0.56 ns
Prov. (Species)	10	2021.70	2.43*	11.08	2.55*	9.36	1.88 ns	0.274	1.30 ns
Error	25	5808.72		34.189		33.119			

Note: ns= non-significant; *= significant (α=0.05); **= highly significant (α=0.01)

Results for the least square means' test for diameter at 1.40 m height and straightness are presented in Table 7 and Table 8 respectively.

In terms of diameter at 1.40 m height, there are two groups of seedlots significantly different. The best seedlots were two Victorian provenances of *E. globulus ssp globulus* (Jeeralang North and Lorne), *E. globulus ssp. pseudoglobulus* from Victoria; a provenance of *E. globulus ssp. globulus* from the Bass Strait Islands (Flinders) and *E. nitens* from New South Wales. The poorest seedlots were *E. regnans, E. globulus ssp. bicostata* and a Tasmania provenance of *E. globulus ssp. globulus.*

The group of middle performers including *E. fastigata*, a Central Victorian provenance of *E. nitens* and most of the Tasmanian seedlots of *E. globulus ssp. globulus*, did not show significant differences with either the best or the poorest seedlots.

Even though the differences between New South Wales *E. nitens* and Central Victoria *E. nitens* were non-significant, *E. nitens* from Tallaganda performed better than *E. nitens* from Toorongo. In spite the fact that at the time of assessment there were no differences in health between both provenances, the better performance of Tallaganda could have been due to better health in that warmer site in previous years. (Table 7).

Table 7. Least-square mean's test for diameter at 1.40 m height

Sign. Diff.	Seedlot	DBH4 mean (mm)	Species	Provenance
A	10	139.13	*E. globulus ssp. globulus*	Jeeralang North, Vic.
A	5	137.17	*E. globulus ssp. globulus*	Lorne Po., Vic.
B A	12	133.65	*E. nitens* (NSW)	Tallaganda, NSW
B A	1	132.10	*E. globulus ssp. pseudoglobulus*	Wiebens Hill via Orbovic, Vic.
B A	9	131.45	*E. globulus spp. globulus*	Flinders Island, Tas.
C B A	14	128.51	*E .fastigata*	Badja Mnt, NSW
C B A	8	127.52	*E. globulus ssp. globulus*	King Island
C B A	6	126.68	*E. globulus ssp. globulus*	Moogara, Tas.
C B A	3	126.19	*E. globulus ssp. globulus*	Strathblane, Tas.
C B A	11	125.16	*E. nitens* (Cent.Vic)	Toorongo, Vic.
D C	4	120.40	*E. globulus ssp. globulus*	Orford, Tas.
D C	7	116.09	*E. globulus ssp. globulus*	St Marys, Tas.
D C	2	113.43	*E. globulus ssp. bicostata*	Nullo Mtn. NSW
D	13	103.79	*E. regnans*	Tas.For.Comm.

In terms of straightness, *E. regnans*, Cental Victoria *E. nitens*, *E. globulus ssp. pseudoglobulus*, and *E. globulus ssp. globulus* from Jeeralang North were statistically different from the seedlots from the Bass Straight Islands (Table 8).

Table 8. Least-square mean's test for straightness

Sign.diff.	Seedlot	STR Mean	Species	Provenance
A	13	8.45	*E.regnans*	Tas.For.Comm.
B A	3	7.48	*E.globulus ssp. globulus*	Strathblane, Tas.
C B A	11	7.47	*E. nitens* (Cent.Vic)	Toorongo, Vic.
C B A	1	7.46	*E.globulus ssp. pseudoglobulus*	Wiebens Hill via Orbovic, Vic.
D C B A	10	7.26	*E.globulus ssp. globulus*	Jeeralang North, Vic.
E D C B A	14	7.24	*E.fastigata*	Badja Mnt, NSW
E D C B A	6	7.18	*E.globulus ssp. globulus*	Moogara, Tas.
E D C B	5	7.15	*E.globulus ssp. globulus*	Lorne Po., Vic.
E D C B	4	6.93	*E.globulus ssp. globulus*	Orford, Tas.
F E D C B	7	6.74	*E.globulus ssp. globulus*	St Marys, Tas.
F E D C	2	6.37	*E.globulus ssp. bicostata*	Nullo Mtn. NSW
F E D	12	6.12	*E.nitens* (NSW)	Tallaganda, NSW
F E	9	6.03	*E.globulus ssp. globulus*	Flinders Island, Tas.
F	8	5.78	*E.globulus ssp. globulus*	King Island

CONCLUSIONS AND RECOMMENDATIONS

The results from this trial showed similar growth performance of most of the provenances tested of *E. globulus ssp. globulus*, as well as provenances of *E. nitens* and *E. fastigata* that perform well in New Zealand. It is important to notice that *E. nitens* New South Wales had a very good growth performance. The performance of *E. regnans* tested seedlot has been significantly inferior to most of *E. globulus*, *E. nitens* and *E. fastigata* seedlots, but similar to provenances of *E. globulus* with poor growth.

This trial was based on eight provenances of *E. globulus* from the broad range of natural distribution. The experimental design lacked precision because the trial had 2-3 replications per seedlot and was established in only one site. To be able to draw statistically valid conclusions, it is necessary to establish a new provenance trial extending the range of provenances and including more provenances of the other subspecies of *E. globulus*. *E. globulus ssp. maidenii* with its high density wood offers new possibilities to increase handsheet bulk, a property highly sought after by the paper industry. The trial should be established in several sites to determine whether there is provenance x site interaction.

Health issues will continue to be a concern with *E. globulus* and will be the major factor in determining the potential of the species for plantations in New Zealand.

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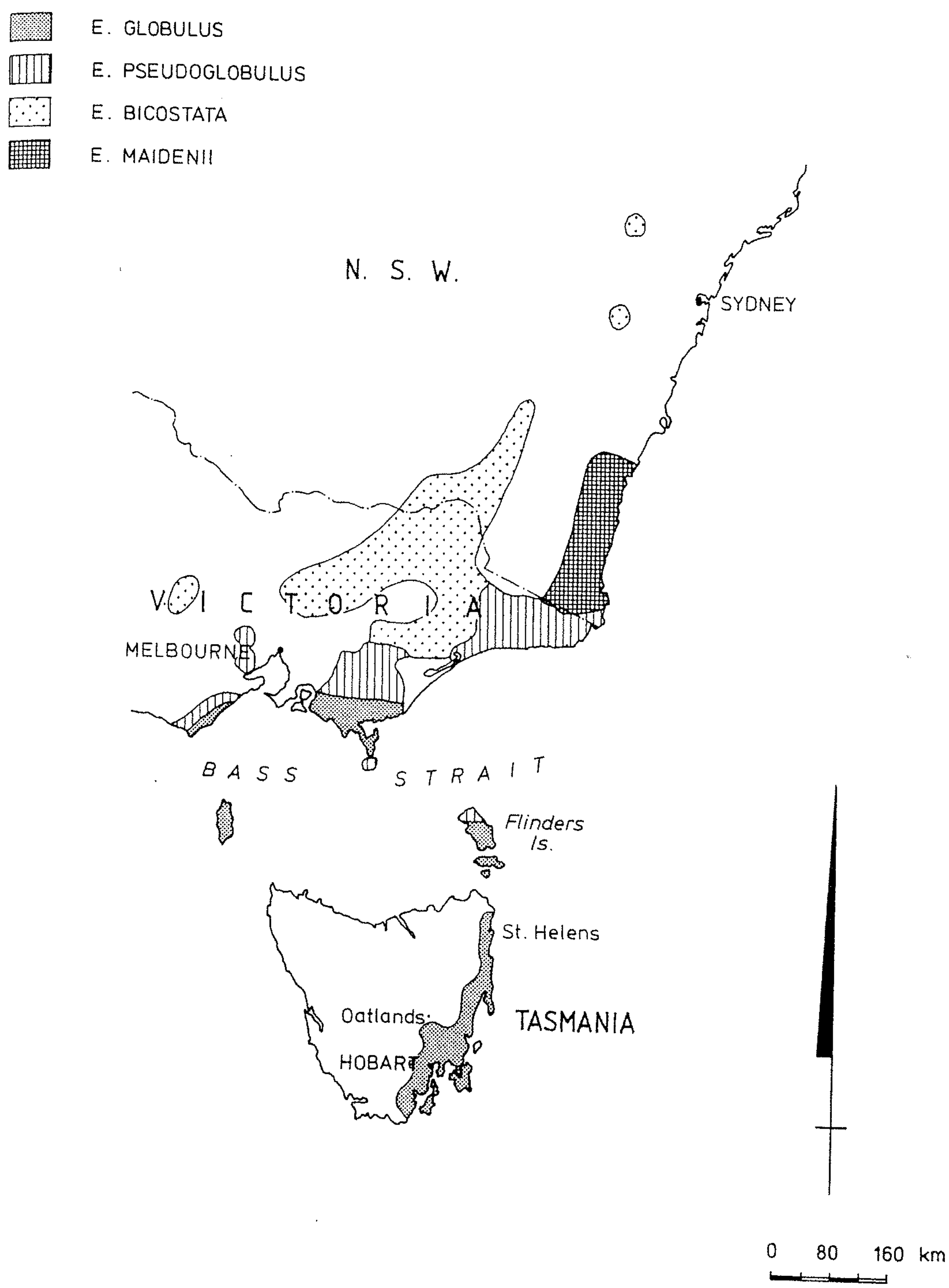
APPENDIX 1

Natural area of distribution of *E. globulus* and its subspecies
(From Orme 1977)



APPENDIX 2

Description of Species and provenances in the 1993 *E. globulus* Provenance Trial

Seedlot Code	Species	Origin	Altitude (m)	Australian Tree Seed Centre N°
1	*E. globulus ssp. pseudoglobulus*	Wiebens Hill via Orbovic	370	18111
2	*E. globulus ssp. bicostata*	Nullo Mt. S.F. Erylston, NSW	1120	18316
3	*E. globulus ssp. globulus*	Strathblane, Tas.	180	18400
4	*E. globulus ssp. globulus*	Orford, Tas.	340	18397
5	*E. globulus ssp. globulus*	Lorne Po, Vic.	200	16405
6	*E. globulus ssp. globulus*	Moogara, Tas.	500	16470
7	*E. globulus ssp. globulus*	St Marys, Tas.	400	16474
8	*E. globulus ssp. globulus*	King Island	40	17608
9	*E. globulus ssp. globulus*	Flinders Island, Tas.	15	17799
10	*E. globulus ssp. globulus*	Jeeralang North	220	16319
11	*E. nitens* (Central Victoria)	Toorongo Plateau	1000	16869
12	*E. nitens* (NSW)	Tallaganda S.F.	1250	16619
13	*E. regnans*	Tas. For. Comm.		88/166
14	*E. fastigata*	Badja Mt., NSW	1070	79/237