J. W. Gottstein Memorial Trust Fund

The National Educational Trust of the Australian Forest Products Industries

GOTTSTEIN
TRUST

PLANTATION EUCALYPT SPECIES FOR SOLID WOOD PRODUCTS – A PROFILE OF *EUCALYPTUS MUELLERIANA*

CLINTON TEPPER

2002 Gottstein Fellowship Report

JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships and Awards - each year applications are invited from eligible candidates to submit a study programme in an area considered of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate. Skill Advancement Awards recognise the potential of persons working in the industry to improve their work skills and so advance their career prospects. It takes the form of a monetary grant.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to,

The Secretary,
J.W. Gottstein Memorial Trust Fund,
Private Bag 10,
Clayton South, VIC 3169, Australia

The information contained in this report is published for the general information of industry. Although all reasonable endeavour has been made to verify the accuracy of the material, no liability is accepted by the Author for any inaccuracy therein, nor by the Trustees of the Gottstein Memorial Trust Fund. The opinions expressed are those of the author and do not necessarily represent the opinions of the Trustees.

Acknowledgements

The author wishes to acknowledge the following people and/or groups for their valuable assistance in preparing this report:

- The Trustees of the Joseph William Gottstein Memorial Trust Fund for funding this project. In particular their patience and understanding as they waited for the completion of the initial draft has been appreciated
- Dr. Rod Bird and Tim Jackson
- Ian Bail, Timbercorp
- Ian Nicholas for organizing and being my chauffeur for an action packed and informative week in New Zealand. No one else could have done it better. Thanks also to the Nicholas family for their kind hospitality.
- The following landholders in New Zealand that met with and showed me *E. muelleriana* plantings on their properties: Peter and Richard Davies Colley, Thom family, Furniss family, John and Christine Pederson, Kerry McGee and Mr. Withers.
- Tony Shelbourne, Forest Research, NZ
- Russell McKinley, Forest Research, NZ
- Chris Wiffen of Timber Specialists Ltd.
- Dennis Budd, Sawmiller, NZ
- Timber Promotions Council for providing references
- Blue Ridge Hardwoods Pty. Ltd.
- North Eden Timbers Pty. Ltd.
- Louise Maud, South East NSW Private Forestry
- Mark Lutze, NRE Orbost
- Bruce Bell
- Braden Jenkin, Sylva Systems P/L
- Timber Promotions Council
- Paul Harris, Terra Timbers Pty. Ltd.
- Peter Creighton (State Forests NSW) for doing all the homework, keeping the ticks away and driving me to several plantations in the Hunter Valley.
- Andy Knorr and Chris McEvoy from Radial Timber Australia Ltd.
- Darius Culvenor for assistance in locating references
- Michael Hall
- Barry Tomkins
- Justin and Michael Ballantyne for the use of their scanner
- Tim Worth for document production assistance
- Jon Lambert, Woollybutt Pty. Ltd. for providing a vehicle and other assistance throughout the fellowship

Most of all I would like to acknowledge the understanding and patience of my wife – Michelle as she endured my trips away, too many one-way discussions about Yellow Stringybark, editing and the write up phase that went for 4 months longer than was originally indicated!

Author Profile

Since December 1999 Clinton has been the plantation manager with Woollybutt Pty. Ltd. Woollybutt is a Victorian owned and based forestry company that "Maximises your forestry investment". Clinton manages the establishment and silviculture of plantations and native forest on behalf of private landowners and companies in eastern Victoria. Woollybutt manages a wide range of forestry species in plantations including *E. cladocalyx*, *E. globulus*, E*. botryoides*, *E. muelleriana*, *E. nitens*, *E. tricarpa*, *Corymbia maculata*, *Acacia melanoxylon*, *Acacia mearnsii* and *Casuarina cunninghamiana*.

Prior to working with Woollybutt, Clinton was employed as a Farm Forestry Extension Officer with Gippsland Farm Plantations Inc. in Sale and as a Forest Officer with the then Department of Natural Resources and Environment based in Noojee, Victoria. Clinton graduated from the University of Melbourne in 1994 with a Bachelor of Forest Science.

Figure 1. The author next to a 42 year old, 106cm dbh *E. muelleriana* in the Tairua Forest, New Zealand

Contents

Acronyms

AGA	Australian Gas Association
ASL	Above sea level
ATSC	Australian Tree Seed Centre
BBM	Best Bet Management
BRH	Blue Ridge Hardwoods Pty. Ltd.
CCA	Copper chrome arsenic preservative
CNC	Computer numerically controlled
CSIRO	Commonwealth Scientific and Industrial Research Organization
DBH (dbh)	Diameter at breast height
DBHOB (dbhob)	Diameter at breast height over bark
EC	Electrical conductivity
FPC	Forest Products Commission, WA
FR	Forest Research, New Zealand
GRP	Grand Ridge Plantations Pty. Ltd.
GPa	Giga Pascal
GV	Gunns Veneers Pty. Ltd.
HDa	Harris Daishowa Pty. Ltd.
IRR	Internal Rate Of Return
MAI	Mean annual increment
MAR	Mean annual rainfall
MAT	Mean annual temperature
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MPa	Mega Pascal
MPO	Maximum probability of occurrence
MTH	Mean total height
NCT	Non commercial thinning
NET	North Eden Timbers Pty. Ltd.
NRE	Department of Natural Resources and Environment
NSW	New South Wales
PC	Phytophthora root rot (*Phytophthora cinnamomi*)
QERN	Qualitative environmental realised niche
RTA	Radial Timber Australia Ltd.
RGP	Red Gum Plains
RGP BBM	Red Gum Plains Best Bet Management trial
SE NSW PF	South EAST New South Wales Private Forestry
SFNSW	State Forests New South Wales
TPC	Timber Promotion Council, Vic
TS	Timber Specialists Ltd.
TTP	The Tree People Pty. Ltd.
TT	Terra Timbers Pty. Ltd.

Executive Summary

The start of the 21st century is a critical time for Australia's forest industry. It is burdened with a significant trade deficit ($2.2 billion in 2001) and is shrouded in controversy as public pressure to cease timber harvesting in native forests continues to escalate. Both of these issues are mounting pressure on the industry to increase the production of sawn timber from plantations.

During the past 10 years in south-eastern Australia, the growth and utilisation performance of many hardwood species in plantations has been assessed. The plantation industry is now at the stage where the selection of "best bet" species for hardwood plantation development in some geographic regions is being finalised. Whilst many of these species show good potential for sawn timber production, they are often plagued by problems that detrimentally impact their ability to produce acceptable recoveries of high quality sawn products.

Despite a good reputation in native forest, the stringybark group of eucalypts from the sub-genus *Monocalyptus,* have generally been overlooked as genuine sawn timber plantation options. Of this group, Yellow Stringybark (*Eucalyptus muelleriana*) has been trialed most extensively (particularly in New Zealand) and has delivered some promising results.

E. muelleriana is a medium sized to tall forest tree that occurs naturally within 100km of the coast between Warragul in Victoria and Wollongong in New South Wales (NSW). It is generally found at elevations between 0-450 metres in mixed eucalypt forests and prefers a temperate climate with a mean annual rainfall of 600 -1200mm/yr. The best development of the species is on protected slopes with well-drained soils.

E. muelleriana has not been extensively established in plantations. Nonetheless it has been established successfully within its natural geographic range. It has also been established successfully outside of its natural range both within Australia and internationally (e.g. New Zealand, South Africa, Hawaii and China).

New Zealand and South East Australian Field Trips

In southwest Victoria several plantations established in the early 1990's have shown *E. muelleriana* to perform well where good initial weed control had been applied and where it was not subject to periodic waterlogging.

In the Northland region of New Zealand, *E. muelleriana* has been trialed in plantations more extensively than anywhere else in the world. The New Zealand Forest Research Institute Ltd. (Forest Research) in partnership with many landholders have established a network of provenance trials and permanent sample plots (PSP's) for *E. muelleriana* and many other durable eucalypt species. These trials and PSP's have and will continue to yield invaluable information about these species. Forest Research has also investigated some wood properties of plantation grown *E. muelleriana*.

Forest Research has found the distribution, frequency and severity of frost events to be a vital consideration to successfully establish the species. In New Zealand, *E. muelleriana* is capable of rapid growth on a wide range of sites, providing site and climatic requirements are met. Relative to *Pinus radiata*, *E. muelleriana* is more specific in terms of its site requirements.

The form of *E. muelleriana* in New Zealand is far superior on ex-forest sites or on infertile pasture sites relative to fertile ex-pasture sites. On sites with a good fertiliser history *E. muelleriana* is plagued with form problems such as forking and sweep. Forest Research has found that the substantial and significant variation between families within provenances indicates that there is a large scope to select families to improve form characteristics.

Eucalypt wood processors in New Zealand confirm that *E. muelleriana* has a small defect core and therefore has a superior ability compared to most eucalypts to produce high sawn recoveries of good quality sawn timber suitable for flooring and furniture products. In New Zealand durable species such as *E. muelleriana* are highly valued by the market for their exterior durability and also for features commonly related to durability such as strength and hardness.

Native forest grown *E. muelleriana* is a strongly preferred and demanded species in the south coast region of NSW. Timber processors in NSW and East Gippsland value the excellent sawing characteristics of the species. The relatively small defect core and low levels of wood distortion during sawing commonly facilitates higher sawn recoveries for *E. muelleriana,* particularly in small logs, compared to most eucalypts processed in this region.

Blue Ridge Hardwoods (BRH) based in Eden, NSW, has found *E. muelleriana* to have good drying characteristics in a controlled environment. They have found it to be more expensive to dry than Ash species, however this is largely compensated for by the lower levels of drying degrade and the production of a more valuable product. The sapwood of *E. muelleriana* is resistant to lyctid borer attack that could potentially reduce processing and preservation costs.

North Eden Timbers (NET) based in Pambula, NSW produce flooring and furniture products using timber from *E. muelleriana* grown in native forest. *E. muelleriana* is the preferred species for NET because its wood has ideal colour, texture and durability properties for use in flooring and furniture products. Whilst the natural light colour of the wood is attractive, the timber also responds well to darker stains and finishes which give the final product more versatility. NET have found that both backsawn and quartersawn boards from *E. muelleriana* can be easily dried, machined and finished to an excellent standard for high value products. NET has found that the combination of wood colour, strength and durability characteristics give *E. muelleriana* products a strong consumer demand. They believe the market for high value durable timbers will expand in the short to medium term.

In 2002, South East NSW Private Forestry commissioned a study that demonstrated the posts from 3-5 year old *E. muelleriana* have a stiffness and strength advantage over pine posts. The posts used for this study confirmed that *E. muelleriana* produces heartwood early than many other eucalypt species.

In East Gippsland, *E. muelleriana* has performed better in plantations established on sandy soils than on heavy clay soils. It also performed considerably better on sheltered sites. *E. muelleriana* plantations appear to have an increased chance of suffering windthrow on heavy to medium clay soils that have been ripped. In accordance with provenance trials established by Forest Research, leaf size and canopy density were observed to increase with decreasing latitude.

E. muelleriana was one of many species established in a series of State Forests NSW trials during the 1970's, in the Hunter Valley and Eden regions of NSW. *E. muelleriana* performed best in trials located in the Watagan State Forest on sandstone-derived soils in sheltered slope locations. In the Watagan a 1990 assessment showed *E. muelleriana* and *E. agglomerata* to be the best performed out of 17 species trialed. At age 30, *E. muelleriana* averaged 30-40m tall and 35-50cm diameter at breast height (dbh) across the four Watagan sites. On most Hunter Valley sites, *E. agglomerata* demonstrated slightly faster growth than *E. muelleriana*. *E. muelleriana* generally showed excellent form in this trial series. This supports New Zealand findings that stringybarks tend to exhibit better form on ex-forest sites or sites with poor fertiliser history.

The largest *E. muelleriana* plantation in Australasia is located in the Alberton West State Forest near Yarram in Gippsland, Victoria. This plantation was established in 1986. Inventory conducted in 2002 showed that the mean annual increment of the plantation to be ~15m^3/ha/yr. Given the primitive establishment techniques and high levels of inter-tree competition that have persisted in recent years, this plantation shows that *E. muelleriana* is capable of attaining acceptable commercial growth rates in South Gippsland.

In Yarram, the Radial Timber Australia Ltd. sawmill provides a market for both native forest and plantation grown *E. muelleriana*. *E. muelleriana* is one of their preferred species for the production of durable wood products.

E. muelleriana was included in several species trials established in the early 1990's in the south and central Gippsland region. In these trials *E. muelleriana* demonstrated its best comparative performance on low rainfall sites with soil profiles that contained a sand component.

Establishment and Management

E. muelleriana prefers well-drained soils on southern and/or protected aspects. The preferred mean annual temperature (MAT) is 13.5°C – 16°C. Where *E. muelleriana* is planted on sites with a MAT below 13.5°C survival and growth can be dramatically reduced by frost.

Field observations of *E. muelleriana*'s root structure are in accordance with research that shows *Monocalyptus* species to concentrate root development higher in the profile relative to *Symphyomyrtus* species. This root configuration may be related to *E. muelleriana*'s propensity to suffer from windthrow on soils with heavy clay subsoil.

Where it is appropriately sited *E. muelleriana* is not generally susceptible to severe attack and damage from any insects. *E. muelleriana* is susceptible to the fungal disease Phytophthora Root Rot (*Phytophthora cinnamomi*). Fungal infection and subsequent tree mortality is worst on relatively infertile sites where drainage is impeded. Research shows that there is good potential through tree improvement programs to produce families of *E. muelleriana* with improved resistance to *Phytophthora cinnamomi.* If there is any risk of *Phytophthora cinnamomi* infection, it is important that soil samples designated for testing the presence of the fungus, are taken prior to establishment

Research and qualitative assessment of *E. muelleriana* shows that genetic variability both within and between provenances is sufficient to promise good genetic improvement in a variety of traits including diameter, height, form, frost resistance and health. Firm recommendations regarding the best provenances and/or families for establishment cannot be made at this stage. However if a grower requires a relatively high frost tolerance it is recommended that they consider seedlots from altitudes greater than 250 metres above sea level. In the absence of tree improvement, it is recommended that *E. muelleriana* plantations intended for wood production be planted at 1000 stems per hectare (sph).

Prior to selecting *E. muelleriana* for establishment the following soil properties should be evaluated: presence/absence of *Phytophthora cinnamomi,* fertility, waterlogging, soil texture and salinity.

E. muelleriana can respond significantly to soil cultivation. However other species should be considered for establishment if deep ripping has been performed in wet soil conditions.

Pre-planting and post planting weed control are the most important operations in facilitating the successful establishment of *E. muelleriana*. *Monocalyptus* species (such as *E. muelleriana*) have a greater proportion of roots higher in the soil profile. Therefore *Monocalyptus* species will be more affected by weed competition during the first two to three years after establishment.

The root configuration of *Monocalyptus* species could potentially mean that they are not as tolerant to the application of residual herbicides as *Symphyomyrtus* species. Until more research is completed, low to moderate levels of residual herbicides are recommended. Residual herbicides for pre-planting treatments should only be applied during the winter period in moist soil conditions.

It is apparent that *E. muelleriana* is well adapted to sites that exhibit low fertility; therefore the value of applying fertiliser at establishment is questionable. A better practice would be to survey the trees at age 1 and schedule a foliar analysis if symptoms of nutrient imbalance are present. To optimise growth it is likely that *E. muelleriana* plantations will require different nutritional management strategies compared to many commercial eucalypt species.

To produce wood suited to the production of high value wood products within 30-35 years, *E. muelleriana* plantations require thinning and pruning operations to be conducted in a timely fashion. Regimes will be similar to those currently recommended by extension agencies for other eucalypts, except that the initial non-commercial thinning should be lighter to account for *E. muelleriana's* requirement for shelter.

Assessment of unmanaged *E. muelleriana* plantations shows that mean annual increments (MAI's) greater than 15m^3/ha/yr are achievable on a wide range of sites. If "best practice" site selection, plantation establishment and management are applied, it is expected that growth rates could be significantly improved.

Wood/Timber Properties

The heartwood of *E. muelleriana* is yellowish brown with a pink tinge. The wood grain is usually straight with some interlocking. The density of *E. muelleriana* is generally lower when grown in plantation compared to native forest. The density of plantation grown *E. muelleriana* has only been recorded in New Zealand.

The stability of *E. muelleriana* during sawing and its relatively small defect core indicate that this species suffers less from growth stress related problems than most eucalypt species. This is a significant advantage that can facilitate higher recoveries of sawn timber. The fine texture and light colour of *E. muelleriana* make it amenable to a wide range of uses.

E. muelleriana dries readily with minimal degrade providing the appropriate schedule is used. The largest commercial processors of *E. muelleriana* in Australia, NET and BRH have implemented customised and fully controlled drying regimes to minimise drying degrade. Both groups are achieving good levels of dried timber recovery. NET have no requirement to recondition timber during the drying process. In New Zealand where plantation grown *E. muelleriana* has been air dried prior to kiln drying, good levels of dried timber have been recovered.

Timber produced from *E. muelleriana* is rated in the S3 and SD3 strength groupings. *E. muelleriana* is rated as a durable timber species – class 3 "in ground contact", class 2 for "outside above ground" applications. Plantation *E. muelleriana* strength groupings are not available. However plantation grown *E. muelleriana* is rated as a durable species in New Zealand.

E. muelleriana timber from native forest and plantations generally has good machining, gluing and finishing properties.

E. muelleriana produces a versatile wood that is suitable for a wide variety of applications. Today the most popular products of *E. muelleriana* are flooring, decking, cladding, weatherboards, poles, indoor and outdoor furniture, pulpwood and firewood. Whilst *E. muelleriana* demonstrates good potential to produce high quality timber products in plantations, the potential and marketing direction for residual wood is not so clear. To maximise returns from plantations, it is important that a reliable outlet is found for this material.

Research shows that *E. muelleriana* plantations managed on a 30-35 year rotation are likely to produce pulpwood of an acceptable quality. Industry has indicated that pulpwood produced from *E. muelleriana* plantations will find a market when there is a hardwood pulp mill within an economic haulage distance. Some pulpwood markets are likely to refuse mature age *E. muelleriana* logs on the basis of poor pulping properties.

Throughout its natural range in Victoria and NSW, *E. muelleriana* has long been regarded as a preferred species for poles. Research work shows that *E. muelleriana* plantations are well suited to the production of round timbers in plantations. In Gippsland, industry has already expressed strong interest in sourcing post and poles from the Alberton West *E. muelleriana* plantation. Post and pole applications are likely to be a valuable market for wood generated from thinning operations.

E. muelleriana possesses good firewood properties that compare particularly favourably with the other main plantation species options in Gippsland and southern NSW where it best suited for establishment. Whilst it could be argued that there is good potential for residual grade *E. muelleriana* to be sold as firewood, it is important to note that only 34% of firewood used in Victoria is purchased. Until this percentage rises it is unlikely that firewood will be a good commercial market option for large quantities of residual grade wood.

Whilst markets for residual grade products will improve financial performance, they do not necessarily determine the commercial viability of a sawlog focussed plantation project. Experience and financial analysis demonstrates that timely thinning of a sawlog plantation has a more significant influence on financial performance than the presence or absence of residual wood markets.

Conclusion

The available evidence commends *E. muelleriana* as having good potential as a plantation species for the production of high value wood products on suitable sites in south-eastern Australia.

E. muelleriana offers many benefits as a plantation species managed principally for sawlog production. Evidence shows that *E. muelleriana* has good to excellent utilisation properties. Indeed these properties may become its trademark as a plantation species. In southeast NSW, *E. muelleriana* grown in native forest is already the basis of an established and thriving solid timber products industry. These markets for *E. muelleriana* give plantation developers a ready base to work from. *E. muelleriana* has several market options for residual grade wood. However at this stage none of these options have been widely tested in the market place.

E. muelleriana offers some challenges to plantation developers. It is relatively site specific and exhibits significant form problems when established on fertile ex-pasture sites. Generic establishment models need to be adjusted to optimise growth rates, tree health and form and to maximise the production of high quality solid wood. Providing a co-ordinated approach is adopted, these challenges can be overcome using methodologies that have already been developed for other plantation species.

Considering the sawing and drying experience with many more widely planted eucalypt species, it is significant that growing *E. muelleriana* in a plantation may prove more challenging than processing it for high value wood products.

Background

Why profile *Eucalyptus muelleriana*?

The Australian Bureau of Agricultural and Resource Economics (ABARE) found that in 2001 imports of forestry related products rose to $3.8 billion with only $1.6 billion in exports. This equates to a $2.2 billion trade deficit for the 1999/00 financial year. The importation of sawn timber from Canada, New Zealand, South East Asia and the USA is contributing significantly to the trade deficit. New homes in Australia are often built using imported timbers such as red cedar for windows, baltic pine for flooring and oregon for pergolas. A wide range of imported rainforest timbers is used for furniture, picture frames, matches, paintbrushes, and kitchen chopping boards. Whilst the rising trade deficit is bad news for Australians, there are many opportunities for the Australian forestry industry to reduce the trade deficit and become a net exporter of sawn timber products.

Moving parallel to the push to cut the trade deficit, is a strong public pressure to reduce the area of native forest in Australia available for timber harvesting and subsequent sawn timber production. These two factors have contributed to a significant research effort being invested during the past ten years into the evaluation and ongoing research of a number of plantation species for establishment particularly in southern Australian regions. The major species included in this research program are: - *Eucalyptus globulus* (Blue Gum), *E. nitens* (Shining Gum), *E. regnans* (Mountain Ash), *E. saligna* (Sydney Blue Gum), *E. grandis* (Rose Gum), *E. camaldulensis* (River Red Gum), *Corymbia maculata* (Spotted Gum), *E. cladocalyx* (Sugar Gum) and *E. sideroxylon/tricarpa* (Red Ironbark). The research has shown that many of these species show good potential for sawn timber production in plantations. Unfortunately the species that demonstrate the best potential are often plagued by other problems such as frost tenderness, poor tree form, high levels of growth stress and low dried recoveries of high quality sawn products.

Markets for hardwood-sawn timber are also changing. For example a significant number of sawmills and timber wholesalers in Australia and New Zealand are receiving increasing enquiries and real demand for naturally durable timber species. However whilst some durable timber species are being trialed as plantation options in low rainfall areas (MAR<650mm/yr), they are generally receiving scant consideration in medium to high rainfall areas (>650mm/yr).

One group of species that has the potential to address problems experienced with the currently recognised suite of eucalypt plantation species options, are the stringybarks in the series *Pachyphloius*. Several of the stringybark species in this series have shown good growth and utilisation potential in preliminary trial work. *E. muelleriana* is one of these species. In relatively small trials and plantings it has shown moderate frost resistance, acceptable to outstanding form and good growth rates on suitable sites. Importantly, industry experience and limited utilisation studies on plantation grown timber, have demonstrated that this species shows exceptional potential to produce high recoveries of sawn dried timber suited to a wide range of products from furniture to flooring. Residual grade E. muelleriana wood produced in plantations is also suited for use in firewood, pulpwood and post and pole applications.

Bootle (1983) in his publication “Wood in Australia”, comments that *E. muelleriana* is probably the best of the stringybarks for wood quality. Historically many processors and foresters have also regarded *E. muelleriana* as the best of the stringybark timbers. This is emphasised by the regular occurrence of stringybark logs being incorrectly branded “in the bush” as “Yellow Stringy” because this species in some areas commands a premium in the market place relative to some other stringybark species.

E. muelleriana timber carries a significant advantage over many other eucalypts because its sapwood is not susceptible to Lyctid Borer. This potentially enables the sapwood to be included in sawn products (i.e. weatherboards) and eliminates the need to either re-saw boards to exclude sapwood or to apply chemical treatments to prevent Lyctid attack in the sapwood. This property may also assist improving sawn recoveries from small logs.

Whilst *E. muelleriana* is a species that demonstrates excellent potential for plantation sawlog forestry, if adopted as a plantation species it would also introduce some new challenges to plantation developers and processors. Relative to some mainstream plantation species such as *E. globulus*, *E. nitens* and *Pinus radiata, E. muelleriana* is regarded as having a slow to moderate growth rate. Being a "stringybark" species it is unsuitable for agroforestry systems because it is easily ringbarked and killed by grazing animals. In Australia, timber produced from stringybarks (including *E. muelleriana*) sourced from native forest is regarded by some processors as being prone to surface checking[1] and therefore difficult to dry and unsatisfactory for appearance grade products. Native forest grown *E. muelleriana* is not regarded as a preferred pulpwood species and therefore there may be some difficulty in selling residual grade wood produced in plantations. Subsequently the financial viability of *E. muelleriana* plantations could be jeopardised.

It is inevitable that *E. muelleriana* as a sawlog plantation option would introduce some new challenges to the forestry industry. Nonetheless the potential advantages of this species make it worth a second look – or for some, a first.

The objective of this report is to establish the potential of *E. muelleriana* as a sawlog plantation option in south-east Australia. Many of the observations and findings may also be useful to the developing eucalypt forestry industry in New Zealand.

Introduction

E. muelleriana was named after Baron von Mueller, a government botanist for Victoria (Young 1983). The common name of Yellow Stringybark refers to the appearance of the bark, which is very yellow when freshly cut (Maiden 1917).

Taxonomy

The classification presented by Brooker (2000) has been used to outline the taxonomy of *E. muelleriana* for this report[2]. Table 1. illustrates the classification of *E. muelleriana.*

Table 1. Taxonomy of *E. muelleriana*

Genus	Sub-genus	Section	Series	Species
Eucalyptus	*Monocalyptus*	*Capillulus*	*Pachyphloius*	*E. muelleriana*

The series Pachyphloius contains 28 stringybark species. Some of the more commonly known species of this group include *E. muelleriana, E. laevopinea, E. macrorhyncha, E. globoidea, E. eugenioides, E. agglomerata* and *E. baxteri.*

In botanical terms Boland(et al. 1984) implies that *E. muelleriana* is closely related to *E. laevopinea*.

Appearance

In its natural environment *E. muelleriana* is a medium sized to tall forest tree to 45 metres that generally exhibits a straight trunk and a well developed crown (see Figure 2). Its appearance is

[1] Checking – is a separation of fibres along the grain which produces a crack which does not extend from one surface to the other.
[2] Shelbourne (2001) also used this classification.

similar to other stringybark species, particularly *E. globoidea* and *E. agglomerata*. Visually it can be distinguished from these species by observing the following features:

- Tree crown (see Figure 2) – leaves are generally wider giving the crown a thicker appearance, that enables it to cast more shade;
- Fruit and buds (see Figure 3) – are significantly larger and not as tightly clustered;
- Generally flowers during the Nov-March period (Costermans 1994). *E. globoidea* flowers during the March –June period (Costermans 1994).

Figure 2. An example of *E. muelleriana* the tree and a close up of its bark (Brooker et al. 2000)

Figure 3. The fruit and leaves of *E. muelleriana* (Brooker et al. 2000)

Mature seed for this species can usually be collected during the Dec-Feb period. *E. muelleriana* is a fairly constant seed producer, producing new crops of seed on an almost annual basis (Anon., 1966 cited by State Forests of NSW 1983).

E. muelleriana has a typical stringy bark, which ranges from grey to brown and is persistent to small branches (see Figure 2). The inner bark is usually a yellow – brown colour.

For a more thorough account of the physical features of *E. muelleriana* refer to (Brooker et al. 2000)

.

Distribution

E. muelleriana occurs naturally in the foothills and coastal plains of southeast New South Wales and Victoria. It is found as far north as Woollongong, NSW[3] (Brooker et. al. 2000) and extends in a south-westerly direction around to Warragul[4] in West Gippsland, Victoria. Its latitudinal range is 34-39°S (Poynton 1979). Figure 4 taken from Brooker et al. 2000, illustrates the distribution of *E. muelleriana*.

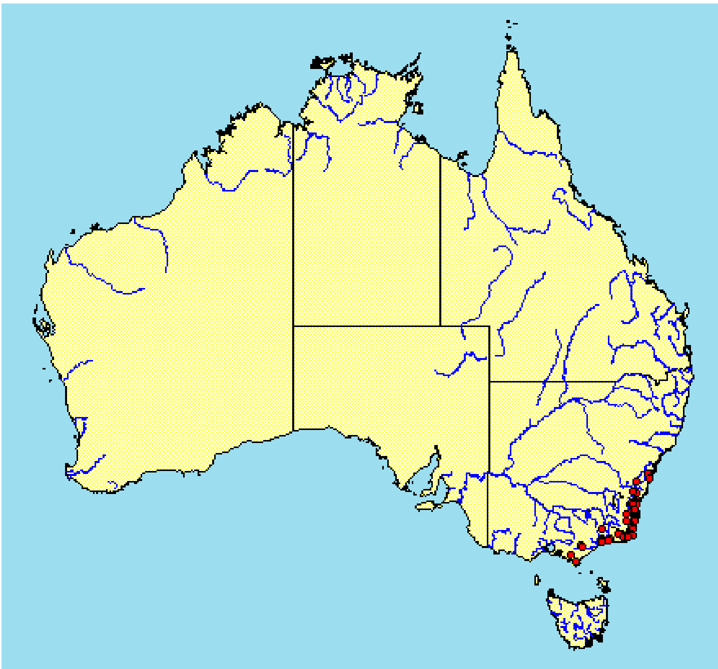

Figure 4. Distribution of *E. muelleriana* (Brooker et al. 2000)

E. muelleriana is generally found within 100km of the coast at elevations between 0 to 450 metres, sometimes extending to 600 metres above sea level (Boland et. al. 1984). In south-eastern NSW *E. muelleriana* has a maximum probability of occurrence (MPO) at altitudes from 200 to 400 metres (Austin et. al. 1983, Shelbourne 2001 in prep). In the South Gippsland region of Victoria the distribution of the species indicates that the MPO may be at a slightly lower altitudinal range of 100-300 metres above sea level (ASL).

E. muelleriana is generally found in sheltered valleys and on protected slopes rather than exposed sites. *E. muelleriana* usually grows in mixed eucalypt forests with *E. globoidea, E. cypellocarpa, E.*

[3] latitude 34°24' and longitude 150°54'.
[4] latitude 38°10' and longitude 145°55'.

sieberi, E. obliqua and *E. agglomerata*. In South Gippsland it is often associated with *E. globulus* ssp *globulus*.

E. muelleriana prefers a temperate climate with a relatively dependable rainfall. The mean maximum temperature of the hottest month ranges between 24°C-28°C and the mean maximum of the coldest month between 1-6°C (Boland et. al. 1984). Frost occurs on up to 20 nights of the year, and occasional snowfalls may be experienced at the highest elevations (Poynton 1979). The MAR across the range of the species ranges from 600-1200mm/yr and is distributed over 80-150 days of the year (Poynton 1979). Most of the precipitation takes place during winter in the southwest and during summer in the northeast (Poynton 1979).

Location of existing plantations

This species has not been extensively planted in plantations compared to some eucalypt species. In addition to being planted successfully within its natural geographic range, *E. muelleriana* has performed well as a plantation species in the following areas:

- Northland region of New Zealand
- Far south west Victoria
- Chichester, Bulahdelah and Newcastle NSW.
- Mt. Gambier, South Australia (Peter Feast pers. comm. 2002)[5]
- South West of Western Australia (Graeme Siemon FPC pers. comm. 2002)
- South Africa (Poynton 1979)
- Yunnan Province, China (Wang et al. 1999)
- Nuuanu Valley, Hawaii (Fujii 1976)

In response to a request made in August 2002, Trevor Booth, a member of the CSIRO Farm and Environmental Forestry Research team, generated an indicative map[6] that illustrated climatically suitable areas for *E. muelleriana* in Australia. He based this map on the climatic profile of the species described in Boland et. al. 1984. Generally speaking the map did not expand the distribution of *E. muelleriana* to a large extent. Although the climatically suitable range of *E. muelleriana* did include significant new area north of its natural distribution towards and just beyond the Queensland/NSW border. Significantly the range did not extend any further south than the natural range of the species. However there was a slight increase in distribution to the west; finishing at Melbourne, Vic.

Whilst it must be stressed that the map generated by Mr. Booth was purely indicative, it does demonstrate that *E. muelleriana* similar to most other members of the sub-genus *Monocalyptus*[7] and unlike members of subgenus *Symphyomyrtus*, is not likely to be suitable for commercial plantation establishment over a large geographic area outside its natural range.

New Zealand and South East Australian Field Trips

During April-November 2002 several field trips were undertaken to view *E. muelleriana* plantations and processing facilities and to discuss various aspects of the species with "experts".

South West Victoria – Hamilton

On the 22-23 April 2002 five plantation sites established with the technical assistance of Rod Bird of the Pastoral and Veterinary Institute – Hamilton were inspected. Three of these sites were established in 1985 (Branxholme 1, Hensley Park and Melville Forest) and two in 1994 (Chatsworth and Branxholme 2). These sites receive a mean annual rainfall (MAR) of 600-700mm/yr.

[5] Peter Feast is a farm forester and nurseryman near Mount Gambier
[6] The map was generated using the "Australia Climatic Mapping Program".
[7] For verification refer to Jovanic, T. and Booth, T.H. (2002). Improved species climatic profiles. RIRDC Publication No. 02/095.

The following establishment specifications were summarised from Bird et al. 1996. The three sites planted in 1985 were each ripped with a tractor to 40-60cm on a grid of 4m. No mounding was conducted. Glyphosate (4L/ha) and Simazine (6L/ha) were applied before planting as the pre-plant weed control treatment. All trees were grown from Australian Tree Seed Centre (ATSC) 11961[8] – Narooma provenance. Trees were hand planted in spring using a Hamilton Tree Planter. Forty to forty eight species were established at 625 stems per ha (sph) and thinned at age 8 to ~ 310 sph. Sixteen trees were originally planted per plot. Some trees were also pruned for demonstration purposes.

The survival and growth of *E. muelleriana* at the Branxholme 1 and Hensley Park sites established in 1985 was very poor. At age 7 (1992) the survival was 41% and 8% respectively for these two sites. At 13 years of age (1998) the surviving trees were less than seven metres tall (Tim Jackson NRE pers. comm. 2002). Both sites were composed of heavy brown clays and showed signs of heavy pugging (particularly Hensley Park), indicating that the sites were prone to becoming waterlogged for extended periods during the year. Wet, heavy clays are widely regarded as being prohibitive to the survival and good growth of *E. muelleriana* (Bird 2000).

The survival and growth at Melville Forest was significantly better. This site consisted of a sandy loam soil (A2 horizon) overlying a clay subsoil (B horizon) and was better drained than the previous two sites. At age 7 (1992) the survival was 81%. The plots were small and some trees had been pruned and thinned making the extraction of meaningful measurement data difficult. Nonetheless five trees in each of two of the three replicates were measured. Total tree height ranged between 11.3 - 14.1 metres at age 16.5 years. The diameter at breast height (dbh) varied from 23.8 - 33cm. In terms of stem volume visual estimates showed *E. cypellocarpa, E. sieberi* and *P. radiata* to have produced more wood on this site. In 1998, *E. muelleriana* was ranked 3rd out of 40 species on this site in terms of wood volume (Tim Jackson pers. comm. 2002). Tree form was fair, with forking and sweep being the main defects.

Figure 5. *E. muelleriana* at Melville Forest

[8] Seedlot number.

The two sites planted in 1994 (Chatsworth and Branxholme) were established at higher stockings and exhibited superior survival to all of the other sites. The Chatsworth site was well drained and positioned on a gentle northern aspect that provided some protection from harsh westerly weather. At establishment the two species planted:- *E. muelleriana* and *Casuarina cunninghamiana* had to compete with vigorous and dense phalaris (*Phalaris paradoxa*) dominated pasture which considerably slowed the growth of both species. The site appeared to have been ripped and not mounded. Despite the persistent weed competition, the *E. muelleriana* at ~ 8 years of age, after a slow start, have now passed the *C. cunninghamiana* and range between 4 to 6 metres tall and had a dbh of 8-12cm[9]. The form and health of the trees was excellent.

The Branxholme site planted in 1994 was the most impressive site visited in southwest Victoria. Eighty *E. muelleriana* seedlings were planted on a stony rise, which contained free draining, sandy loam soil, over clay and floating basalt rock; some of which could be seen on the surface. Four other species; *E. viminalis*, *E. botryoides*, *E. cypellocarpa* and *Allocasuarina verticillata* were also planted on the site. The growth and survival of the *E. muelleriana* was impressive, particularly considering the stony soil profile, exposure to westerly winds and minimal site preparation[10]. Trees averaged ~ 9 metres in total height and 15-20cm dbh. Tree survival was > 80% and form was generally very good (see Figure 6). The landholder Michael Holcombe had conducted a first pruning lift to ~2.4 metres in the *E. muelleriana* and also in other species lots where trees were large enough. He was very happy with the growth of the *E. muelleriana* and claimed that they were the easiest and quickest trees to prune because of their fine branching habit and soft wood relative to the *E. botryoides* in particular. Interestingly *E. muelleriana* was outgrowing *E. botryoides* on this site.

Figure 6. *E. muelleriana* at Michael Holcombe's property, Branxholme

[9] Trees were measured in April 2002.
[10] Ripping and pre-plant weed control appears to have been the only site preparation.

Summary
The inspection of the five sites in the Hamilton region demonstrated that *E. muelleriana*:

- ✓ Is not a good option for sites prone to waterlogging for extended periods of the year. Survival rates and growth are likely to be poor on these sites;
- ✓ Prefers well drained soils and can not only tolerate dry rocky soils, but demonstrates potential to produce commercial timber in these harsh conditions;
- ✓ Can be a realistic plantation option away from its natural distribution;
- ✓ Requires at least two seasons of weed control to adequately out compete vigorous weeds such as phalaris.

New Zealand – Northland region of the North Island

During the 25 – 29 May 2002 Ian Nicholas from the Forest Research chauffeured me around eight Yellow Stringybark trial/woodlot sites and one eucalypt sawmill in the Northland region of New Zealand. The site and stand details for all the sites visited are recorded in Appendix A.

On the 30th May the day was spent with Forest Research staff that specialized in all aspects of growing hardwoods. On the 31st May the morning was spent with Chris Wiffen from Timber Specialists Ltd. Ltd. Following is a summary of the seven days in New Zealand.

Chris & Norm Thom's property near Helensville

The Thom's had planted *Pinus radiata* and a variety of eucalypts on their property including *E. muelleriana*, *E. globoidea* and *E. microcorys*. All species had been planted at low "agroforestry" type stockings[11]. Subsequently the amount of heavy branching was considerable. The *E. microcorys* and *E. muelleriana* in particular had been planted on sites prone to seasonal waterlogging. At the time of the inspection the *E. globoidea* had slightly better form than the *E. muelleriana*, which was badly affected by multiple sweep[12] in many instances. Most of the *E. muelleriana* had been pruned to 4.5m and showed no signs of epicormic shoot development, despite the large diameter of some branches at thinning. With the benefit of hindsight, the Thom's would have been better to reverse the locations of the two stringybark species, placing *E. muelleriana* on the better drained mid-slope site.

Whilst the growth of *E. muelleriana* was impressive on this site, the form was poor in many instances (Figure 7), and hence sawlog yield is expected to be low.

[11] Trees planted at wide spacings and therefore low stockings e.g. <500 sph
[12] Multiple sweep – when the bole of a tree deviates in a curved fashion from the vertical axis more than once.

Figure 7. ***E. muelleriana*** **planted on the Thom property near Helensville.**

Furniss property near Kaukapakapa

The Furniss's had established several hectares of eucalypts and Monterey Pine on their fertile, high rainfall property. The eucalypt species that had been planted included *E. pilularis, E. microcorys, E. globoidea* and *E. muelleriana*. Mature stands of the *E. saligna* and *E. botryoides* planted in gully regions were also prominent. The Furniss's had planted their eucalypts at high stockings (1600sph) with the aim of conducting several thinning operations throughout the rotation. Sweep and forking was present within the eucalypt plantations although this is likely to be overcome as the defective stems are progressively removed during thinning operations.

Only a small number of *E. muelleriana* had been planted in a narrow belt in an upper slope position on the edge of a *E. pilularis* plantation. These trees had the characteristic appearance of edge trees. They were growing quickly and demonstrated poor to moderate form expressed through heavy branching and some sweep.

Some *E. globoidea* that had been established at 1600sph in a protected position adjacent to a drainage line, demonstrated good growth and excellent form on this property.

John & Christine Pederson's property near Parakao

The Pederson's are a prominent farm forestry family in Northland. *E. muelleriana* is just one of many species that they have planted on their farm 32km west of Whangarei. The first of two sites visited was a 1.16ha *E. muelleriana* provenance/family trial planted in 1994. This trial was originally established at 1234 sph (2.7m x 3m). Due to possum and frost damage the density at the time of measurement was substantially less than this (500-600sph). Figure 8 illustrates the *E. muelleriana* at age 8.

Figure 8. *E. muelleriana* provenance/family trial planted at Pederson's near Parakao

Seedlings from 6-10 open-pollinated families from seven provenances, spanning the geographic range of the species, were planted in a "single tree plot set in replication design" with 30 replications (Shelbourne et. al. 2000).

There were significant differences between provenances at age 2 and 6 for all traits (except dbh and wood density at age 6). Family differences not generally significant at age 2, were highly significant for all traits at age 6 (Shelbourne et. al. 2000). The growth rate and crown health were good. The overall mean dbh was 200mm and mean height of dominants and codominants was 15m by age 6 (Shelbourne et. al. 2000). At age 6 the MAI was estimated to be ~15m^3/ha/yr. Whilst this may only appear to represent a moderate growth rate, it should be remembered that the average plantation stocking across the site was relatively low and that the MAI will not yet have peaked. Tree form was extremely variable being excellent in some cases and poor in others. Sweep and forking defects were particularly prevalent. Forking in particular had led to top breakage in many instances throughout the stand. This was despite John Pederson having conducted some form pruning in the plantation. It was suggested during the visit that the forking and sweep might be more strongly correlated with site fertility rather than being a species characteristic. The differences between families within provenances in all traits at the 6-year assessment were substantial and significant and there are evident opportunities for selection of better-grown and better – formed families (Shelbourne et. al. 2000). This trial is described in more detail later in the report.

The second site visited was in many ways a stark contrast to the first. *E. muelleriana* was planted at a wider spacing (6m x 6m) and pruned to 7 metres. These trees were planted on a steep eastern aspect and demonstrated superior form to the previous site. Some form pruning had again been performed on this site (John Pederson pers. comm. 2002). Given the steepness of the site it is likely that this site had not received as much fertiliser over the years as the nearby trial site. The appearance and growth of the pasture at the time of the inspection also indicated this. In 1998 one tree (45-50cm dbh) in this plantation fell over. It was left on the ground for two days before it was processed on the farm. The processed timber was then stacked in a shed, which is where we saw it. The straightness and lack of drying defect in the boards was notable. I collected two back sawn sample sections from the recovered timber – one from the heart and the other from the log periphery (Figure 10). These samples also reflected the absence of defect despite being backsawn and selected from non-preferred sections of the log.

Figure 9. *E. muelleriana* planted in an agroforestry design at age 14.

Figure 10. Backsawn boards (left and right) sawn from a 10-year-old *E. muelleriana* tree. The middle board is from native forest near Eden, Vic.

Davies-Colley property near Titoki

At this property we inspected *E. muelleriana* plantings, a eucalypt value adding facility owned by the Davies- Colley family, a eucalypt mill (formerly owned by the Davies-Colley family), and a mixed species plantation established and managed by Peter's company "The Tree People" (TTP).

The Davies-Colley family are regarded as a pioneering farm forestry family in Northland. Not only had they established significant areas of eucalypts, but they were also leaders in the development of domestic eucalypt flooring markets and in processing / drying eucalypt species in New Zealand. Their processing facility has since been sold to Campbell and Katrina Moore (CBM Sawmills Ltd.), who continue to process eucalypt species grown in Northland.

The family has a high regard for the wood produced by Stringybark eucalypts. They have grown and processed their own plantation of 31-year-old *E. muelleriana* into flooring and furniture products (Figure 11). Twenty tonnes of logs were milled and the green sawn recovery was estimated to be 58-60%. Richard incurred no problems associated with growth stresses during processing and found that *E. muelleriana* was softer to cut relative to *E. pilularis* and *E. saligna* due to less silica being present in the wood. All wood was cut at 25mm x 100mm for tongue and groove flooring (19mm thickness) or at 18mm x 100mm for flooring overlay (12mm thickness). Compared to *E. saligna* and *E. botryoides* there was a marked reduction in defect core wood; restricted to 100-125mm diameter. This was a major reason behind the higher than average green sawn recovery (Richard Davies-Colley pers. comm. 2002).

Figure 11. Bookcase made from 31-year-old *E. muelleriana*

Only backsawn boards showed any sign of distortion during drying. The timber was dried in a low-medium temperature kiln within two weeks of sawing. After machining (planing and moulding), the only checking that was observed was in backsawn timber that was exposed to excessive sunlight off the saw (Richard Davies-Colley pers. comm. 2002).

Logs that were <360mm in diameter at the large end were sold as pulpwood. In Northland there is little or no demand for low-grade sawn products (e.g. pallet grade) that would commonly be processed from these smaller logs when grown in native forest in southeast Australia.

Peter Davies-Colley owns and operates a forest management company called "The Tree People" (TTP) and has established several *E. muelleriana* and *E. globoidea* plantations throughout the Northland region. He likes these two stringybark species because they satisfy the five criteria he uses to identify a good commercial timber species prospect:

1. Growing – these species grow well in the Northland region and are regarded as being relatively straightforward to manage. A big advantage is that they are relatively free of damaging insect pests and diseases;
2. Processing – both species are easy to process and commonly produce high green sawn recoveries using conventional sawing techniques;
3. Machining and finishing – have good machining and finishing properties;
4. Versatility – can be manufactured into a variety products to suit market demand;
5. Market – these species have existing markets for flooring, furniture, pulpwood and firewood in New Zealand.

In 1992 Forest Research Institute established a durable species trial that included four eucalypts; *E. pilularis*, *E. microcorys*, *E. globoidea* and *E. muelleriana* on the Davies-Colley property. At age 6 Forest Research assessed the trial and they reported that the *E. muelleriana* were growing less rapidly than the *E. globoidea*, but faster than *E. pilularis*. The occurrence of frost had impacted the survival of all eucalypts in this trial. Survival rates indicated *E. globoidea* to be more frost hardy than *E. muelleriana*. At the inspection the *E. muelleriana* were growing well although not as quickly as at the Pederson property[13]. The form of the *E. muelleriana* was superior relative to the Forest Research trial site at Pederson's. However, the *E. muelleriana* had been thinned and this

[13] This is presumed to be due to the site quality being lower.

limited the legitimacy of the comparison. The form of *E. globoidea*, which had also been thinned, was slightly superior to *E. muelleriana*. Forking was the major form defect observed in the *E. muelleriana* replicates. Peter Davies-Colley stated the he believed the commonly observed poor form of *E. muelleriana* grown in New Zealand, was related to high levels of nitrogen in the soil, rather than the relatively low establishment stocking rates.

Figure 12. ***E. muelleriana*** **established in a durable species trial – 1992.**

At the inspection *E. globoidea* demonstrated slightly better form and growth relative to *E. muelleriana*. It is important to note that the presence of *Juncus* spp. on this site indicated the presence of periodic waterlogging.

Following the trial inspection we visited another site where *E. muelleriana* had been established in a wide spaced design at 300 stems per ha (3 stems per spot). Early in the rotation the three tree spots were thinned back to one, reducing the stand density to 100 stems per ha. The site was established at this low stocking in an effort to manipulate crown form by increasing branch to stem angles, subsequently making the crown less prone to top breakage (Peter Davies-Colley pers. comm. 2002). Predictably the *E. muelleriana* demonstrated rapid diameter growth on this site. Branch angles were certainly larger relative to the previous site and tree crowns did appear to exhibit less signs of breakage. However sweep was worse on this site relative to the durable species trial.

Peter Davies Colley then guided us through a large mixed plantation of *E. muelleriana, E. globoidea* and *Pinus radiata*. The *P. radiata* was planted in alternate rows to the stringybark species. Not long before the inspection the site had been thinned and pruned to six metres. This plantation was aesthetically pleasing and contained some impressive trees. The stringybark species were growing at a slightly faster rate relative to the *P. radiata*. In Peter's experience this is not unusual in the Northland region. The form of most trees was excellent. It was noted that the crown shapes of the stringybark and the pine complimented each other. The rounder shape of the pine fitting in nicely with the triangular shaped eucalypt crown. This crown configuration appeared to stimulate more dominant leader development and smaller side branching in the stringybarks. The growth and form of the *P. radiata* did not appear to be disadvantaged by being planted in alternate rows with the stringybarks.

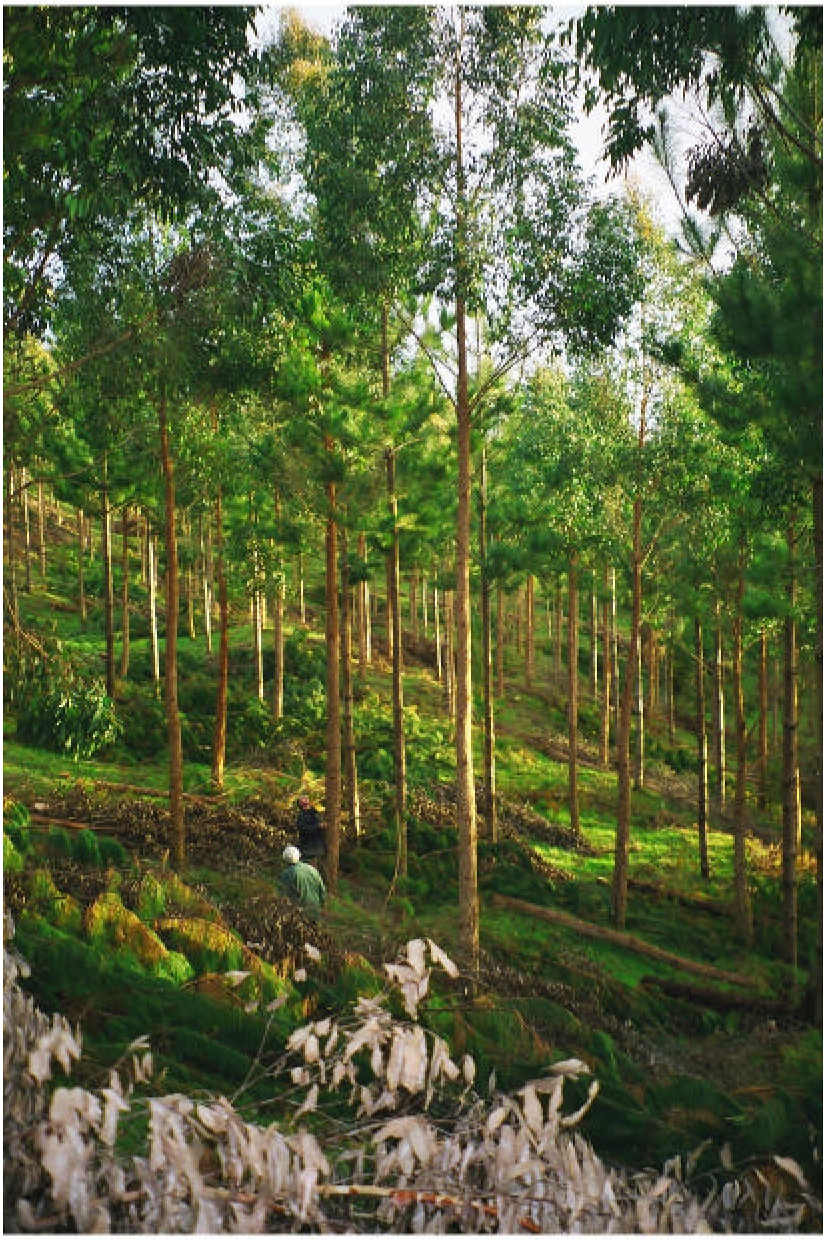

Figure 13. Mixed plantation of *E. muelleriana* and *P. radiata*

The final stop was at CBM Sawmills Ltd., where ~10,000 tonne of eucalypt logs per year were processed. Campbell Moore (the owner of the mill) indicated that he had difficulty in differentiating between *E. pilularis*, *E. globoidea* and *E. muelleriana* logs. He was of the opinion that they had similar sawing properties. Richard Davies Colley stated *E. globoidea* (relative to *E. muelleriana*) mixed in much better with *E. pilularis* colour wise.

Figure 14. Richard Davies-Colley (left) and Ian Nicholas (right) identifying *E. muelleriana* and *E. pilularis* logs in the CBM Sawmills log yard. Yellow log ends are *E. muelleriana*. Note the greater end splitting in the grey *E. pilularis* log ends.

Kerry McGee's property near Warkworth

Around 1950 the previous owner of the McGee property established a mixture of overstorey, middlestorey and understorey trees on what was classified as the least fertile part of the farm (by Kerry). None of the plantings were fertilized (Kerry McGee pers. comm. 2002). The planting grew so well that after a number of years the stand was so thick with foliage from top to bottom that "you couldn't see through it" (Kerry McGee pers. comm. 2002). Eventually the understorey and middle story species were removed from the stand leaving behind a range of eucalypt species (including *E. muelleriana*) with excellent form.

The *E. muelleriana* trees averaged ~75.9cm dbh and total tree height averaged 38.1 metres. The outstanding feature of these trees was their form. The merchantable sawlog length averaged ~ 70% of the total tree height (Figure 14). The presence of *Juncus* spp would indicate that the site was subject to seasonal waterlogging.

Figure 14. *E. muelleriana* (foreground)[14] planted on Kerry McGee's property near Warkworth.

Compared to *E. saligna* on the same site, the *E. muelleriana* trees were larger and possessed fuller and more healthy crowns. Repeated insect attack had reduced the growth of *E. saligna*.

Tairua Forest

In 1960 five eucalypt species were planted in a trial on a failed *Pinus* site in the Tairua forest near Whangamata. The heavy clay soils in the Tairua forest are known for being phosphorus deficient. The foliage of the *P. radiata* in the area reflected this. This eucalypt plantation was thinned in 1979.

Similar to the McGee site, the growth and form of the *E. muelleriana* was outstanding. The merchantable sawlog length averaged ~ 75% of the total tree height. Dbh averaged ~76.2cm and total tree height averaged 40.1 metres.

[14] Trees with sparse crowns in the background are *E. saligna*.

Figure 15. Ian Nicholas with *E. muelleriana* planted in Tairua Forest.

Gourley's property near Tauranga

This was the second of the two 'Durable Hardwood Species" trial sites[15]. All of the eucalypt species planted in this trial were severely damaged by frost. The *E. pilularis* and *E. microcorys* sites were abandoned whilst the two stringybark species – *E. muelleriana* and *E. globoidea* continue to be measured despite the survival being reduced to 50% or less the year after planting (1994). Similar to the previous "Durable Species" trial site, the *E. globoidea* were again slightly more frost tolerant than *E. muelleriana*.

Whilst the growth of some of the remaining trees was generally good, the form and survival across all three plots was poor. Hay and McKenzie (2002 unpub.) calculated the average survival to be approximately 30% in March 2002. The crown length of the stringybarks was short relative to *E. muelleriana* of comparable age on sites previously inspected.

[15] The first 'Durable Hardwood Species" trial site was on the Davies-Colley property.

Meeting with Forest Research staff

On the 30 May 2002, I met with a selection of Forest Research staff that had some experience working with *E. muelleriana*. My first meeting was with Tony Shelbourne and Ruth McConnochie. Tony has played a major role in the appraisal of stringybark species[16] in New Zealand during the last few years. Ruth is leading an effort to implement growth and yield trials of eucalypt species with solid wood end-use potential in New Zealand. The "stringybark" group comprise the majority of species being tested in these trials. A concerted effort is being made to seek international input and support to establish these trials in an effort to optimise the outcomes for both New Zealand and other collaborators.

Both Tony and Ruth were enthusiastic about the prospects of stringybark eucalypts to grow wood suitable for high quality solid timber products. To investigate the value potential of developing a stringybark plantation resource in 2003/04 the Forest Research are planning to conduct a sawing trial that evaluates the performance of three stringybark eucalypts including *E. muelleriana*.

Tony is particularly keen to evaluate the prospects of *E. laeovpinea* more thoroughly, because he believes it has the attributes to be a successful plantation species for solid wood production on a relatively wide range of sites in New Zealand.

The second meeting was with Russell McKinley who has worked on a range of wood quality aspects of a range of species in New Zealand, including *E. muelleriana*. He supplied me with another data point to add to the whole tree basic density curve that was included in McKinley (et al. 2000).

The final meeting was with Ian Nicholas and Errol Hay who has co-authored several eucalypt species reports and assisted the establishment and monitoring of several trials and farm forestry plantings, which have included *E. muelleriana*. From a form, growth and frost resistance perspective Errol believed that *E. globoidea* had been a superior plantation performer compared to *E. muelleriana* in New Zealand.

Meeting with Timber Specialists Ltd. – Chris Wiffen

On the 31 May 2002, I met with Chris Wiffen of Timber Specialists Ltd. (TS) to discuss the potential of solid wood production attributes and marketing of stringybark timbers in New Zealand.

TS are importers, exporters and wholesalers of timber. They purchase their New Zealand grown eucalypt timbers at the green sawn stage from the two major eucalypt mills in the Northland region (Dennis Budd's sawmill and CBM Sawmills Pty. Ltd.). They dry and further process the timber to sell into flooring and joinery markets.

Of the New Zealand grown eucalypt timbers TS predominantly purchase green sawn *E. saligna*, *E. botryoides* and *E. pilularis* from the Northland region. *E. saligna* and *E. botryoides* are marketed as "Saligna". *E. pilularis* is marketed as "Pillularis". TS stocks of "Pillularis" appeared to also contain small quantities of *E. muelleriana*.

According to Chris, the majority of sawn eucalypts received by TS comes from logs that are approximately 60 years of age. Whilst Chris acknowledged that he is not a wood technologist, he was sceptical about the prospects of sawn timber production from eucalypts less than 40 years of age.

[16] "Stringybarks" are defined as a distinctive, closely-related group of eucalypts with rough, persistent, long fibred bark.

TS prefer their intake of New Zealand grown eucalypt timber to be quarter sawn because they lose less timber to waste during the drying and machining stages. TS finds wider boards easier to market, compared to narrow boards (3'-4' x 1') commonly used for flooring.

Chris has high expectations for eucalypts in the future development of TS. He views the joinery and furniture markets for durable eucalypt species as "lucrative" with very good profit margins. Chris regarded the flooring market as a commodity market synonymous with low margins for TS. He views durable eucalypt species as having a significant advantage over non-durable species such as ash type eucalypts, because of their superior durability, strength and hardness. These three properties are particularly important when considering New Zealand's building regulations for timber life in certain applications.

Dennis Budd, Sawmiller in Northland

Unfortunately I was unable to meet Dennis and inspect his mill. TS rate Dennis as the best eucalypt sawmiller in Northland. Dennis processes approximately 5000m^3 of eucalypt logs per year and is a major supplier of green sawn timber to TS. The principal species sawn by Dennis are *E. saligna* and *E. botryoides*. He also receives small quantities of *E. pilularis* and *E. muelleriana*.

The log specifications for Dennis's mill are as follows:

- Log length – 3.0 to 3.7 metres. Logs are preferred in these short lengths because of the large distortion commonly experienced for *E. saligna* and *E. botryoides* species during sawing;
- SED – 40cm.

According to Dennis where *E. saligna* and *E. botryoides* logs meet these specifications the average green sawn recovery is ~ 35%.

Early in 2002 he processed a 600 tonne parcel of 50 to 55 year-old *E. muelleriana* plantation logs that were grown on a site not far north of Auckland. When Dennis received the logs he remembered being initially disappointed because they were 6.0 to 6.1 metres long, which was substantially longer than his specification. Nonetheless he processed the logs in their delivered lengths and was surprised to observe that there was minimal distortion off the saw throughout the entire sawing process which included both backsawn and quartersawn sawing methods (Dennis Budd pers. comm. 2002). Dennis also noted that the defective zone of core wood in the *E. muelleriana* was much smaller compared to that of *E. saligna* and *E. botryoides*. For a eucalypt species Dennis stated that "muelleriana is the best species to saw. Much better than pilularis". Relating the strong attributes of *E. muelleriana* back to his specifications Dennis stated the following:

"I could reduce the mill SED specification and increase the log length specification for *muelleriana* and still expect similar recoveries to the saligna and botryoides cut at my original spec".

<u>*Summary*</u>

The inspection of several plantation sites, and discussions with growers, processors, Forest Research staff and a wholesaler of plantation grown hardwood timber highlighted the following features of *E. muelleriana* in New Zealand:

- Trialed more extensively in New Zealand as a plantation species option than anywhere else in the world
- The substantial and significant variation between families within provenances indicates that there is a large scope to select families for superior silvicultural and wood property characteristics
- The distribution, frequency and severity of frost events is a vital consideration to successfully establish the species. Where mean average temperatures are <= 13-14^{o}C in New Zealand *E.*

muelleriana needs to be sited away from frost prone areas. Alternatively less frost sensitive species such as *E. globoidea* or *E. laevopinea* could be considered for these sites

- Trials indicate that *E. muelleriana* is less frost sensitive than *E. pilularis* and *E. microcorys*
- The form (regarding sweep and forking defects) improves significantly on less fertile sites (e.g. ex-pine, pasture sites with poor fertilizer history) relative to fertile ex-pasture sites. To successfully establish *E. muelleriana* for sawn timber production on fertile pasture sites, a tree improvement program would be required to identify families/provenances that perform satisfactorily in the conditions. Alternative approaches to be considered include:

    - Establishing at higher stockings to enable more aggressive selection
    - Establishing species better suited to fertile soils

- Capable of fast growth (faster than *E. pilularis*) on a wide range of sites providing site and climatic requirements are met;
- Can grow well on wet sites, providing soils are not waterlogged for extended periods.
- Can exhibit good form at wide spacings on protected infertile sites;
- Can produce large quantities of wood suitable for high value backsawn and quarter sawn products in <=30yrs;
- Grows well in plantations of mixed species (e.g. with pine and understorey species)
- Plantation grown *E. muelleriana* has the capacity to produce high recoveries of good quality sawn timber suitable for flooring and furniture products;
- Has a relatively small defect core which contributes to high % sawn recovery;
- During drying back-sawn boards are more likely to check than quarter sawn boards;
- FR and industry regard durable timbers as having an expanding market niche in the long term;
- Durable timbers are valued by the market not only for their exterior durability but also for features commonly related to durability i.e. strength and hardness;
- Has better sawing properties than *E. saligna* and *E. botryoides*. For a given volume of wood *E. muelleriana* usually provides higher green sawn recoveries than these species.

Australia - Southeast NSW and East Gippsland

On the 6-9 August 2002 a range of processors and *E. muelleriana* plantation sites in southeast NSW and EAST Gippsland were inspected. Following is an account of these visits.

Blue Ridge Hardwoods (BRH) – Eden, NSW

The BRH mill at Eden processes approximately 35,000 m^3 of sawlog per year. This is comprised of an intake quota of 24,000m^3 of sawlog per year and an additional 11,000m^3 per year of "Z class" wood[17], which they apply for through a tendering process. The large majority of this sawlog (>95%) is harvested from native state forest. Wood from Victorian based BRH mills is dried at Eden. It is understood that BRH are largest processor of *E. muelleriana* in Australia.

In years gone by, 50% of the BRH quota was composed of *E. muelleriana*. However the recent formation of new parks has in the words of the BRH mill manager "regrettably" reduced the intake of *E. muelleriana* to 20%. The shortfall in *E. muelleriana* has been replaced with an increased proportion of *E. sieberi* which is now the major species processed by BRH in Eden (50-60%).

The majority (100m^3/month) of the green *E. muelleriana* sawn timber produced by Blue Ridge is sold under a long-term supply agreement to North Eden Timbers P/L (NET) located at Pambula. NET dry and further process *E. muelleriana* into flooring and furniture products. BRH further process and sell the remaining *E. muelleriana* sawn timber as decking, posts, green structural and bridge timbers. BRH have a high regard for *E. muelleriana* because its durability, strength, predictable sawing characteristics and colour make it a versatile timber species suited to the production of several products.

Figure 16. A pack of green sawn *E. muelleriana* ready to be taken to NET

Whilst the sapwood of *E. muelleriana* is resistant to attack by the lyctid borer (*Lyctus brunei*) BRH regard this as being only a minor advantage to their operation because no sapwood is permitted to

[17] Equivalent to "D-grade" wood in Victoria

be a component of exported or imported eucalypt sawn products in NSW. Nonetheless Michael Beavan (the timber-drying manager at BRH) indicated that lyctid borer resistance, may be regarded as more of an advantage as processors focus more attention on increasing sawn recoveries from smaller logs harvested from native forest. If the sapwood of *E. muelleriana* was included in sawn timber, recoveries are estimated to improve by 1-2% (Michael Beavan pers. comm. 2002).

The processing manager at BRH - Noel Hall regards *E. muelleriana* as the best timber species sawn at BRH for the following reasons:

a. Smaller logs (<40cm SED) typically demonstrate less distortion[18] during sawing. This facilitates higher green recoveries than produced from other species sawn by BRH[19]. As logs of all species get bigger (>40cm) the difference between *E. muelleriana* and other species becomes smaller
b. Smaller *E. muelleriana* logs can be sawn for merchantable timber closer to the heart than all other species sawn by BRH;
c. Compared to most durable species *E. muelleriana* produces a clean timber that suffers less from gum vein and line borer (associated with ambrosia fungus);
d. *E. muelleriana* is an easy and forgiving log to handle relative to species with straight free grain such as *E. sieberi. E. sieberi* logs can shear apart if dropped by the loader.

Noel Hall also mentioned that old *E. muelleriana* logs (usually large >1m dbh) commonly demonstrate larger pipe and "bardi grub" related defects compared to other species sawn in the southeast NSW region. Noel suspects this to be strongly correlated with the preferred sites for the species which are lower slope / riparian areas. Rot is generally more commonly associated with these positions compared to dryer upper slope locations.

Figure 17. Noel Hall with a large *E. muelleriana* log exhibiting pipe.

BRH have developed a modern and sophisticated kiln drying facility. They use a pre-drying kiln, a de-humidifier to recondition timber and a final drying kiln. All kilns are computer operated and the

[18] Spring in quarter sawn boards and bow in backsawn boards
[19] Other species sawn at BRH include *E. sieberi*, *E. globoidea*, *E. agglomerata*, *E. regnans*, *E. delegatensis* and *E. cypellocarpa*.

results electronically tracked and recorded. Michael Beavan likes the drying properties of *E. muelleriana* and has found that radial and tangential shrinkage Figures included in the publication – "Wood in Australia" (Bootle 1983) are an excellent guide to the drying behaviour of *E. muelleriana* logs produced from native forest. Michael favours drying properties of *E. muelleriana* because he has found it to:

- Has a low shrinkage rate
- Suffers from minimal collapse
- Predominantly straight grained
- Predictable, forgiving timber that can tolerate more variation in drying schedules (particularly in relation to temperature) than ash and gum species
- Demonstrate comparatively low levels of drying degrade

BRH have experienced *E. muelleriana* to be slower and therefore more expensive to dry than ash species. However, this is largely compensated for by the lower levels of drying degrade in *E. muelleriana* (<2%) relative to Ash species[20] (~10%) and the more valuable F27 (Ash – F17) product (Michael Beavan pers. comm. 2002). Following is a general description of a regime commonly used by BRH when drying *E. muelleriana*:

a. Pre-drying – racked packs are placed in the pre-drier seven days after cutting. Temperature starts at 30^{o}C and are progressively increased to ~50^{o}C over a 60 day period. Michael believes *E. muelleriana* could tolerate temperatures starting at 40^{o}C which would shorten the existing pre-drying treatment;
b. Following pre-drying the timber is reconditioned for 6-8 hours with pure steam;
c. After reconditioning, the final drying phase usually takes six days. Temperatures of ~ 70^{o}C are applied during this period;
d. The duration of the entire *E. muelleriana* drying schedule is 67-70 days.

When asked about the vulnerability of *E. muelleriana* to surface checking, Michael stated that it was not regarded as a problem by BRH. However, he stated that *E. muelleriana* can check if an inappropriate drying schedule is used. To prevent checking in *E. muelleriana* it is critical that the timber is subject to controlled conditions immediately after sawing. Leaving green sawn *E. muelleriana* timber in the sun for only a few hours can begin the checking process. Drying defects in *E. muelleriana* can be controlled for the most part by preventing the exposure of green sawn *E. muelleriana* timber to direct sun and hot winds (e.g. store in shed under hessian) and using a three stage drying process –1) Pre-drier, 2) Reconditioner and 3) Final drying.

E. muelleriana is a preferred species for drying at BRH because its good drying properties combined with the controlled drying facility and procedures at BRH, lead to the reliable production of a timber that can be used for a wide variety of end uses. Despite their controlled environment and specifically tailored drying schedules, BRH find that many other species including *E. nitens* and *E. dalrympleana* continually suffer from high levels of drying degrade, which increases production time and restricts the range of final end uses.

North Eden Timber Pty. Ltd. – Pambula, NSW

NET produce flooring and furniture products predominantly using timber produced from *E. muelleriana* grown in native forest. After BRH, NET are the second largest timber industry employer in the Eden forest district, employing 25 people at their two production facilities at Pambula and Manna Park. Both backsawn and quartersawn *E. muelleriana* boards are purchased from BRH. NET has not processed any plantation grown *E. muelleriana*. At the Pambula plant, they dry all the timber they receive from BRH and further process it into flooring, decking and

[20] Ash species includes *E. regnans* and *E. delegatensis*.

cladding products. Any flooring sections that are >=0.9m in length are transferred to Manna Park where they are used to produce bedroom furniture products.

E. muelleriana is the preferred species for NET because its wood possesses ideal colour, texture and durability properties for use in flooring and furniture products (Simon Greenaway pers. comm. 2002). Whilst the natural light colour of the wood is attractive, the timber also responds well to darker stains and finishes which give the final product more versatility.

Figure 18. Natural colour *E. muelleriana* timber product

Figure 19. Stained *E. muelleriana* timber product

The golden honey brown colour, combined with the fine to medium even texture of the timber is proving to be particularly popular in the Sydney and Melbourne flooring and bedroom furniture markets. At the time of the visit to NET (Aug 02), the demand for both their flooring and furniture products was increasing substantially. NET's wood products are sold exclusively through architects, builders and the bedroom furniture chains "40 Winks" and "Sleepdoctor". NET does not sell its flooring products through wholesalers (i.e. Bunnings, Mitre 10 etc.) because they receive a better price from other markets.

To ensure uniformity of product and also to maximise production efficiencies, NET commissioned a project whereby *E. muelleriana* sawlogs could be more accurately identified in the field. This resulted in minimising the mixing of *E. muelleriana* log loads with *E. globoidea* and *E. agglomerata*. The project has proved to be very successful, providing NET with a uniform single species resource that gives them greater confidence in the manufacturing and marketing of their products.

Green sawn timber is received from BRH 26mm thick. NET air-dry the timber in protected stacks for 6-8 months; down to ~20% moisture content. Following air-drying, the timber is dried for approximately three weeks down to 11-12% moisture content using automatically controlled solar powered kilns. The gentle drying schedule which uses relatively low temperatures, generates a seasoned product with very low levels of drying degrade. Hence NET has no need to recondition their timber. Throughout the drying and processing process each piece of timber is individually tracked using a customised computer system.

NET has not had any major problems with surface checking of *E. muelleriana* in quarter or backsawn boards. They attribute this to their controlled low temperature-drying environment. Surface checking is not regarded as a real issue (Simon Greenaway pers. comm. 2002). In fact NET regards *E. muelleriana* as being easier to dry than other Stringybark species (i.e. *E. globoidea* and *E. agglomerata*) (Simon Greenaway pers. comm. 2002).

After kiln drying, the timber is machined to a thickness of 19mm for flooring applications. NET produces three grades of flooring based on appearance. The timber is graded as follows:

- High grade – clear wood with even colour and no defect;
- Intermediate – predominantly clearwood with small amount of defect;
- Low grade – equivalent to natural feature grade in Victoria. This grade has some gum, knot and line borer defect.

Figure 20. Low, intermediate and high grade packs of *E. muelleriana* flooring product

The high and intermediate flooring timber grades are subject to substantially higher demand than the low grade.

All off cuts >=0.9m (in length) generated during the manufacturing of the flooring product is machined further to a thickness of 15mm, prior to being used in the manufacture of furniture products.

NET has found *E. muelleriana* to have excellent planing and finishing properties. Dried *E. muelleriana* timber can be bent, glued and stained very successfully (Figure 21 and 22). The timber can be nailed or screwed easily. NET have found the majority of the machining, gluing and finishing guidelines stipulated in the Yellow Stringybark User Manual prepared by the CSIRO and the TPC in 1999[21] to have been a good basis from which to develop their production prescriptions.

Figure 21. Bedside chest of drawers made from *E. muelleriana*

[21] Ozarka, B. et. al. (1999). The use of Australian hardwoods for high value-added wood products – Yellow Stringybark, User Manual. CSIRO client report No. 559.

Figure 22. Example of bending *E. muelleriana* in furniture applications

The only problem NET has found with *E. muelleriana* has been the inclination of some dried pieces to absorb moisture from separator sticks ("stick shadow") prior to being machined into the finished flooring product. At the time of the inspection, NET were still working on ways to overcome this problem. They had found that the best way to minimise "stick shadow" was to convert the fully dried timber into the final product as quickly as possible. The timber is then triple wrapped to prevent moisture uptake.

Whilst NET had not processed any plantation grown *E. muelleriana* they are supportive of its development as a plantation species. The likelihood of *E. muelleriana* plantation timber being less dense than wood grown in native forest was regarded as being a potential advantage in reducing wear and maintenance on machines and tools used to further process the timber (Simon Greenaway pers. comm. 2002).

South East NSW Private Forestry – Bega, NSW

South East NSW Private Forestry (SE NSW PF) is a Regional Plantation Committee (RPC) established to encourage the development of a commercially viable and ecologically sustainable regional private forestry industry[22]. In their region SE NSW PF primarily recommend four species for plantation establishment; *E. botryoides, E. saligna, Pinus radiata* and *E. muelleriana* (Louise Maud[23] pers. comm. 2002). *Acacia dealbata* and *A. implexa* are also being trialed as high value plantation species options.

SE NSW PF believes that *E. muelleriana* is a good species option on harsh sites that are unsuitable for *E. botryoides* and *E. saligna*. Local trials indicate that *E. muelleriana* is slower growing than *E. botryoides* and *E. saligna*. This slower growth may be compensated for by the production of better quality timber at harvest (Treescene – Infosheet 13).

In this region the form of *E. muelleriana* has been variable. Hence it is recommended that surplus trees should be planted to allow for severe thinning to ensure an adequate population of good

[22] Taken from South East NSW Private Forestry website www.privateforestry.com
[23] Louise Maud is the Executive Officer with SE NSW PF.

quality trees (Treescene – Infosheet 13). Early form pruning to remove excessive branching is also recommended (Treescene – Infosheet 13).

During 2002, SE NSW PF commissioned a trial to determine the relative stiffness and strength in bending of small diameter poles produced from 3 to 5 year-old *E. botryoides, E. cypellocarpa, E. muelleriana, E. nitens* and *E. saligna* plantation thinnings. A sample of small-diameter *P. radiata* poles was also supplied for comparative purposes. This trial was conducted to assess the potential of thinnings from young eucalypt plantations for use in rural fencing. All poles were CCA- treated.

The mean modulus of elasticity (MOE)[24] and modulus of rupture (MOR)[25] values determined for each of the supplied samples are given in table 4:

Table 4. Strength and stiffness values for the tested species (Warden 2002 unpub)

Species	MOE (GPa)	MOR (MPa)
E. cypellocarpa	6.8	88
E. botryoides	6.6	78
E. muelleriana	6.1	74
E. nitens	6.0	75
E. saligna	5.9	65
P. radiata	4.2	44

Within the eucalypt species, none of the differences in the stiffness or strength values were statistically significant (Warden 2002 unpub). Compared to *P. radiata*, only *E. cypellocarpa* was significantly (statistically) stiffer (see MOE figures). With the exception of *E. saligna*, all the eucalypts were significantly stronger than *P. radiata* (Warden 2002 unpub.). The reliability of these values as estimates of the true species means was limited by the small sample sizes (five poles per species). A more extensive mechanical test program would be required to reliably estimate the true property means and differentiate between the performances of the species examined (Warden 2002 unpub). Nonetheless, the results indicated that most of the tested eucalypt species (including *E. muelleriana*) demonstrated a significant strength advantage over the same sized pine post.

Interestingly the CCA penetrated into the core of all the hardwood posts except the large diameter *E. muelleriana* (~90mm diameter), but even this was within industry standards (Louise Maud pers. comm. 2002). This indicates that the large diameter *E. muelleriana* at 3-5 years of age had formed more heartwood than the other species tested.

In Victoria, hardwood posts for fencing are becoming increasingly difficult to obtain (Danny Ryan[26] pers. comm.). This combined with a gradual but definite worldwide shift away from the use of CCA preservatives for exterior wood products (Chris McEvoy, Preschem pers. comm. 2002) suggests that the market for posts and poles from plantation grown durable species will expand, providing the resource is available to supply the demand.

1992 NRE Species/Provenance trial series. – East Gippsland, Vic.

In 1992 four species/provenance trials were established in East Gippsland by NRE. Two Victorian provenances of *E. muelleriana* – Hartland and Maramingo were included in these trials. This trial series was established to:

[24] MOE is a measure of timber stiffness and resistance to deflection.
[25] MOR is a measure of the ultimate short term load carrying capacity of a beam when the load is applied slowly (Bootle 1983)
[26] Danny Ryan is a fencing contractor based in Lancefield, Victoria

- Assist in making site specific recommendations for planting species and provenances;
- Identify provenances for further tree breeding work.

The trials at these sites have not been assessed since they were established (Tom Baker, Forest Science Centre, pers. comm. 2002).

Table 5. summarises the main details of these trials:

Table 5. 1992 East Gippsland Trial Series summary (Ryan et. al. 1992)

Location	Year Established	No. of Provenances	No. of Replicates	MAR (mm/yr)	Geology	Soils	Altitude
West Bemm	1992	2	5	1000	Sedimentary	Duplex	80m
Kuark	1992	2	4	1200	Metamorphosed sedimentary rock	Duplex	460m
Loongelaat	1992	2	4	900	Sedimentary located near granitic interface	Gradational sandy clay loam	240m
Tamboon	1992	2	5	1000	Granite	Yellow duplex soil with high course sand content	160m

Mark Lutze a Research Officer with the Forest Science Centre in Orbost showed me the West Bemm site on the 8 August 2002. Unfortunately we did not have access to a map and therefore it was difficult to make any meaningful conclusions about the growth performance of the *E. muelleriana*. Nonetheless observations indicated that measurement and data analysis of all four of these sites would produce useful growth data for a wide range of species (~18 species, 47 seedlots) including *E. muelleriana*. This data could potentially be an invaluable addition to the existing *E. muelleriana* dataset given the range of site types (altitude, soils, rainfall, temp) established. Regrettably there was not enough time to conduct inventory at any of these sites.

Waygara (or Painted Line) Eucalypt Trial

This trial was established in 1989 and was planted with 56 seedlots representing 19 eucalypt species, in 24 tree plots (Duncan et. al. 2000). Table 6 summarises the site details of this trial.

Table 6. Waygara trial summary (Duncan et. al. 2000)

Location	Year Established	No. of *E. muelleriana* provenances	No. of Replicates	MAR (mm/yr)	Geology	Soils	Altitude
Painted Line Track, Waygara	1989	4[27]	5	870	Sedimentary	Duplex. Sandy clay loam over medium clay	80

Prior to establishment this site was occupied by native forest affected by *Phytophthora cinnamomi* dieback (Ryan et. al 1992). In an attempt to negate the effect of *Phytophthora cinnamomi*, 50 grams of the fungicide "Ridomil" was applied to both *E. sieberi*[28] and *E. muelleriana* seedlings either at planting or during the week following planting.

[27] The 4 provenances were APP seedlots from Yarram, Curlip, Hartland and Mararmingo (Duncan et. al. 2000).
[28] Like *E. muelleriana, E. sieberi* is classed as being moderately susceptible to *Phytophthora cinnamomi* .

This trial was assessed at age 10 and the stem volume m^3/ha data was presented in Duncan (et al. 2000). All four of the *E. muelleriana* provenances were ranked in the bottom 28 seedlots for stem volume per ha production at age 10 (ranked 29, 34, 42 & 51). During the inspection of the *E. muelleriana* replicates at age 13 it was apparent that the form of the *E. muelleriana* was also poor (Figure 23).

Figure 23. A typical *E. muelleriana* replicate at Waygara

The most interesting facet of this trial was the contrasting performance of the *E. muelleriana* planted in 1990, adjacent to replicates 4 and 5 on the western and southern boundaries of the trial. As shown by Figures 24 and 25 the form and growth of these trees was excellent and comparable to some of the better-performed species/seedlots within the trial. The 'ash-bed" effect of the burnt windrows on the perimeter of these areas is likely to have contributed to the improved performance of some of the trees in these areas (Mark Lutze pers. comm. 2002). However, a large proportion of these better trees were planted ~ 50 metres from the windrows, indicating that other factors (e.g. provenance, establishment techniques etc) are contributing to the improved performance of these trees.

Figure 24. Buffer rows of *E. muelleriana* at Waygara

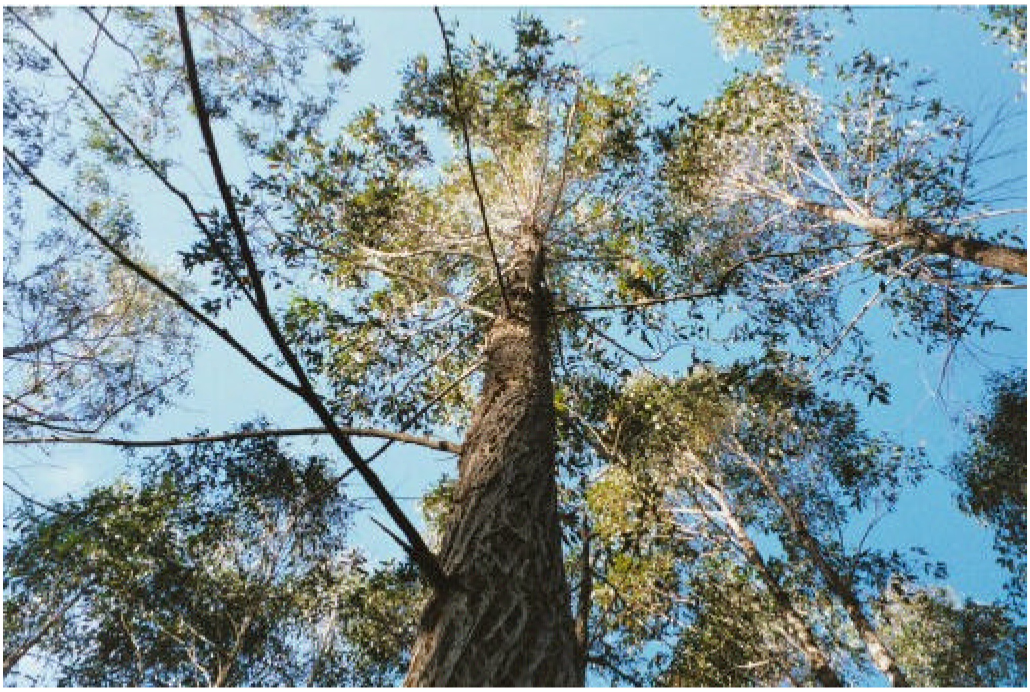

Figure 25. An individual *E. muelleriana* tree in the buffer rows at Waygara

Tostaree eucalypt trials

E. muelleriana is included in two plantings in the Tostaree eucalypt trial site located near Nowa Nowa in East Gippsland. In 1991 it was included in a species x provenance trial (Ta2) and in 1992 it was planted as a buffer on the west side of some *E. globulus* trials (Tf2/Tp4). The 1991 species provenance trials have not been assessed since establishment (Tom Baker pers. comm. 2002).

During my brief inspection on the 8 August 2002, a small sample[29] of *E. muelleriana* in the Ta2 trial were measured and averaged 16 metres in height and 20-23 cm in dbh.

Terra Timbers Pty. Ltd.

Terra Timbers Pty. Ltd. (TT) is comprised of seven individual sawmillers who have combined to develop, manufacture and export kiln dried, machine engineered products manufactured from timbers native to EAST Gippsland. In April 2002, TT formally opened their new 3.2 million dollar drying facility near Bairnsdale. At this stage the large majority of the TT wood intake is composed of *E. sieberi, E. obliqua, E. fastigata, E. viminalis* and *E. delegatensis* (Paul Harris pers. comm. 2002). Of these species only *E. sieberi* is rated as "durable" for exterior use[30]. With the exception of *E. sieberi* the durability rating of the timber produced from these species[31] makes them unsuitable for exterior uses such as cladding, decking and outdoor furniture products. It is expected that the market for durable eucalypt species such as *E. muelleriana* (rating 2) will grow in coming years (Bruce Bell pers. comm. 2002), mainly due to the following:

- Replacement of imported rainforest species products;
- A gradual "move outside" by the Australian public resulting in a move back to more traditional building styles including outdoor decking and cladding (Paul Harris pers. comm. 2002).

Terra Timbers already report a steady increase in enquiry for durable timbers during the latter half of 2002, particularly in regard to decking, cladding and to a lesser extent outdoor furniture product (Paul Harris pers. comm. 2002). Currently it is difficult to meet the increasing demand for this product because the supply of durable species from Gippsland is too inconsistent[32].

Staff from TT were unable to definitively comment on the utilisation properties of *E. muelleriana*, however, they were enthusiastic about the market prospects of the species particularly in regards to the development of durable timber markets, similar to TS and FR.

Red Gum Plains Demonstration Sites near Bairnsdale

In 1999 Gippsland Farm plantations Inc (GFP) established 27 ha of farm forestry trials on five properties located between Stratford and Bairnsdale. On four of the properties identical trials were established on both clay and deep sand soil types. *E. muelleriana* was one of the 31 species were established in the trials.

At the "Gracemere" property owned by Rick and Jenny Robertson, eight hectares of "Best Bet Management"[33] trials were established on two sites (one sand and one clay). During the site inspection in August 2002 each of the nine species planted on each site were qualitatively ranked[34] using growth rate, form and health as the principal criteria. The higher the ranking the more successful the species. The rankings are shown in Table 7.

---

[29] 3 dominant and sub-dominant trees were selected
[30] E. sieberi is rated 2 for natural durability for exterior above ground uses (Standards Australia 2002 draft)
[31] The other species are all rated 3 for natural durability for exterior above ground uses (Standards Australia 2002 draft)
[32] Inconsistent - the supply of wood from durable timber species harvested from NRE managed native forest, fluctuates too much for firm supply contracts to be committed to by TT.
[33] "Best Bet Management" trials were established to trial a range of management techniques that may be considered to produce sawlogs on low rainfall sites.
[34] Ranked by the author.

Table 7. Species performance rankings at Gracemere at 35 months

Sand		Clay	
Ranking	**Species**	**Ranking**	**Species**
1	*Acacia mearnsii*	1	*Acacia mearnsii*
2	*Eucalyptus botyroides*	2	*Eucalyptus botyroides*
3	*E. grandis*	3	*E. grandis*
4	*E. muelleriana*	4	*E. muelleriana*
5	*E. globulus*	5	*E. globulus*
6	*Pinus radiata*	6	*E. cladocalyx*
7	*Corymbia maculata*	7	*Corymbia maculata*
8	*E. tereticornis*	8	*Pinus radiata*
9	*E. cladocalyx*	9	*E. tereticornis*

At the time of the inspection (Aug 02) the *E. muelleriana* planted on the sand site were performing better than those planted on the clay site. Dominant and sub dominant *E. muelleriana* on the sand site were ~4 to 5.5 metres tall on the sand site, with dbh ranging between 5 to 10cm. Whereas the same categories of *E. muelleriana* on the clay site were 3 to 5 metres tall with similar dbh measurements. It was noticeable that the form of the *E. muelleriana* improved markedly as shelter from nearby trees and/or topography increased.

Perhaps the most significant observation was the difference in performance between the Won Wron and Orbost provenances. The replicates containing the Won Wron provenance (reps 4 and 8) demonstrated significantly higher survival and better form (straighter and finer branching) than replicates containing the Orbost provenance on both soil types. The Won Wron provenance trees also had smaller and narrower leaves than the Orbost provenance. A similar observation was made by Shelbourne et al. 2000. In this study a crown health score was calculated based on the density of the crown. Shelbourne et al. 2000 reported that the Yarram provenance of *E. muelleriana* had significantly lower crown density's than both the Bruthen and Cann River provenances. The NSW provenances (Mount Kembla, Batemans Bay and Narooma) and eastern most Victorian provenance (Genoa) all had higher crown density scores than the three previously described Victorian provenances. Shelbourne et al. 2000 indicates that crown density was closely correlated with leaf size and concluded that the differences in crown health may reflect a regional trend in leaf size rather than health.

Figure 26. The Orbost provenance *E. muelleriana* at 35 months

Figure 27. The Won Wron provenance *E. muelleriana* at 35 months

At establishment it was noted that the Orbost provenance suffered minor frost damage, whereas no frost damage was observed on the Won Wron *E. muelleriana*. Even at age 3 some small Orbost provenance *E. muelleriana* were obviously being damaged by frost events. *E. cladocalyx* and *Corymbia maculata* were in some places severely damaged by frost events.

Figure 28. Stunted *E. muelleriana* damaged by frost at 35 months of age

Trial sites at the Bairnsdale Aerodrome and on the clay soil type at Andrew and Louise McArthur's property were also inspected. Whilst growth at the aerodrome site was good several of the trees in the western outermost rows were suffering from windthrow. Various eucalypt and acacia species planted in this trial were also affected by windthrow, however, the *E. muelleriana* was one of the worst affected species. Windthrow has also been observed on Brian Joy's 1998 *E. muelleriana* planting at Foster North and some minor cases at Ben Tweddle's 1997 shelterbelt planting. Whilst at Brian Joy's property the windthrow was mainly attributed to ripping in wet conditions, it is clear that windthrow of young trees is an issue on certain soil types. All of the above incidences of windthrow occurred on heavy to medium clay – clay loam soils that were deep ripped.

The growth and survival of *E. muelleriana* at two years of age in the species trial on McArthur's clay site was good. However since this age the *E. muelleriana* has performed poorly. The heavy clay soil type on this site was waterlogged for extended periods when the trees were 24-36 months old. Subsequently the survival in 3 of the 4 replicates was < 50% and is likely to get worse. Clearly *E. muelleriana* is not suited to poorly drained, heavy clay soils. Many other species also appeared to suffering from the effects of waterlogging on this site (i.e. *E. oreades*, *Cupressus lusitanica*).

In January 2003 the "Best Bet Management" trial at "Gracemere" was inspected again. The *E. muelleriana* had grown markedly since the August 2002 inspection, particularly in the protected eastern most replicates of both sites. Dominant and sub-dominant trees ranged between 6-8 metres in height and dbh ranged between 8-13cm for these trees. On the sand site the growth ranking of the *E. muelleriana* had improved to a "3" as it was judged to be superior to *E. grandis* for growth and form. The consistent good growth and form of the *E. botryoides* and *A. mearnsii* across all four replicates (including the more exposed western replicates) on the sand site ensured their higher ranking. On the clay site the species rankings for growth and form remained the same as the August assessment.

Summary

The inspection of sawing and drying facilities, several plantation sites, and discussions with processors, the SE NSW RPC and NRE research staff highlighted the following features of *E. muelleriana* grown in native forest:

- Is a strongly preferred and demanded species by both processors and consumers of wood products in the southeast region of NSW;
- Has excellent sawing characteristics (i.e. stability during processing and easy handling in the log yard);
- The relatively small defect core and low levels of wood distortion during sawing commonly facilitates the higher sawn recoveries particularly in small logs compared to most eucalypts processed in southeast NSW and East Gippsland;
- Produces a clean timber with less downgrading defects (e.g. gum vein, line borer) than other species (e.g. gum species);
- In a controlled processing and drying environment this species has good drying characteristics;
- Slower and more expensive to dry than Ash species. However this is largely compensated for by lower levels of drying degrade and the production of a more valuable product;
- The sapwood is resistant to lyctid borer attack, which could potentially reduce processing and preservation costs. This characteristic may also provide another avenue whereby sawn recoveries from small logs can be improved;
- Both backsawn and quartersawn boards can be easily dried, machined and finished to a high standard for high value products such as flooring and furniture;
- The combination of wood colour, strength and durability characteristics give *E. muelleriana* a strong consumer demand;
- The market for durable timbers is likely to expand in the short and long term;

The inspection of several plantation sites, and discussions with the SE NSW RPC and NRE research staff highlighted the following points of growing *E. muelleriana* in plantations:

- Slower growing than *E. saligna* and *E. botyroides* in south east NSW
- A preliminary study indicates that posts from 3-5 year old *E. muelleriana* have stiffness and significant strength advantages over pine posts
- Several trials established in 1991-92 in East Gippsland that include *E. muelleriana* have not been assessed since establishment and are potentially a valuable source of information on the species
- Better suited to sandy soils compared to heavy clay soils
- Will not tolerate heavy clay soils prone to extended periods of waterlogging
- Performs considerably better on sheltered sites
- Has the capacity to grow rapidly at similar rates to *E. botryoides* on sheltered deep sand sites during the first 40 months
- Substantial differences between Won Wron and Orbost provenances are demonstrated in the RGP farm forestry demonstration trials:

    - The Won Wron provenance demonstrates superior form (i.e. stem straightness and branch size) on both clay and sand soils
    - The Won Wron provenance has much smaller leaves and subsequently less dense crowns at age 40 months compared to the Orbost provenance
    - The Orbost provenance demonstrates a superior growth rate

- *E. muelleriana* appears to have an increased chance of suffering windthrow on heavy to medium clay soils that have been ripped.

Figure 29. ***E. muelleriana* at 42 months of age on the sand site at Gracemere**

Hunter Valley, NSW

On the 20-23 August 2002, Peter Creighton a Harvest Planner with State Forests NSW (SFNSW) took me to a range of *E. muelleriana* plantation sites established during the 1972-78 period in the Hunter Valley region of NSW. The key details of these sites are summarised in Appendix B. Trial establishment generally followed the following schedule:

1. The site to be planted was harvested for wood products;
2. Remaining debris heaped or windrowed and in some cases burnt;
3. Seedlings were hand planted on a grid (e.g. 3mx 3m)
4. On some sites fertiliser was applied

For specific details of site establishment refer to Johnson and Stanton (1993). The establishment procedure employed was basic compared to those used in current establishment programs. No pre or post plant weed control or soil cultivation was performed. Therefore the growth rates are slower than what is regarded satisfactory by most eucalypt plantation managers.

Bulahdelah, Chichester and Watagan trial sites were inspected. Whilst the trials enabled good visual comparisons between species for growth and form, the plots were too small for long-term volume comparisons without buffer rows established between plots and around the trial (Shelbourne 2001 unpub.). To provide an indication of tree dbh and total height, dominant and sub-dominant trees were selected in a spot inventory process. Following is an account of these inspections. Appendix C summarises the site and growth details for all of the trials that included *E. muelleriana*.

Bulahdelah, NSW

These trials were established during the 1972-74 period to determine if *E. pilularis* was the best species to be re-establishing in this area. Nineteen species including *E. muelleriana* were established on four sites in the Bulahdelah region. Of the four trial blocks only site 3 and 4 remained intact. A drought occurred during 1980-81, which resulted in the mortality of many of the trees planted in these trials.

Site 4 was a moist high quality gully site with well-drained loam soil (Johnson and Stanton 1993). The trial was established on a northeast aspect. The survival rate had not changed since 1990[35] and remained at 44%. In 1990 the average survival across the site was 49% (Johnson and Stanton 1993). The diameters of surviving trees varied between 22 and 46cm. Similar to the 1990 data, *E. muelleriana* remained one of the poorer performing species in this trial. It was obvious that the vigorous undergrowth had suppressed some of the *E. muelleriana*. The form of many of the trees was poor and some of the sub-dominant stems had developed epicormic shoots close to occluded branch stubs.

Table 8. Comparison between inventory in 1990 & spot measurements in 2002 for site 3 & 4.

Site	Year measured	DBHOB (cm)	MTH (m)	Comments
4	1990	15.7	17.4	
	Aug 2002	32.4	-	9 trees measured
3	1990	18.5	18.0	
	Aug 2002	27.6	-	11 trees measured

Site 3 is a mid-lower slope site planted on a north aspect. In 1990, *E. muelleriana* was ranked sixth[36] for dbhob (18.5cm) and ninth[37] for mean total height (18.0m). Whilst the height of the *E.*

[35] see Johnson and Stanton (1993)
[36] Ranked 6th out of 19 species.
[37] Ranked 9th out of 19 species.

muelleriana in Aug 2002 had not increased significantly, spot measurements of eleven trees demonstrated a mean dbhob of 27.6cm. The form of the *E. muelleriana* was better on this site relative to site 4. Whilst less prominent, epicormic shoot development was still a factor on this site. *E. agglomerata* was clearly a superior performer on this site in terms of survival, form and growth (photo 2-3 Newcastle CD).

Site 2 was an upper slope site with clay loam soil (Johnson and Stanton 1993). Johnson and Stanton (1993) comment that whilst survival was "mostly poor"[38], *E. agglomerata, E. globoidea. E. muelleriana* and *E. pilularis*[39] showed high ranks for growth. This site could not be located.

Chichester, NSW

The Chichester site is of relatively high site quality with an easterly aspect and a red/yellow podsolic soil (Johnson and Stanton 1993). This site has been measured regularly since it was established in 1973. In 1991 *E. muelleriana* was ranked fifth out of nine species in terms of total volume and MAI.

During the inspection five dominant and sub-dominant trees were measured across the two *E. muelleriana* replicates. Whilst the results of the spot inventory can only be regarded as indicative, it is evident in Table 9. that the *E. muelleriana* have grown significantly since 1991.

Table 9. Comparison between inventory in 1991 and spot measurements in 2002.

Species	Year measured	DBHOB (cm)	MTH (m)	Comments
E. muelleriana	1991	26.7	28.9	
E. muelleriana[40]	Aug 2002	50.1	37.2	5 trees measured

The growth and form of the *E. muelleriana* was excellent on this site. The basal area in the *E. muelleriana* replicates was approximately 30-35m^2/ha. Again there was some epicormic growth however, it was confined to the suppressed trees in the western most replicate. *E. pilularis* and *E. laevopinea* both showed significant epicormic growth.

Given the good measurement history of this block, it would be an ideal source of logs for plantation sawlog processing and drying studies.

[38] survival av eraged 29% at site 2
[39] The surivival for the listed 4 species was 6%,44%, 28% and 22%.
[40] 2002 data based on the measurement of 5 dominant and sub dominant trees

Figure 30. Peter Crichton with *E. muelleriana* at Chichester

Watagan Species Trials

This trial was planted on four sites in 1972. The original vegetation of sites 1-3 was a high quality forest that included *E. saligna*. Site 4 was located on less fertile sandy soil dominated by *E. piperita*.

The growth and form of *E. muelleriana* at site 1 was very impressive. This site was located on a protected lower slope adjacent to a drainage line. The performance of one replicate (northern) was significantly better than the other. This seemed to be the trend for most species on this site.

Table 10. Comparison between inventory in 1990 and spot measurements[41] for site 1, 2 & 4 in 2002.

Site	Year measured	Mean DBHOB (cm)	MTH (m)	BA (m^2/ha)	Comments
1	1990	21.9	30.3		
	Aug 2002	47.9	40.2	55 (north rep)	4 trees measured
2	1991	21.7	25.0		
	Aug 2002	38.1	32.4	64	5 trees measured
4	1990	24.0	18.1		
	Aug 2002	35.8	22 to 33m	39	7 trees measured

In 1990 *E. muelleriana* was ranked second for survival, ninth for mean DBHOB and first for mean height (MTH) (Johnson and Stanton 1993). In 2002, *E. muelleriana* was clearly performing better

[41] Dominant and sub-dominant trees were measured

in terms of growth (BA, DBHOB and MTH) than both *E. agglomerata* and *E. pilularis* which were ranked in front of *E. muelleriana* in 1990.

This data in Table 10 combined with observations shows that the *E. muelleriana* has grown significantly faster than many of its rival durable species during the past 12 years. The moderate early growth rates of *E. muelleriana* may indicate that this species is not as tolerant to competition as other eucalypt species within 15 years of establishment.

Figure 31. *E. muelleriana* at site 1 in the Watagan S.F.

At site 2, the performance of *E. muelleriana* was more consistent across the two replicates. In 1991 *E. muelleriana* was ranked third[42] for survival on this site (Johnson and Stanton 1993). Given the high survival of *E. muelleriana* the trees in both plots have excellent diameter growth. Table 10 lists the comparison between measurements in 1991 and 2002.

The basal area data in particular demonstrates that the *E. muelleriana* has performed very well on this site in terms of volume but also in form (Figure 32). The *E. agglomerata* replicates appeared to contain slightly more wood relative to the *E. muelleriana*.

[42] 3rd out of 17

Figure 32. ***E. muelleriana*** **at site 2 in the Watagan S.F. (Peter Crichton in left photo)**

On site 3, the overall growth performance of *E. muelleriana* was also good. Johnson and Stanton (1993) record *E. muelleriana* as being ranked first[43] for survival on this site (89% in 1990). Unfortunately a small number of trees had been removed from at least one and possibly both plots. The dbh range for dominant and subdominant trees was 32-37cm and the total height range was 33-34 metres. There was some forking above 20 metres. Shelbourne (2001 unpub.) noted during his visit that in site 2 and 3 that the *E. agglomerata, E. pilularis* and *E. muelleriana* were similar in terms of growth and form. He also observed that *E. laevopinea* had less volume per hectare. *C. variegata* had performed poorly on these sites and *E. dunni* showed substantially slower growth than the stringybarks (Shelbourne 2001 unpub).

[43] 1st out of 17

Figure 33. ***E. muelleriana* at site 4 in the Watagan S.F.**

One of the two *E. muelleriana* replicates (north replicate) on site 4 showed good survival (72%) form and growth. Survival (24%) and growth in the other replicate was disappointing. The average survival for this site in 1990 was 42%. The reason for the poor survival and growth in the southern replicate was not apparent.

E. agglomerata demonstrated excellent growth in both replicates on this site.

Of the seventeen species assessed Johnson and Stanton (1993) concluded that *E. agglomerata, E. muelleriana, E. oreades* and *E. pilularis* were the best performing species in the Watagan trials.

After inspections of the trials during 2000 and 2001, Ian Johnson concluded that *E. muelleriana* had performed quite well on the more fertile sites in the Hunter region. He believes *E. muelleriana* together with *E. agglomerata* and *E. laevopinea* have potential for wider planting in the Hunter and South Coast regions managed by State Forests NSW (Ian Johnson pers. comm. 2002). It should be noted that the "more fertile sites" referred to, are ex-native forest sites that have no fertiliser history.

Similar to Chichester, the Watagan species trials offer great and unrivalled opportunities for wood property and utilisation comparisons for a number of species that are not well represented in plantation trials planted in south-eastern Australia. This opportunity was also noted by Shelbourne (2001, unpublished) during his visit to NSW in 2001.

East Boyd Plantation Trial

In 1974 *E. muelleriana* was one of eight eucalypt species established in trial investigating both species suitability and performance at three different stocking rates. This trial was not inspected, however, based on assessment in 1989, Johnson and Stanton (1993) concluded that *E. globoidea* and *E. muelleriana* were the best performing species in this trial for survival and growth at age 15.

<u>Summary</u>

During the inspection of the SFNSW trials the following conclusions were made:

- In terms of relative growth rates and survival *E. muelleriana* performed best in the Watagan and East Boyd trials;
- *E. muelleriana* has adapted and grown well on sites ~ 250km north (Chichester lat 32^{o}14’) of the northern most point of its natural distribution (Wollongong – lat 34^{o})
- In terms of growth *E. agglomerata* outperformed *E. muelleriana* on all of the sites except site 1 of the Watagan trials. This site more than any other resembled a typical *E. muelleriana* site. Nevertheless based on the trial data, the results indicate that on most sites except sheltered lower slope locations *E. agglomerata* is likely to be the better stringybark option in the southeast to central coastal locations of NSW. This was not unexpected given that *E. agglomerata* is indigenous to the Hunter Valley and *E. muelleriana* is north of its natural range
- Observations suggest that to achieve good growth rates on high quality ex-forest sites it is critical that competition within the root zone of *E. muelleriana* is minimised during the first few years after establishment;
- It is important that *E. muelleriana* is thinned on time to prevent the development of epicormic shots around the sites of occluded branch stubs.
- The form on most sites was excellent. It should be noted that all sites inspected were ex-native forest sites with no fertiliser history except at establishment (only some sites);
- *E. muelleriana* commonly demonstrated significantly better performance in one of the two replicates in this series of trials, suggesting that it is a fussy species to establish.
- Several replicates in this trial series (particularly Watagan and Chichester trials) contain trees of a wide variety of species that would be highly suitable for utilisation studies. This is a research opportunity that is unique in Australia.

South Gippsland, Victoria

E. muelleriana is indigenous to the South Gippsland region of Victoria. This population of *E. muelleriana* has been isolated from central and east Gippsland, and NSW populations due to clearing of forested land for agricultural development. The MAR across the South Gippsland population ranges between 600-1100mm/yr. This range includes the lowest MAR localities of *E. muelleriana* across its natural distribution. Within this region *E. muelleriana* has been established in several trials, farm forestry plantings and in one large plantation. It is also a preferred species for the Radial Timber Australia Ltd. (RTA) mill in Yarram. The following section details the main plantation and processing developments that incorporate *E. muelleriana* in this region.

Hedley Stringybark Plantation

In December 2002 some basic volume inventory was performed in the largest *E. muelleriana* and *E. globoidea* plantation in Australasia. This plantation is located on Coal Mine Rd. near Hedley, approximately 20km west of Yarram in South Gippsland. The 80 ha plantation is owned and managed by the Victorian Department of Primary Industries (formerly NRE) and was established in 1986/87 on formerly cleared agricultural land. The plantation is established on grey sandy loam soils derived from Cretaceous sedimentary rock and is estimated to receive a MAR of 850-900mm/yr. The terrain is undulating and the soil is poorly drained in some sections.

The plantation was established to the dominant indigenous species of the area, *E. muelleriana, E. globoidea* and *E. globulus. E. muelleriana* and *E. globoidea* comprise the majority of the plantation area with *E. globulus* being confined to drainage lines and low-lying terrain. Seed used to propagate the seedlings for plantation establishment was collected from within the Yarram region.

Records of site establishment are incomplete, however, it appears that the site was established according to the following schedule:

1. Top soil was scalped and heaped to achieve a level of weed control;
2. The site was contour ripped and mounded on 3 metre centres;
3. Trees were planted at a stocking of ~1200 stems/ha.
4. A standard quantity of fertiliser (e.g. Agriform tablet) was probably applied at planting.

The inventory was completed in a lower slope area that was mostly comprised of *E. muelleriana*. The results of the inventory are summarised in Table 11.

Table 11. Results of inventory conducted in the Hedley Stringybark plantation – Nov 02.

Year est.	Plot area	No. trees measured	Stocking rate	Av. dbh	Basal Area	Vol/ha	MAI
1986	0.02 ha	21	1188 sph	20.2cm	$41m^2$/ha	$238m^3$/ha	$14.9m^3$/ha/yr

The usefulness of this data is limited by the small sample size. Nonetheless these figures provide a guide to the potential productivity of *E. muelleriana* plantations in the South Gippsland region. Given the primitive establishment techniques and high levels of competition that have prevailed in the plantation in recent years, this MAI demonstrates encouraging growth potential.

The form of trees within this plantation is generally excellent. The lateral branching is fine and sweep within the plantation is minimal.

Figure 34. 13-year-old *E. muelleriana* at Hedley.

During 2003 it is expected that a more comprehensive inventory will be performed in this plantation as part of a thinning and fertilising project managed by Woollybutt Pty. Ltd. in conjunction with Radial Timber Australia Ltd. , Gippsland Farm Plantations Inc. and the Department of Primary Industries.

Radial Timber Australia Ltd.

The Yarram RTA mill has been in operation since 1989. Radial sawmilling involves the cutting of logs into long radial wedges of timber. Growth rings are consistently aligned in radially sawn a product, which leads to improved and predictable behaviour during drying and use (Radial Timber Australia 1999). Andrew Knorr the Managing Director of RTA has been an advocate of the development of durable plantation species resource for a number of years. A large percentage of the products manufactured by RTA including weatherboards, decking, cladding, posts and poles, veranda posts, structural columns, drop segment fencing and outdoor furniture all require wood from durable eucalypt species. RTA report a steady increase in sales and demand for durable wood products in recent years (Braden Jenkin pers. comm. 2002).

The durability, lyctid borer resistance, stability and versatility of wood products produced from *E. muelleriana* contribute to it being one of RTA's preferred timber species.

Gippsland eucalypt trials

Duncan (et al. 2000) analysed growth data from 140 seedlots of 36 Eucalyptus species grown on twelve sites across Gippsland. On average *E. muelleriana* could only be classed a moderate performer in terms of growth across most sites. Subsequently it was not one of the seven species selected for further evaluation. At age 11 the MAI for *E. muelleriana* within the analysed trials ranged from 4.1 (Mt. Kembla prov.) to 13.2 m^3/ha/yr (Genoa prov.). The lowest productivity at age 11 was at Flynns Creek[44] and the highest at Delburn[45].

E. muelleriana was established in six of the twelve sites analysed by Duncan et al. 2000. Five of these sites were in the 1987 trial series established by Grand Ridge Plantations (formerly Australian Paper Plantations). The following trends were evident in these five GRP trial sites:

- The three *E. muelleriana* provenances in terms of species and seedlot growth rankings, demonstrated better performance on the low rainfall (<=760mm/yr) sites (i.e. Flynns Creek, Stradbroke and Stockdale) with sandy soil profiles compared to the high rainfall (>=1000mm/yr) sites with more fertile loam to clay loam soil types.
- The Yarram provenance significantly outperformed the Genoa and Mt. Kembla provenances on all low rainfall sites.
- The only instance where the Yarram provenance was significantly outperformed by one of the other two provenances was on the ex-pasture Mt. Worth East site where the Mt. Kembla provenance averaged 135m^3/ha at age 11 years and the Yarram provenance 110m^3/ha.

In terms of species and seedlot rankings the best performance by *E. muelleriana* was at the Stockdale site where the Yarram provenance was ranked 8 and 12 for species and seedlot growth performance respectively. Twenty seven species and 67 seedlots were trialed on this site. The soil type at Stockdale is classified as "Stockdale loamy sand". It is an infertile yellowish, brown texture contrast soil with subsurface bleaching (Duncan et. al. 2000).

None of these five trial sites were established on sites where *E. muelleriana* is an indigenous species.

<u>Summary</u>

- *E. muelleriana* is capable of attaining acceptable commercial growth rates in plantations within the South Gippsland region
- Yarram region provenance seed, similar to the RGP BBM site has produced trees that demonstrate excellent form;
- *E. muelleriana* is a preferred species for the production of durable wood products at the RTA mill in Yarram;
- In terms of seedlot growth rankings, *E. muelleriana* demonstrated its best performance on low rainfall sites with soil profiles that contained a sand component;
- The Yarram provenance outperformed the Genoa and Mt. Kembla provenances on all low rainfall sites

[44] The Flynns Creek trial site has a MAR of 760mm/yr and is established on a brown texture contrast soil with subsurface bleaching called "Maryvale sandy loam".
[45] The Delburn trial site has a MAR of 1000mm/yr and is established on a brown gradational texture soil without subsurface bleaching called "Silver Creek loam".

Establishment and Management

Siting

Austin et al. 1990 analysed the qualitative environmental realised niche (QERN) of five eucalypt species including *E. muelleriana* in south-eastern NSW. He defined the QERN as being a region of environmental space where the probability of finding a particular species is >0.1. This region was regarded as representing the limit of feasible establishment and growth of a species on a regular basis (Austin et. al. 1990). Regions of environmental space where the probability of occurrence was high (>0.7) were regarded as the optimal QERN or best site for the species. The predicted optimal QERN for *E. muelleriana* was defined as protected southern aspects on soft sediments with a mean annual temperature 13.5°C and 16°C and a MAR between 950-1150mm/yr (Austin et. al. 1990). The QERN for *E. muelleriana* (probability >0.1) included locations on intermediate and exposed northern aspects on sedimentary derived soils with mean annual temperatures as low as 11.8°C. However, a prospective plantation developer considering establishment on these type of sites should be encouraged to consider a range of species options which may include *E. muelleriana*, rather than considering it as the sole option.

In another study of response to climatic variables (Austin et. al. 1994), the frequency distributions of mean annual temperature (MAT) were compared in the natural distributions of nine eucalypt species including *E. muelleriana* and *Corymbia maculata* which is commonly regarded as a frost sensitive species. The ranges of MAT for these species were 9.35-16.55°C and 13.65-16.95°C respectively. The probability of occurrence was greatest (>0.7) at respective MAT's of 13.5°C and 15.6°C (Austin et. al. 1994).

It has been demonstrated in both New Zealand and Victorian plantations that *E. muelleriana* will not tolerate severe frosts as a newly established seedling. Shelbourne et. al. 2000 was forced to abandon an *E. muelleriana* family provenance trial established in November 1993 at Omataroa in New Zealand. The site was described as having poor air drainage[46]. The MAT of the trial site was 13.16°C (Shelbourne et al. 2000). All seven provenances trialed on the site were badly affected by frost. The frost scoring system used to quantify the severity of frost damage demonstrated that there was significant differences between some provenances. Cann River and Mt. Kembla provenances were significantly less affected by frost than the other provenances. Narooma was the worst affected provenance. A similar trial was established at Parakoa in 1994. The MAT of this site was 14.4°C. Whilst there was also some frost induced death on this site, the survival rate was satisfactory for the trial to continue.

When *E. muelleriana* was planted at Mildura and Horsham for an irrigated wastewater trial, Stewart and Flinn (1984) reported high mortality due to frost. A large percentage of *E. muelleriana* seedlings[47] established 5 km south of Kyneton in central Victoria during September 2001 were also killed by frequent and repeated frost events that occurred at establishment and throughout April – October 2002 period. The MAT at Kyneton is 12.1°C[48]. A small percentage of *E. muelleriana* seedlings established in plantations near Foster and Bengworden in 1998 and 1999 respectively were also damaged by frost in the early years following establishment. At Bengworden it was noted that the Orbost provenance of *E. muelleriana* was burnt by frost[49]. At both of these sites the *E. muelleriana* has survived the frost events and is now performing well.

[46] Poor air drainage usually occurs in areas in hollows or at the base of slopes where air flows are reduced. Frosts are usually more severe in these areas.
[47] Won Wron, Victoria provenance
[48] Source Bureau of Meteorology website –www.bom.gov.au
[49] The survival of *Corymbia maculata* and *E. cladocalyx* established at Bengworden has been significantly reduced by frost events.

An analysis of the growth performance of natural and planted stands of *E. muelleriana* demonstrates that it prefers sheltered sites usually found on mid to lower slope locations.

Soil requirements

E. muelleriana naturally occurs on a wide variety of soil types ranging from sandy loams through to heavy clay loams derived from slates, shales, sandstones and granites (Poynton 1979). Clinnick (2002) rates *E. muelleriana* as being moderately tolerant to salinity levels of <5dS/m. Poynton (1979), Costermans (1983), Boland et al. 1984 and Bird (2000) state that the best examples of *E. muelleriana* are positioned on deep, clay loam soils with a heavy but nonetheless well drained subsoil (B horizon). Whilst *E. muelleriana* has the ability to tolerate medium clay soils, it will not tolerate poorly drained clay soils subject to prolonged periods of waterlogging.

Observations suggest that the likelihood of *E. muelleriana* succumbing to windthrow on soil profiles that have a heavily textured B-horizon is increased; particularly where deep ripping has been conducted in wet soil conditions. In a study on the root configuration of several eucalypt species in south east NSW, Neave and Florence (1994) found that the only two *Monocalyptus* species in the trial; *E. pilularis* and *E. globoidea* differed markedly from *Corymbia*[50] and *Symphyomyrtus*[51] species by allocating the majority of photosynthates to root development higher in the soil profile. These results are consistent with those of plantation grown *Monocalyptus* and *Symphyomyrtus* species in Tasmania (Turnbull et al. 1993 cited by Neave and Florence 1994). The *Monocalyptus* species were severely affected by windthrow where waterlogging had occurred. They were described as having shallow roots in a flat plane with a weak taproot and ill defined lateral sink roots. The roots of the *Symphyomyrtus* species, which were much less affected by windthrow, were deeper with vigorous lateral sinker and taproots. Hence it would appear that the propensity of *E. muelleriana* (a *Monocalyptus* species) to suffer from windthrow on specific soil types might be related to its root configuration. These observations made by Turnbull et al. 1993 are very similar to mine when the soil in the close vicinity of several wind thrown *E. muelleriana* at Brian Joy's property north of Foster was excavated in 2002.

In South Africa, Poynton (1979) noted the ability of *E. muelleriana* to grow well on well-aerated, infertile sandy soils derived from sandstone. He stated "*E. muelleriana* possibly merits consideration as an alternative to *E. diversicolour* or *E. cladocalyx* when afforesting soils of intermediate quality (in South Africa)".

The data presented by Duncan et al. 2000 showed *E. muelleriana* to be more highly ranked for growth relative to other eucalypt species when planted on infertile sandy soils. It was also shown that *E. muelleriana* was only a moderate performer in terms of volume production per hectare on a former improved pasture (highly fertile) site.

One of the main limitations of *E. muelleriana* found in New Zealand is its propensity to fork. This tendency is possibly worse on nutrient rich sites (Shelbourne et al. 2000). Peter Davies Colley (pers. comm.) believed the poor form of *E. muelleriana* on some sites was associated with high levels of nitrogen in the soil. There is no doubt that the form of the *E. muelleriana* inspected in New Zealand was substantially better on less fertile clay and sand soils. The growth on these sites remained impressive despite the low fertility levels. The best stand in terms of growth and form seen during the New Zealand trip was at Tairua Forest where the *E. muelleriana* was established on P-deficient clays.

In the Hunter region of NSW *E. muelleriana* performed best on the more fertile, well drained ex-native forest sites[52] that contained soils with a sand fraction. *E. muelleriana* also performed well on

[50] Corymbia species – *C. maculata* and *C. gummifera*.
[51] *Symphyomyrtus* species *E. paniculata*, *A. pellita*, *E. saligna*, *E. camaldelensis*
[52] ex-native forest sites compared to improved pasture sites are commonly regarded as having low fertility levels.

soils the Eden area which are known have low and variable concentrations of phosphorus and other nutrients (Kelly and Turner 1978).

Whilst undertaking the establishment of *E. muelleriana* on ex-pasture sites in the west and south Gippsland regions, I have not observed a positive growth response attributable to the application of common fertiliser blends (i.e. 100gms DAP, Urea) at establishment. However, *E. nitens* and *E. globulus* planted on the same sites have demonstrated good growth responses to the application of the same fertiliser blends. Whilst this observation is not based on quantitative data, it suggests that *E. muelleriana* grown in plantations will require a different nutritional management strategy to optimise growth, compared to mainstream hardwood plantation species such *E. nitens* and *E. globulus*.

As part of a wastewater irrigation trial Stewart and Flinn (1984) established *E. muelleriana* on a hard pedal yellow duplex soil at Horsham and a grey cracking clay at Mildura. Both sites were irrigated with secondary treated municipal wastewater using the border-strip flooding method. The growth of the *E. muelleriana* was extremely poor with height increment being less than 50cm/yr (Stewart and Flinn 1984). At the conclusion of the trial *E. muelleriana* was one of three species regarded unsuitable for irrigation with wastewater in Victoria. The exact cause of the poor growth demonstrated by *E. muelleriana* was not established. However, on sites with good fertiliser history or where fertiliser is applied post planting, it is apparent that *E. muelleriana* has deficiencies compared to other species (particularly of the subgenus *Symphyomyrtus*).

Pests and Diseases

Noble (1989 cited by Simpson et al. 1997) hypothesized that species of the sub-genus *Monocalyptus* suffers less damage from insects and fungal pathogens than *Symphyomyrtus*. Results from Simpson et al. 1997 confirmed this hypothesis. *E. muelleriana* was one of the species included in this study and it demonstrated no particular susceptibility to any fungal pathogens or insect agents. The Orbost provenance at the Kenniacle Creek site did suffer moderate insect attack in June 1995. However, this was presumably due to large numbers of Christmas Beetles (*Anoplognathus chloropyrus* and *A. porosus*) that caused severe damage in *Corymbia* species and many species in the *Symphyomyrtus* sub-genus.

This study supports the view that *E. muelleriana* is susceptible to severe attack and damage from any insects. This is a significant advantage particularly in New Zealand and South Africa where many species of eucalypt suffer badly from a wide range of insects.

E. muelleriana is prone to being ringbarked by cattle and therefore cattle grazing within plantations is not recommended. In Gippsland it has been reported that isolated *E. muelleriana* trees have been ringbarked by wallabies (Graeme & Colin Crawford pers comm. 2002)[53]

Following the Ash and Peppermint eucalypt groups, Stringybarks including *E. muelleriana* are amongst the most susceptible species to Phytophthora Root Rot (*Phytophthora cinnamomi*). *Phytophthora cinnamomi* is a root fungus that enters young tree roots and attacks the soft tissues of trees that are vital for water and nutrient uptake. Tree mortality appears to be worst on relatively infertile sites where drainage is impeded (Marks et al 1972)(Marks et al. 1982).

In 1978/79 a *Phytophthora cinnamomi* tolerant *E. muelleriana* trial was established in the Mullungdung forest to test the progeny of apparently resistant trees found in the Mullungdung forest. Thirty-four families were established. There were significant differences between families of *E. muelleriana* in survival. The mean family survival ranged from 40-95% with an average of 81% (Jo Sasse, Forest Science Centre pers. comm. 2002). Height and dbh measurements at age seven also showed considerable variation: – 4 to 7.4cm (average 5.9cm) and 1.8 to 5.3m (average 4.2m) (Jo Sasse pers. comm. 2002). Marks (et al. 1982) stated that there is considerable variability

[53] Graeme and Colin Crawford are farm foresters that own land located south east of Traralgon.

in resistance to the fungus, both within and between species of eucalypt. The data from this trial demonstrates that considerable variation in resistance to *Phytophthora cinnamomi* likely to be found between families of the one provenances.

This within provenance variation indicates that there is good potential through tree improvement programs to produce families of *E. muelleriana* that exhibit superior resistance to *Phytophthora cinnamomi*. Given the apparent variation in resistance to *Phytophthora cinnamomi* that was demonstrated at age 7 (1985/6), further assessment of this trial could be a worthwhile exercise.

Whilst advances may be made in the development and production of planting stock with superior *Phytophthora cinnamomi* tolerance, to minimise the chance of *Phytophthora cinnamomi* detrimentally impacting *E. muelleriana* plantation development in the short term, the establishment of poorly drained sites should be avoided. If a plantation developer was considering the establishment of *E. muelleriana* and was unsure of whether *Phytophthora cinnamomi* was present, it is important that soil samples designated for testing are taken. A map showing the known distribution of *Phytophthora cinnamomi* in Victoria can be found in Marks et al 1972.

Tree improvement

For this report, tree improvement will be defined as a process where target characteristics of a tree species are improved through the implementation of appropriate breeding strategies. At this stage target characteristics for *E. muelleriana* would be growth rate, form, frost tolerance, *Phytophthora cinnamomi* resistance and perhaps canopy density.

The six-year results of a *E. muelleriana* family/provenance trial reported by Shelbourne et al. 2000 showed that genetic variability, mainly amongst families within provenances and also between the seven provenances[54] was sufficient to promise good genetic improvement in all traits from selection. The mean dbh of the control seedlot from an unknown Victorian origin was superior (238mm) to the mean dbh of the seven provenances tested (196-207mm), indicating that faster grown provenances apart from the seven selected for this trial[55] do exist.

In the low rainfall RGP BBM trial in Gippsland, the Won Wron, Vic[56] provenance of *E. muelleriana* at age 35 and 40 months showed markedly better survival, bole straightness and much finer branching relative to the Orbost, Victoria provenance.

Tony Shelbourne (pers. comm. 2002) reports that the Cann River and Mt. Kembla provenances of *E. muelleriana* were significantly more frost tolerant than the other five provenances included in the six year results from the provenance/family trial located at Omataroa New Zealand. The results for the frost assessment are presented in Table 12.

Table 12. Revised[57] frost assessment results adapted from Shelbourne (et al. 2000)

Ranking	Provenance	Elevation (m)	Latitude	Longitude	Mean frost score
1	Cann River, Vic.	280	37°38'	148°49'	1.99
2	Mt. Kembla, NSW	420	34°29'	150°44'	2.14
3	Batemans Bay, NSW	160	35°32'	150°10'	2.67
4	Bruthen, Vic.	200	37°41'	147°48'	2.96
5	Yarram, Vic.	120	38°24'	146°53'	3.02
6	Genoa, Vic.	140	37°27'	149°43'	3.03
7	Narooma, NSW	160	36°17'	149°58'	3.29

[54] Diameter, straightness, form, height, malformation and health
[55] Seven provenances were Mt. Kembla, Batemans Bay, Narooma, Genoa, Cann River, Bruthen and Yarram
[56] Won Wron is ~ 10km north of Yarram, Vic.
[57] These results were not referenced directly from the Shelbourne (et al. 2000) publication because the frost assessment data was presented in the wrong order (Tony Shelbourne pers. comm. 2002).

Table 12 shows that the most frost tolerant provenances (i.e. Cann River and Mt. Kembla) are also the two highest elevation provenances, indicating the frost tolerance for *E. muelleriana* is likely to be correlated to some extent with altitude. This is to be expected given that studies on the frost tolerance of *C. maculata* (Tibbits and Sasse 1999), *E. regnans* (Eldridge 1968) and *E. delegatensis* (Hallam and Read 1989) have shown some correlation with altitude.

The regional trend in leaf size suggested by Shelbourne (et al. 2000) where the leaves of *E. muelleriana* are generally observed to get bigger with increasing longitude and decreasing latitude, was further confirmed by observations at the RGP BBM trial site. At this site leaves of the Orbost provenance trees were observed to be markedly bigger than those of the Won Wron provenance. This regional difference is significant because the larger leaves were reported by Shelbourne (et. al. 2000) and observed in the RGP BBM trials to give the *E. muelleriana* a denser crown compared to the South Gippsland provenances. It is well accepted that with an increase in the size of the photosynthetic canopy, the growth rates of eucalypts is likely to increase (Simpson et al 1997). Given a denser tree crown generally equates to a larger photosynthetic canopy, it could be reasonably expected that provenances with bigger leaves and denser canopies will grow faster than provenances with smaller leaves (e.g. Yarram, Won Wron). It will be important to continue monitoring the trait of leaf size to see if the expected correlation between canopy density and growth rate is realized.

Establishment regime

To consistently achieve good establishment results and growth rates with *E. muelleriana* on sites judged to be suitable for the species some subtle changes are required to establishment regimes commonly employed for mainstream eucalypt plantation species (e.g. *E. globulus* and *E. nitens*).

Planting stock

Research into the selection of specific provenances and/or families of *E. muelleriana* for plantation establishment is in its infancy and therefore firm recommendations regarding this aspect of plantation cannot be made with complete confidence. Nonetheless, trials established to this stage in the south and east Gippsland regions of Victoria show that:

- The Yarram, Vic provenance exhibits significantly better growth than the Genoa and Mt. Kembla provenances on low rainfall sites;
- The Won Wron, Vic provenance displays markedly better form than the Orbost provenance at the low rainfall RGP BBM trial site.

Trends on high rainfall sites are difficult to identify. As previously established, it is likely that frost tolerance will demonstrate a correlation with altitude. If a grower requires higher degrees of frost tolerance it is suggested that they consider seedlots from altitudes >250m asl such as Mt. Kembla, Cann River and Whitelaws Track.

According to Pieter Klein the owner of Kleins Nursery[58], *E. muelleriana* is ranked on a par with *E. saligna* and *E. grandis* for frost tolerance in a nursery environment. It exhibits inferior frost tolerance to *E. globulus* but demonstrates superior frost tolerance to *E. cladocalyx* and *C. maculata* in the nursery. To maximize the frost tolerance of *E. muelleriana* at planting in Gippsland, Pieter recommends that seed is sown prior to the 20th December in the year before planting. In his view plants grown from seed sown after the 20th January in Gippsland are likely to have elevated levels of frost tenderness.

[58] Kleins Nursery is located at Yarram in Victoria.

E. muelleriana seedlings are well suited to most containerised, cell propagation systems where the seed has been direct seeded into a plug or cell tray (e.g. HIKO, LANNEN tray systems).

As shown earlier, *E. muelleriana* can be successfully established at both high (~1200sph) and low (~300sph) stockings providing that the management regime applied is tailored to the needs of the selected stocking rate. For example:

- ✓ Plantations established at lower stockings are likely to require more frequent and laborious form and stem pruning operations;
- ✓ Plantations established at higher stockings will require an earlier thinning operation (e.g. age 4).

Given that the currently available *E. muelleriana* seedlots have undergone minimal tree improvement (other than provenance selection), it is recommended plantations for wood production be established at 1000sph.

Soil analysis

To gain a complete picture of soil properties, samples should be taken across the area proposed for planting and analysed. For larger plantation areas (>10ha) it is recommended that 3-4 metre deep soil pits be excavated to determine soil properties. During the evaluation of soils for *E. muelleriana,* it is particularly important to evaluate the following characteristics:

- *Phytophthora cinnamomi* – If there is any risk of *Phytophthora cinnamomi* being present on a proposed planting site it is critical that testing for *Phytophthora cinnamomi* be conducted. This can be arranged through a range of forestry research organizations (e.g. Forest Science Centre, Victoria). Given the preliminary stage of the development of *Phytophthora cinnamomi* tolerant provenances and/or families of *E. muelleriana*, if *Phytophthora cinnamomi* is detected it is suggested that alternative species tolerant to the fungus are considered
- Fertility – *E. muelleriana* appears to perform best on relatively infertile sites (i.e. pasture sites with poor fertiliser history, ex-native forest or plantation sites). Trials and observations suggest that other species are better options for fertile ex-pasture sites
- Waterlogging – *E. muelleriana* will not tolerate sites that are subject to extended periods of waterlogging (e.g. months at a time)
- Clay subsoil – *E. muelleriana* appears to be more prone to windthrow on sites with heavy clay subsoil that have been deep ripped
- Soil texture - *E. muelleriana* appears to perform well compared to other species on soils that have a sand component
- Salinity – *E. muelleriana* should not be established on sites that have salinity or EC levels >5dS/m. The lower the EC the better.

Soil Cultivation

If *E. muelleriana* is to be established on sites with moderate to poor drainage, mounding[59] should be performed in accordance with standard establishment prescriptions. Mounding will improve soil drainage and raise planted seedlings above zones of temporary waterlogging at establishment. It is important that mounds have good soil tilth to assist the facilitation of effective weed control during the first 2-3 years following establishment. Steep to undulating sites characterized by good soil drainage and an effective rooting depth[60] of > 80cm do not require mounding to attain satisfactory growth rates. Nonetheless where mounding is undertaken the following benefits will be realised:

[59] Also termed ridging
[60] Effective rooting depth is the depth to an impeding layer such as a hardpan, bedrock, massive structured clays (Laffan 2002) etc.

- Improved weed control
- Easier and quicker planting
- Increased growth rates during the first few years after planting

In accordance with the findings of Neave and Florence (1994), the act of ripping needs to be carefully considered. On heavy clay soils it is imperative that ripping is conducted when the soil profile is dry. If ripping is conducted when soils are wet, alternative species options should be considered for establishment.

On heavy clay soils prone to waterlogging, *E. muelleriana* should not be considered as a species option. Given the findings of Neave and Florence (1994) ripping may still provide a benefit on moderate-well drained soils that have otherwise impermeable clay lenses within one metre of the soil surface. Ripping in these situations may assist *E. muelleriana* to develop roots at depth, particularly in dry conditions.

Ripping is not absolutely necessary to attain satisfactory growth rates on well-drained soils that possess good levels of effective rooting depth. However similar to the case for mounding, it can be reasonably expected that growth rates will be increased where ripping is conducted in the right conditions.

Weed Control

Pre-planting and post planting weed control are the most important establishment operations in facilitating the successful establishment of *E. muelleriana*. After Neave and Florence (1994) reported that the *Monocalyptus* species *E. pilularis* and *E. globoidea* have a greater proportion of roots higher in the soil profile, they concluded that in the early growth stages, at least, these species may be less competitive where surface soils dry out periodically, and moisture is only available at increasing depths. Therefore *Monocalyptus* species (such as *E. muelleriana*) are likely to be more affected by weeds during the first few years after establishment when the majority of the tree roots and weeds are competing for water and nutrients within the same zone of soil (see Figure 35). Consequently it is particularly important that an area around the tree (e.g. at least 0.75m radius) is kept weed free for at least the first 2-3 years. This is a longer period than commonly advised for most eucalypt plantations.

Figure 35. The rooting configuration of *E. muelleriana* age 42 months on deep sand near Bengworden. Most roots are in the top 50 cm of the soil profile.

The root configuration findings of Neave and Florence (1994) could potentially mean that *Monocalyptus* species are not as tolerant to the application of residual herbicides[61] as *Symphyomyrtus* species (e.g. *E. globulus*, *E. saligna*). This is because some residual herbicides can move readily through the soil and affect nearby plants via root uptake (Monsanto TT 65). Plants that have a high percentage of roots near the soil surface may be more affected by residual herbicides than deeper rooting species. Barry Tomkins (Melbourne University pers. comm. 2002) commented that State Forests NSW on the north coast of NSW have found *E. pilularis* (a *Monocalyptus* species) to have a low tolerance to a range of residual herbicides. This suggests that *E. muelleriana* may also have a relatively low tolerance to residual herbicides. It is common for rates of residual herbicides to be reduced on sandy soils due to their ability to move through the profile into the tree root zone and subsequently cause phytotoxicity (Barry Tomkins pers. comm. 2002). *E. muelleriana* performs well on sandy soils, hence prospective plantation developers are likely to target these areas. Given this information, a cautious approach is required for residual forms of weed control in *E. muelleriana* plantations. Compared to most Victorian trials, *E. muelleriana* has performed exceptionally well in the Gippsland RGP demonstration plantings. A contributing factor to this good performance may have been that an alternative residual herbicide – Visor (active ingredient – thiazopyr) was used as a component of the pre-plant weed control rather than the most commonly used residual option, "simazine". Visor is highly regarded for its environmental safety due to its low water solubility, soil surface stability and low use rate compared to other residual herbicides. Barry Tomkins rated Visor as being "very ecologically safe and extremely soil fast. Its solubility in water is very low (2.5ppm)". In July 1999, Barry commented

[61] Residual herbicides persist in the soil for some time and are able to kill weeds seeds as they germinate (Monsanto TT 65).

"Visor is probably the safest herbicide in terms of selectivity) that I know of" (i.e. kills weeds and doesn't damage trees). Unfortunately Visor was withdrawn from the market by its parent company, because of poor sales (largely due to high retail price) and high manufacturing cost (Barry Tomkins pers. comm. 2002).

Until more research is completed, low to moderate levels of residual herbicides (e.g. A maximum of 4kg active ingredient per hectare Simazine pre-plant) are recommended. Residual herbicides for pre-planting treatments should only be applied during the winter period in moist soil conditions (Barry Tomkins pers. comm. 2002).

Planting

If the seed of *E. muelleriana* has been sown before Dec 20 in the year prior to planting and the plants have been well hardened, they can usually be planted as early as August in Victoria. If they are to be planted onto a frosty site and/or have been sown after Dec 20 they should not be planted before the start of September in Victoria.

If planting can only be conducted after September, weed control will need to be excellent because *E. muelleriana* will struggle through the summer if soil moisture is reduced by summer active weeds (e.g. paspalum – *Paspalum dilatatum*).

If planting is to be performed in uncultivated ground, it is recommended that seedlings be planted using a planting spade rather than a "potti-putki" or similar device, because the correct planting spade technique will include a level of "micro" soil cultivation that will assist the seedling to develop a stable root system more rapidly.

Fertilising

In contrast to mainstream eucalypt plantation species, it has been established that *E. muelleriana* does not appear to respond favourably to fertile soils or commonly applied fertiliser prescriptions at establishment. The surface rooting habit of *Monocalyptus* species reported by Neave and Florence (1994) may mean that species of this subgenera are more prone to fertiliser toxicity when it is placed near the plant at establishment. The risk of toxicity would be increased where fertiliser is applied in a clump (i.e. 100 gms in a small hole or boot imprint).

Published or even informal information about the nutritional management of *E. muelleriana* is scarce. However, it is apparent that *E. muelleriana* is reasonably well adapted to sites of low fertility. Given this evidence the value of fertilising *E. muelleriana* at establishment is questionable. It is suggested that a better practice would be to survey the trees for nutrient deficiencies after establishment (e.g. at 1 year of age). If deficiencies are evident at this stage, foliar analysis should be conducted and an appropriately targeted remedial fertiliser applied.

Survival

In their pest and disease study, Simpson et al. 1997 stated that seedling mortality within their trial was significantly higher amongst the monocalypts than the *Symphyomyrtus* or *Corymbia* species. This reduced level of survival was not correlated to either fungal or insect foliar damage. I have noticed a similar occurrence when comparing the survival of species from these two subgenera. It is hypothesized that these lower survival rates could be correlated with the general root configuration of Monocalyptus species. This predisposes species of this sub genera to drought death when surface soils dry out, a greater risk of phytotoxicity from traditional weed control practices and fertiliser toxicity. If this hypothesis is correct, alternative weed control regimes may need to be investigated for *E. muelleriana* and other prospective *Monocalyptus* plantation species options.

Management regime

To grow wood suited to the production of high value solid wood products within 30-35 years, plantations of *E. muelleriana* will have to undergo timely thinning and pruning operations.

Thinning

To grow large *E. muelleriana* sawlogs (>60cm dbh) within 30-35 yrs, it is expected that 2-3 thinnings will be required during the rotation. Table 13 shows that if an *E. muelleriana* plantation was assumed to be growing at an MAI of 16m^3/ha/yr, to maintain the plantation in a freely growing state (i.e. not subject to competition) it is reasonable to expect that thinnings would be required at approximately age 4, 12 and 20 (Woollybutt 2002 unpub).

Table 13. Indicative thinning and pruning regime for *E. muelleriana* growing at an MAI of 16m^3/ha/yr

Age	Thinning specifications	BA (m^2/ha)	Products
4	Select 300 sph and prune to ~ 2.4m	-	-
4	Thin from 1000sph to 500sph	~10 reduced to 5	Non commercial
5	Select 300 sph and prune to ~ 4.5m	-	-
6-7	Select 200 sph and prune to ~ 6.0m		
12	Thin from 500sph to 250sph	~30 reduced to 15	Pulpwood, firewood and posts
20	Thin from 250sph to 125sph	~45 reduced to 25	Small sawlogs, poles, pulpwood, fire wood
30	Final harvest	-	Large and small sawlogs, poles, pulpwood, firewood

The thinning at age 4 would be regarded as non-commercial. Given the current state of wood markets for *E. muelleriana* it is unlikely that wood generated from a thinning at this age would be suitable for any commercial products[62]. All of the subsequent thinnings should produce commercially saleable wood products.

This indicative thinning prescription deviates slightly from the generic prescriptions specified by Stackpole (1998)[63]:

- The first thinning is conducted at age 4 rather than age 3 (Stackpole 1998). This thinning is delayed because *E. muelleriana* does not grow as quickly as mainstream plantation species (e.g. *E. globulus*) in the first 2-3 years after establishment;
- The first thinning reduces the stocking from 1000sph to 500sph rather than 400sph (Stackpole 1998). 25% more stems are retained because *E. muelleriana* prefers sheltered conditions and may be more susceptible to windthrow than some other plantation species.

Pruning

Stem pruning is conducted to produce timber without knots, which is often called "clearwood". Clearwood is commonly prized for appearance uses including furniture, flooring and joinery work (Reid and Stephen 2002). In native forest and in unthinned plantations *E. muelleriana* is a self pruning species. However if large sawlogs are to be produced from *E. muelleriana* plantations within 35 years, the plantations will need to be aggressively thinned using regimes similar to that shown in Table 13. By thinning *E. muelleriana* to relatively low basal areas, large quantities of light will reach lateral branches encouraging them to increase in size, potentially creating large knots (defects) in the final sawlog. Therefore if *E. muelleriana* plantations are aggressively thinned

[62] This may change if a market for plantation grown *E. muelleriana* posts develops.
[63] These prescriptions are based on the results of CFTT thinning trials focussed on *E. globulus, E. nitens*, and to a lesser extent *E. grandis* and *E. saligna*

it is highly likely that stem pruning to approximately six metres in height will also be required to produce sawlogs suitable for high value, appearance grade products.

Practical experience in pruning *E. muelleriana* plantations in Australia is scarce. Relative to other species (e.g. *E. botryoides*) on his farm, Michael Holcombe found that pruning *E. muelleriana* was easy due to its relatively soft wood and fine branches. At the RGP BBM trial site the ease and speed of pruning was found to vary significantly between provenances. The Orbost provenance had larger branches relative to the Won Wron provenance and therefore took much longer to prune. At this site no epicormic shoot or kino vein development at the site of the pruned stub has been observed. Pruned stubs have been occluded in a clean fashion.

Stem pruning is commonly completed in three lifts to approximately six metres in height (Stackpole 1998). Theoretically each lift finishes at a height where the stem diameter is 10cm over bark. Table 13 shows that Woollybutt (2002 unpub) estimate that a *E. muelleriana* plantation predicted to grow at 16m^3/ha/yr would be pruned to a height of six metres within seven years. However a plantation manager need not be constrained by three lifts. If a plantation displays fine branching similar to the previously described Won Wron provenance, pruning to six metres could perhaps be completed more cost effectively in two lifts.

Growth rates

In native forest *E. muelleriana* can attain a very large size. Within the Nadgee State Forest near Eden in southeast NSW, one specimen was recorded as being 52m tall with a dbh of 3.3m[64]. Several large trees were observed during 2002 as shown in Table 14:

Table 14. Outstanding specimens of plantation grown *E. muelleriana*

Location	Year est.	Age when measured	Height	DBH	Comments
Chichester State Forest, NSW	1973	29 years	40.6m	55.0cm	
Watagan State Forest, NSW	1972	30 years	41.2m	56.5cm	BA = 55m^2/ha
Parakao, NZ	1994	8 years	22.0m	32.5cm	FR trial
Parakao, NZ	1988	14 years	24.0m	40.0cm	Agroforestry
Warkworth, NZ	~1950	~50 years	42.3m	83.5cm	
Tairua Forest, NZ	1960	42 years	46.1m	106.1cm	Thinned in 1977

In plantations where site selection and establishment practices have been satisfactory, *E. muelleriana* demonstrates a moderate to fast growth rate. Whilst several spot measurements and basal area sweeps were performed during most of the plantation inspections, robust MAI figures could not be reliably calculated. This was primarily due to small sample sizes, unknown thinning yields and small, inadequately buffered trials. Nonetheless some indicative figures can be generated for two of the NSW sites. At age 30 years, site 2 in the Watagan State Forest is estimated to have an MAI of 18-19 m^3/ha/yr. At age 29 the two *E. muelleriana* plots in the Chichester trial are estimated to have an MAI of 13-14m^3/ha/yr. Site 1 in the Watagan trials is likely to be growing more quickly than site 2; however one of the replicates was not sufficiently sampled to provide data to calculate MAI figures. These MAI figures represent good growth rates particularly given the basic establishment techniques used and the high levels of competition that has persisted throughout the majority of the life of these trials[65].

[64] Source – Silviculture Notes for NSW – Moist Tableland Hardwood Types. pg 21
[65] The basal area in site 2 of the Watagan trials and at Chichester was 65m^2/ha and 32m^2/ha respectively.

Wood/Timber Properties

A good general description of the properties of *E. muelleriana* timber can be found in Bootle (1983). Unfortunately the study of plantation grown *E. muelleriana* wood properties is in its infancy in Australia. Therefore the majority of the wood properties data supplied here are based on wood grown in typical native forest conditions. The Forest Research in New Zealand has performed some research in to the plantation grown wood properties of *E. muelleriana*.

Wood colour and appearance

The heartwood of *E. muelleriana* is yellowish brown with a pink tinge. Bootle (1983) indicates that the sapwood is usually sufficiently pale enough to be clearly distinguishable from the heartwood. In contrast, Ozarka et al. 1999 states that the light brown heartwood is not clearly demarcated from straw coloured sapwood.

NET regards the colour of the timber as a major advantage, because it is both attractive and unique in NSW and Victorian flooring and furniture markets. Hence it is not easily substituted by other species.

The wood grain can be straight with some interlocking (Haslett 1990). "Fiddleback" feature is often observed in sawn boards. The texture is fine to medium and kino veins are not frequent (Ozarka et al. 1999).

Wood Density

Table 15 lists density figures for both Australian native forest grown *E. muelleriana* and plantation grown material produced in New Zealand.

Table 15. Density for *E. muelleriana* grown in native forest and plantations

Density measure	Native Forest (Bootle 1983)	Native Forest (Ozarka et al. 1999)	NZ Plantation (Kininmonth 1974)[66]	NZ Plantation (unpub.)[67]	NZ Plantation[68] (Haslett 1990)
Green Density	1100 kg/m^3	-	-	-	-
Air Dry Density (12%)	870 kg/m^3	926kg/m^3	684 kg/m^3	646 kg/m^3	665 kg/m^3
Basic Density	690 kg/m^3	-	-	536 kg/m^3	550 kg/m^3

Table 16. shows whole tree basic density data collated by McKinley et al. 2000 from plantation grown *E. muelleriana* trees of different ages.

[66] 25-30 year old trees
[67] Unpublished data included by Young (1983)
[68] Trees over 25 years of age

Table 16. Whole tree basic density data for *E. muelleriana* collated by McKinley et al. 2000

Age (yrs)	6	7	15	~39[69]	45
Mean whole tree basic density	434 kg/m^3	453 kg/m^3	536 kg/m^3	-	551 kg/m^3
Range	422-447 kg/m^3	-	510-561 kg/m^3	550-635 kg/m^3	533-576 kg/m^3
Comments	Average outerwood increment core densities	Average outerwood increment core densities			

The density gradient between the ages 15 and 45 years appeared relatively flat for *E. muelleriana* compared to *E. globoidea* and *E. pilularis* (McKinley et al. 2000). The linear relationship between basic and air-dry density found by Young (1983) was of sufficiently high significance and precision for him to conclude that the regression (y = 1.268x – 34) be used to estimate air–dry density in *E. muelleriana* rather than actual measurement.

Basic density may also vary with latitude (Washusen 1998). Bolza (1978 cited by Washusen 1998) reported mature clear specimens of *C. maculata* taken from trees across its natural occurrence exhibiting a highly significant correlation between mean basic density and latitude – basic density decreasing with an increase in latitude. This relationship is important given that generally the denser the wood the greater the mechanical properties (e.g. MOE, MOR) of its clear material (Bootle 1983). The density of plantation grown *E. muelleriana* has only been recorded in NZ within the relatively narrow latitudinal range of $35^o30'$ to $38^o00'$. Clearly there would be value in obtaining density values for plantations established at latitudes outside of this range (i.e. near Newcastle, NSW and Yarram, Vic).

Sawmilling

Where processors have had access to a known *E. muelleriana* resource it is clear that they have a high regard for its excellent stability throughout the sawing process. Richard Davies Colley and Dennis Budd from New Zealand and Noel Hall and Andy Knorr from Australia all confirmed that the stability of *E. muelleriana* was a major advantage of the species. This is a significant conclusion coming from these sawmillers because their log intakes represent a mix of native forest and plantation grown wood. This “stability” has been found in plantation grown trees as young as 31 years old. Considered solely from a wood processors viewpoint *E. muelleriana* would be the preferred species (out of *E. globoidea*, *E. saligna*, *E. botryoides*, *E. pilularis* and *E. muelleriana*) because its fine texture and light colour make it amenable to a wide range of uses (Haslett 1990).

Boland et al (1984), Turnbull and Pryor (1978 cited by Shelbourne 2001) reported that stringybark eucalypts from natural stands generally have a reputation for good sawing properties and have the good sawn timber properties of stiffness, strength, stability on drying and natural durability. Barr (1971 cited by Shelbourne 2001) and (1996) notes the remarkable early durability and consistent stability of timber of this species, in comparison to all the eucalypts grown in New Zealand. Barr (1996) comments that durable heartwood forms early in *E. muelleriana* relative to most eucalypt species. This trait enhances stability during processing, even when sawlogs are processed at a young age. This concept was reinforced by the results of trial conducted by Warden (2002 unpub). In this trial the largest *E. muelleriana* posts (~90mm in diameter) were the only posts from a sample of five eucalypt species where the preservation chemical did not penetrate into the core. This result indicates the presence of impenetrable heartwood in the core of these posts, which were produced from trees that were 3 to 5 years of age.

[69] This is new data that Russell McKinley supplied in graph form in May 2002

Growth Stresses

The inherent stability of *E. muelleriana* would imply that this species does not suffer from the high levels of growth stress common to other eucalypt species (e.g. *E. globulus*, *E. grandis*, *E. saligna* etc.). Haslett (1990) asserts that stringybark eucalypts[70] have only slight growth stress which has little adverse effect on their utilisation. In contrast, *E. saligna* and *E. botryoides* both suffer severe growth stress which frequently causes log splitting and distortion of timber during sawing. The wood density of *E. saligna* and *E. botryoides* increases sharply from the pith outwards (radially). The combination of low density wood surrounding the pith and pronounced growth stress probably accounts for the high incidence of brittleheart failure in *E. saligna* and *E. botryoides* (Haslett 1990). Conversely the more gradual increase in basic density extending radially from the pith found in *E. muelleriana* (Haslett 1990) may be correlated with the small defect core reported by sawmillers.

The small juvenile wood core is obviously of great benefit to a processor because they can reliably saw products from closer to the pith, and therefore improve their overall green sawn recovery. This becomes particularly significant when sawing small logs (<40cm SED). Dennis Budd implied this when he commented that he could saw smaller *E. muelleriana* logs (<40cm SED) relative to *E. saligna* and *E. botryoides* (SED = 40cm) and obtain similar recoveries.

Growth stresses are self generated in the cambium during cell maturation and are present in all tree species Jacobs (1938) and Kubler (1987, cited by Yang & Waugh 2001). The cells in newly formed wood tissue tend to contract longitudinally and expand laterally as they mature, producing a tension stress along the grain and a compressive stress across it (Bootle 1983). In simple terms, wood on the periphery of a tree is in tension whereas wood near the centre of the tree is in compression. When logs are sawn longitudinally these stresses are partially released causing spring in quarter-sawn boards and bow in back-sawn boards (Yang and Waugh 2001).

Where logs suffer from severe growth stresses, the sawmiller is significantly disadvantaged in a number of ways. Maree and Malan (2000) have found that high levels of growth stress in South African eucalypts are undoubtedly the most serious growth phenomenon affecting wood quality, product yield and recovered dimensions. There is little doubt that the utilisation sector of the Australian timber industry would agree. Yang and Waugh (2001) detailed the nature of these disadvantages. Following is a summary of these disadvantages adapted from their 2001 publication:

- Loss of sawlog recovery due to log end splitting – sawlog recovery can suffer heavily from log end splitting. Small logs of straight grained species (e.g. *E. sieberi*) can suffer particularly badly from this phenomenon. Splitting related losses in South African sawmills, exceeds 10%. End splitting is reduced to a certain extent if the wood has interlocked grain. *E. muelleriana* often has interlocked grain (Bootle 1983, Haslett 1990, Ozarka 1999) which may contribute to the lower impact of growth stresses in the species;
- Difficult to accurately saw boards at specified thickness.
- Sawn board distortion due to stress re-balance
- Loss of productivity – re-sawing to ameliorate the affects of sawn board distortion adds further steps to the sawing process, increasing cost and reducing productivity.
- Constraints on log breakdown and sawing patterns – where growth stresses prevail in a log, the sawyer is forced to alter his preferred sawing pattern, which often does not allow the log to be orientated and sawn in the way that minimises the impact of other internal and external defects (e.g. knots, gum pockets).
- Drying degrade due to tension wood;
- Weak material in core wood zone caused by

[70] referring to *E. muelleriana, E. globoidea* and *E. pilularis*

- Heart checks[71] in standing large diameter trees
- Greater effects on conversion of small logs – sawn boards from a small log will display greater distortion than sawn boards of the same thickness from a large log with the same peripheral growth strain. This can be attributed to a greater growth strain gradient being present across smaller logs relative to larger logs.

The impact of these undesirable effects on the economics of processing sawlogs is considerable and will become even more significant as younger and often-smaller diameter logs are processed.

Yang and Waugh (2001) point out that there are several methods that can be employed to counter the effects of growth stress on wood utilisation. Another option, which is often overlooked is to select and grow plantation species that naturally have low levels of growth stress. Years of practical experience in sawmilling native forest grown *E. muelleriana* and plantation grown *E. muelleriana* in New Zealand, demonstrates that this species exhibits relatively low levels of growth stress. Compared to species the exhibit high levels of growth stress, this attribute should make *E. muelleriana* logs easier to process using portable mill technology.

Log defects

Noel Hall and Jim Micah[72] commented that the core of older *E. muelleriana* trees were prone to being attacked by “bardi grubs” which could result in large areas of heart being boxed out during milling. Noel Hall specified that these defects were usually confined to large old trees.

Drying

Bootle (1983) says that *E. muelleriana* dries readily but care is needed to minimize checking and splitting. Some collapse can occur. Shrinkage data from Bootle (1983) is included for *E. muelleriana* and a range of other species in Table 17.

Table 17. Shrinkage data for a range of eucalypt species

Species	Green to 12% moisture content		After reconditioning	
	Radial %	Tangential %	Radial %	Tangential %
E. muelleriana	4.5	7.5	3	5
E. cladocalyx[73]	6.2	10.5	2.6	6.2
E. globoidea	5	9	3	5.5
E. pilularis	4	7	-	-
E. globulus	6	12	4	7
E. regnans	6.5	13	4	7
E. botryoides	5	10	4	7
E. nitens	5	9	3	6
E. saligna	5	9	-	-
Corymbia maculata	4.5	6	-	-
E. sideroxylon	3.5	7	-	-
E. sieberi	6	10	2.5	5.5
P. radiata	3	4.5	-	-

The drying manager from BRH - Michael Beavan has found Bootle (1983) to be accurate in his experience with drying *E. muelleriana*. Ozarka et al. 1999 also produced similar figures for shrinkage in the tangential and radial dimensions – 7.5% and 4.3% respectively.

[71] Heart checks refer to checking that occurs deep inside the tree.
[72] From Moe Timber Supplies. Moe Timber Supplies source their wood from native forest and process the majority of the timber at their processing centre in Erica, Vic.
[73] Kingston, R.S.T., and Risdon, C.J.E. (1961). Shrinkage and density of Australian and other South-west Pacific Woods. Division of Forest Products Technological Paper No. 13. CSIRO, Melbourne.

Ozarka (et al. 1999) found *E. muelleriana* grown under native forest conditions to be a fairly difficult species to dry for appearance products due to it is vulnerability to surface checking. Even quarter sawn boards developed surface checks, although the extent of surface checking was less severe than in backsawn boards. These results were based on a small sample consisting of twelve 600mm long boards; three were 25mm thick backsawn, three were 25mm thick quartersawn, three 40mm thick backsawn and three 40mm thick quartersawn. Ozarka et al. (1999) suggests that their results could be improved upon by a careful drying operator who observes wood behaviour during drying and adjusts practices according to experience and results.

In contrast to the findings of Ozarka et al. (1999), NET and BRH who dry the largest commercial quantities of the species for both structural and appearance grade products in Australia, do not have problems drying backsawn or quarter sawn *E. muelleriana*. In accordance with the suggestion of Ozarka et al. (1999) these companies have implemented customised and fully controlled drying regimes to minimise drying degrade and are achieving good levels of dried timber recovery.

NET in particular have a gentle drying regime that has no requirement for reconditioning nor any demand to differentiate between backsawn and quartersawn boards during the drying process. NET have placed themselves in a unique position to incorporate a gentle and slow drying regime, because they have arranged access to a guaranteed and consistent supply (quantity and quality) of timber from a single species.

Documented experience in drying plantation grown *E. muelleriana* is limited to a small but nonetheless significant quantity of research in New Zealand. In his study on eastern blue gums and stringybark eucalypts (*E. botryoides, E. saligna, E. globoidea, E. muelleriana* and *E. pilularis*), Haslett (1990) found these species to be much less susceptible to collapse and internal checking than the ash eucalypts. Hence he found it possible to dry backsawn material without excessive degrade. Kininmonth (1974) also found that collapse in *E. botryoides, E. saligna, E. muelleriana* and *E. pilularis* did not appear to be a problem where these species were subject to a suitable period of air drying prior to kiln drying. Haslett acknowledges that Australian native forest grown material of these species is prone to surface checking. However, using an approach similar to NET, whereby plantation grown timber is subject to a controlled and gentle drying procedure, he states that surface checking in all of these species can be restricted to well within acceptable levels. Although the above five species are not particularly susceptible to collapse, a period of final steam reconditioning at 100°C and 100% relative humidity will still yield some dimensional recovery, particularly after kiln drying from green (Haslett 1990). After performing some drying studies Young (1983) similar to Haslett (1990) suggested that steam reconditioning might not be necessary for *E. muelleriana*. Of the stringybark species (i.e. *E. globoidea, E. pilularis* and *E. muelleriana*) Haslett (1990 p14) found *E. muelleriana* the easiest to dry. Significantly the air-drying period specified by Haslett (1990) for 25mm thick boards: 5-8 months to 25% MC, is similar as that used by NET: 6-8 months to 20% MC.

Strength

Table 18 details the unseasoned (S) and seasoned (SD) strength groupings for a range of hardwood species including *E. muelleriana* as recorded by Bootle (1983). Additional details on strength groupings are in the Australian Standard AS 2878-1986 – "Timber classification into strength groups".

Table 18. Strength groupings for selected timber species

Species	Unseasoned timber strength grouping	Seasoned timber strength grouping
E. muelleriana	S3	SD3
E. globoidea	S3	SD3
E. pilularis	S2	SD2
E. globulus	S3	SD2
E. regnans	S4	SD3
E. botryoides	S2	SD3
E. nitens	S4	SD4
E. saligna	S3	SD3
Corymbia maculata	S2	SD2
E. sideroxylon	S1	SD3
E. sieberi	S3	SD3
Pinus radiata	S6	SD6

To determine the strength of *E. muelleriana* poles, Boyd (1967) tested only Victorian provenances of the species. He considered this justified because an analysis of data from standard mechanical tests representing trees across the natural distribution of *E. muelleriana,* did not show any difference in strength properties of both green and dried material, between timber grown in NSW and Victoria. This indicates that the strength of timber produced from *E. muelleriana* grown in plantations may be similar irrespective of its location within this range. This aspect may require further research because generally the warmer the climate (or lower the latitude) the stronger the wood (Bootle 1983). For example *C. maculata* and *E. obliqua* from northern NSW are stronger than material from more southerly districts (Bootle 1983).

Durability

The recent draft of the Australian Standard for "Timber – Natural Durability ratings"[74] records *E. muelleriana* as a class 3 (5-15yr life) species for "in ground contact" and a class 2 (15-40yr) species for "outside above ground" applications. Table 19 details the durability ratings for a range of commercial species.

[74] DR 02327 (2002)

Table 19. Natural Durability Ratings of Commercial Species[75]

Species	Lyctid susceptibility of sapwood	Termite resistance of heartwood[76]	Natural durability class of heartwood[77]	
			In-ground contact	Outside above ground
E. muelleriana	Not susceptible	Resistant	3	2
E. globoidea	Not susceptible	Not recorded	2	Not recorded
E. pilularis	Not susceptible	Resistant	2	1
E. globulus	Susceptible	Not recorded	3	3
E. regnans	Not susceptible	Not resistant	4	4
E. botryoides	Not susceptible	Resistant	3	2
E. nitens	Susceptible	Not recorded	4	3
E. saligna	Susceptible	Not recorded	2	2
Corymbia maculata	Susceptible	Resistant	2	1
E. sideroxylon	Susceptible	Resistant	1	1
E. sieberi	Not susceptible	Not recorded	3	2
E. cladocalyx	Susceptible	Resistant	1	1
Pinus radiata	Not susceptible	Not resistant	4	4

E. muelleriana and other durable species (rated 2 or greater) have an advantage over non-durable species because they can be used in exterior applications. In New Zealand E. muelleriana is rated as a "durable" timber (Ian Nicholas pers. comm.).

Unlike many eucalypt species, *E. muelleriana* is not susceptible to attack from the Lyctid borer. This advantage would be particularly prominent where sapwood represents a large percentage of the log volume in fast grown and/or small logs. Washusen et al. (1998) discusses the significant reduction in recovery that the lyctid borer can have on susceptible species such as *E. globulus*, *E. cladocalyx*, *C. maculata* and *E. sideroxylon*.

Bending

Bootle (1983) reports *E. muelleriana* to be unsuitable for steam bending. However NET incorporate curved sections of *E. muelleriana* into many of their bedroom furniture designs. Figure 22 demonstrates that *E. muelleriana* can be (and is) successfully bent or curved without breakage using mechanical methods.

Machining

In a machining evaluation of eight species[78] including *E. muelleriana*, Ozarka et al. (1999a and b) covered six machining operations, which are essential in furniture manufacturing. Following is a summary from the machining evaluation conducted by Ozarka et al. (1999a and b):

1) Circular sawing
   a) Crosscut sawing – both the quality of the sawn surface produced and the degree of tear out on the bottom edge were assessed. Perfect results were achieved for *E. muelleriana* with the Leitz 065889 crosscut circular saw (Ozarka et al. 1999a).
   b) Rip-sawing – Very good results were attained using the Leitz 059250 rip saw. Only very slight tear out was experienced.

[75] DR 02327 Timber – Natural durability ratings. Draft for public comment. (2002) Standards Australia
[76] for "inside above ground" applications
[77] Refer to the Appendix for class definitions
[78] The eight species tested were *E. regnans, E. obliqua, E. viminalis, E. denticulate, E. muelleriana, E. botryoides, E. sieberi* and *Acacia dealbata.*

2) Planing & Moulding/Profiling
   a) Planing – The tests indicated that when planed, most of the species trialed will produce equivalent results to regrowth Victorian ash[79] and are likely to plane well enough for high value furniture. Of the species tested *E. muelleriana* and *E. botryoides* produced the highest percentage of planed pieces acceptable for furniture. Considerably better results were produced for the backsawn timber when planed against the grain rather than with the grain. Planing backsawn *E. muelleriana* produced considerably better results than planning quartersawn timber. The *E. muelleriana* was reported to have a greasy feel after planing.
   b) Moulding – as for most of the species tested the best moulding results were accomplished using a custom tool with a chip breaker. Based on the percentage of defect free pieces *E. muelleriana* was ranked equal second with two other species (83%) behind *E. viminalis* (100%)[80].

3) Drilling/Boring – the performance of every drill bit trialed on all eight species was comparable to Victorian ash. The breakout of the under surface of the through holes caused concern[81]. Ozarka (et al. 1999b) states that the best species were *E. nitens* and *E. muelleriana* (95% and 75% usable holes respectively). No other species returned more than 60% usable holes.

4) Computer numerically controlled (CNC)[82] Routing – The routing tests were relatively brief. Not withstanding the edges produced on *E. muelleriana* samples, were generally rated good to excellent for all router bits tested except bit 4, which caused problems for all species except backsawn *E. sieberi* in one test (Ozarka et al. 1999a).

5) Turning – *E. muelleriana* turned reasonably well, although it was ranked sixth overall (Ozarka et al. 1999b)

6) Sanding – all of the surfaces produced were acceptable for finishing in a polishing shop. The *E. muelleriana* was very prone to clogging of the sanding belt and the depth of cut needs to be kept very shallow to prevent destroying sanding belts.

NET have used many of the machining recommendations made by Ozarka (et al. 1999). They have found *E. muelleriana* to have very good planing and nailing properties (Simon Greenaway pers. comm. 2002).

Only a New Zealand study prepared by Haslett (1990) where the utilisation properties of five eucalypt species (eastern blue gums and stringybark group) were assessed[83], can offer any insight into the machining properties of plantation grown *E. muelleriana*. The following comments are taken directly from Haslett (1990):

1) Blunting – all five species have a more pronounced blunting effect (on steel blade tools) than major New Zealand species Rimu (*Dacrydium cupressinum*) and tawa (*Beilschmiedia tawa*);
2) Planing and moulding – of the species assessed, *E. muelleriana* and *E. globoidea* have particularly good planing and moulding properties;
3) Sanding – no problems in sanding any of the species, although *E. saligna* requires considerable sanding;
4) Sawing – saw burning can be a problem. Fine-tooth tungsten carbide tipped saws should be used;
5) Nailing – green wood of all five species can be nailed without excessive splitting. Dry wood need to be pre-drilled;

[79] Victorian ash is made from regrowth *E. regnans* and *E. delegatensis*.
[80] Fewer sample pieces for some species were available for this trial. Subsequently quartersawn or backsawn pieces of some species were not available for testing.
[81] In other words where the drill came through, the hole was not clean. Chips and splinters could be found on the hole edge.
[82] CNC machines performed the routing operations
[83] This group includes *E. botryoides, E. saligna, E. globoidea, E. muelleriana* and *E. pilularis*

6) Screwing – no problems where holes are pre-drilled for all five species;
7) Turnery - *E. botryoides*, *E. globoidea* and *E. muelleriana* have excellent and superior turnery properties compared to *E. pilularis* and *E. saligna. E. botryoides* and *E. muelleriana* are not thought to have as high a blunting properties as *E. globoidea* and *E. saligna*;

E. muelleriana is regarded as being suitable for furniture production. Haslett (1990) comments that light colour of *E. muelleriana* and *E. globoidea* offers an advantage (over *E. saligna* and *E. botryoides*) because they are amenable to staining in a greater range of final colours.

Krilov (1987) reported that the corrosive properties of *E. muelleriana*, *E. obliqua* and *E. macrorhyncha* on saw blade steels were considerably greater than those of other eucalypts. Krilov (1990) conducted another study more extensively testing the corrosive properties of nine stringybark species including *E. muelleriana*. Of the nine species tested, *E. macroryncha* (mean 6.4027g/m^2/h)[84] and *E. muelleriana* (6.7800g/m^2/h) were the least corrosive of the stringybark timbers. However based on these results *E. muelleriana* timber was still 51% more corrosive than the standard average for other eucalypt species – 4.5 g/m^2/h. These findings are important because processors and furniture manufactures need to be aware that the selection of steel used in saw blades and other shaping tools is an important economic consideration when sawing and machining *E. muelleriana*.

Gluing

Ozarka et al. (1999) found that *E. muelleriana* can be classified as being "difficult to glue". Only one of the four adhesives tested was described as being a "good" performer. Another adhesive was deemed "acceptable with care" and the other two were regarded as "very poor". In contrast, NET class *E. muelleriana* as being easy to glue (Simon Greenaway pers. comm. 2002). This may be because NET are only using the recommended adhesive – AV203.

Interestingly, providing timbers from these species are dust free, freshly machined and dried to appropriate moisture contents, Haslett (1990) indicated that a wide variety of glues can be used successfully on the eastern blue gums and stringybarks (plantation grown). He does however caution against using brands of PVA containing iron because they can cause blue/black stains as the iron reacts with the tannins in the wood. This advice may apply particularly to *E. muelleriana*, which was reported to have the highest tannin content (13%) out of a group of seven eucalypts which included *E. botryoides* and *E. saligna* (Morgan and Newman 1987).

Finishing

Ozarka et al. (1999) found that all eight species can be used in the manufacture of furniture with commercially available coatings. All "Microtone' coatings were suitable for use with *E. muelleriana*. However to select an appropriate type of finish it is important to know how the particular piece of timber will be used in service Ozarka et al. (999). Simon Greenaway from NET described *E. muelleriana* as having "beautiful finishing properties". NET uses the "Microtone" coatings recommended by Ozarka (et al. 1999).

Veneer Production

References detailing veneer production from native forest and/or plantation grown *E. muelleriana* in Australia are scarce. Ozarka (et al. 1999) documents a veneer slicing and drying trial conducted at Gunns Veneers Pty. Ltd. It was reported that the *E. muelleriana* fitches were much denser and harder than the usual Tasmanian oak. Hence they were heated at higher temperatures and for longer times than usual, to facilitate easier veneer handling. During processing *E. muelleriana*, the veneer leaf was inclined to roll up into a tight scroll after it left the knife (Ozarka et al. 1999). Consequently, the leaf was difficult to unroll and stack. These handling problems eased

[84] g/m2/h equates to the loss in steel blade weight and thickness due to corrosion over time

appreciably after the flitch heating time was extended, however the *E. muelleriana* veneer was not as easy to handle as veneer from lower density ash eucalypts (Ozarka et al. 1999).

The *E. muelleriana* veneer was very attractive. It was yellow brown to gold in colour and contained "crossfire" (grain waviness in the tangential plane) with a well-defined ribbon grain on the quartercut surface. Unfortunately the entire *E. muelleriana* consignment processed by GV was marred by extensive Ambrosia borer attack, preventing the production of any face veneer. If defect free *E. muelleriana* flitches could be obtained. Ozarka (et al. 1999) indicated that *E. muelleriana* showed promise as a veneer species.

New Zealand trials have shown plantation grown *E. muelleriana*, *E. globoidea*, *E. botryoides* and *E. pilularis* to slice well (Haslett 1990). Similar to Ozarka et al. (1999), Haslett (1990) indicates that care should be taken to select suitable quality, veneer flitch material.

Markets

General

Bootle (1983) describes wood produced from *E. muelleriana* as being suitable for use as building framework (e.g. stumps, bearers, rafters), sleepers, poles, piles, cross arms and flooring. Ozarka (et al. 1999) adds fence posts and weatherboards to this list. Brooker et al (2000)(Michael Beavan pers. comm. 2002) state that *E. muelleriana* is a common bridge timber. NET have and are continuing to manufacture a wide range of interior furniture from *E. muelleriana*. NET also use large dimension *E. muelleriana* boards in staircases. Arthur Robertson (pers. comm. 2002)[85] preferred species for making outdoor furniture was *E. muelleriana*. RTA use *E. muelleriana* for a variety of additional products including decking, outdoor furniture, cladding, veranda posts and structural columns and drop segment fencing. *E. muelleriana* timber has low electrical resistance properties and therefore is a preferred species to produce "insultimber" droppers used in electric fence design. Wood from *E. muelleriana* has been described as the best firewood in South Gippsland (Geoff Pike pers. comm. 2001)[86]. Whilst in the absence of scientific testing this might be arguable, it is clear that this species has good firewood properties, perhaps similar to *E. macrorycha* (Red Stringybark). When available from native forest in central and south Gippsland, *E. muelleriana* is purchased by Australian Paper - Maryvale as mixed species pulpwood (Harvey Crane pers. comm. 2002). Plantation grown *E. muelleriana* is an accepted pulpwood species in New Zealand (Peter Davies-Colley pers. comm. 2002) and South Africa (Poynton 1979) and would also be accepted by the Australian Paper-Maryvale if it was available (Harvey Crane pers. comm. 2002). *E. muelleriana* clearly produces a versatile wood that is suitable for a wide variety uses.

In today's markets the most popular products manufactured from *E. muelleriana* are flooring, decking, cladding, weatherboards, poles, indoor and outdoor furniture, pulpwood and firewood.

There is no doubt that *E. muelleriana* demonstrates good potential to produce solid wood products in a plantation grown environment. Innovative and enterprising processors are successfully developing species-specific markets for solid wood products developed from *E. muelleriana* grown in native forest. Some processors believe this proven potential can be extended to *E. muelleriana* wood grown in plantations. However the potential and marketing direction for wood that does not meet sawlog specification is not so clear. Even in plantations managed for sawlogs, residual wood from thinnings, toplogs and sawmill residues will make up at least 50% of the volume produced (Hicks and Clark 2001). To maximize returns from *E. muelleriana* plantations, it is important that a commercial outlet is found for this material.

[85] In Bairnsdale, Arthur Robertson during 19 – 1999 manufactured outdoor furniture exclusively from *E. muelleriana*
[86] Forester in Charge at Heyfield

The following section outlines some market options for wood produced from *E. muelleriana* that does not meet sawlog specification:

Pulpwood

Whilst *E. muelleriana* grown in native forest is purchased for pulping in southern NSW (Harris Diashowa) and Gippsland (Australian Paper) it is not generally regarded as a preferred pulpwood species in Australia. Recently Harris Daishowa Pty. Ltd. (HDa) tightened their specifications and have excluded large logs (>60cm dbh) of a range of eucalypt species from their intake. Specifications have been changed in an effort to improve the competitiveness and quality of woodchip produced by HDa, as better quality plantation wood chip commands an increasing share of the market (Peter Mitchell HDa pers. comm. 2002). Species included in the specification change were E. *muelleriana, E. globoidea, E. agglomerata, E. obliqua.* Large logs and more importantly mature age logs of these species were shown to have poor pulping properties relative to younger regrowth logs (Peter Mitchell pers. comm. 2002). This change in specification is in accordance with the findings reported by Mamers et al. (1991a & 1991b) in an assessment of the kraft pulping properties of residual regrowth and mature eucalypt roundwood from east Gippsland. Stringybark species from native forest including *E. globoidea, E. muelleriana, E. macroryncha, E. considenana* when judged in terms of pulping chemical demand, pulp yields and bleachability gave below average results Mamers et al. (1991a). Following is Table 20 that summarizes the results for the ten species analysed:

Table 20. Pulping properties of ten East Gippsland eucalypt species

Species	Active alkali % as Na20[87]	Kappa no.[88]	Screened pulp yield %
E. fastigata	13.0	20.4	49.7
E. sieberi	16.0	19.1	48.7
E. botryoides	17.0	19.6	47.2
E. cypellocarpa	17.0	19.0	44.0
E. obliqua	17.0	19.1	41.8
E. radiata	17.0	19.5	41.7
E. muelleriana	17.0	20.0	41.7
E. macroryncha	17.0	22.4	42.8
E. considenana	17.0	22.4	42.1
E. globoidea	18.0	21.9	39.5

The screened pulp yield of most of the species is poor compared to the yield for 10-year-old *E. globulus* that can produce a screened yield of 53.8% (Hicks and Clark 1991). Based on these figures it would take 1.29 units of mature *E. muelleriana* produce an equivalent pulp yield to one unit of 10-year-old *E. globulus*. Compounding this, *E. muelleriana* requires higher chemical inputs to produce an acceptable pulp.

Mamers et al. (1991b) also reported pulping properties for regrowth eucalypts including *E. muelleriana* in East Gippsland. The eucalypts sampled were much younger (47-77 years of age) than the Mamers et al. (1991a) study and predictably, the pulping properties were substantially better than the mature wood of these species. Unfortunately in this study the woodchips from *E. muelleriana* and *E. globoidea* were analysed in a mixture, making definite conclusions regarding the pulping quality of *E. muelleriana* difficult to make with absolute confidence. Table 21 summarises the results from the study.

[87] % active ingredient required to dissolve the lignin that is binding wood fibres (cellulose) together. The less required the better
[88] number of millilitres of 0.1 N potassium permanganate consumed per gram of pulp. This provides a measure of the amount of lignin present in kraft pulp. The lower the Kappa no. the better

Table 21. Species rankings according to pulping properties (Mamers et al. 1991b)

Ranking	Species	Basic Density kg/m^3	Active alkali % as Na20	Kappa no.	Screened pulp yield %	kg pulp/m^3 wood
Ref sample	*E. regnans (A-grade)*	*507*	*11.5*	*21.5*	*55.3*	*280*
1	*E. sieberi*	580	11	19.8	55.6	322
2	*E. macroryncha/E. baxteri*	562	12.0	20.4	50.1	282
3	*E. muelleriana/E. globoidea*	608	12.5	20.6	51.4	313
4	*E. cypellocarpa*	616	12.75	20.6	49.3	304
5	*E. obliqua*	568	13.5	20.0	48.4	275

This summary shows that the younger regrowth *E. muelleriana* has vastly better pulping properties than the mature wood tested by Mamers et al. (1991) in the earlier study (see Table 20). This is presumably due to the general trend where basic density and extractive content increase while pentosan content[89] tends to decrease as a tree ages. Hall et al. (1973) reports that these changes in wood properties with age, mean that more active alkali is required to produce the maximum screened pulp yield.

The studies of the pulping properties for regrowth and mature wood shows that the gap between the preferred pulpwood species *E. sieberi* and *E. regnans* and the less preferred species – *E. muelleriana* was closed significantly when younger wood samples were taken from each species .

The following findings have been summarised from Mamers (et al. 1991b) regarding the pulping prospects of regrowth *E. muelleriana*:

- The higher basic density of the *E. muelleriana/E. globoidea* sample compared to the A-grade regrowth sample provided an advantage in digester productivity (i.e. more kg pulp produced per m^3 of wood).
- Of the tested species the *E. muelleriana/E. globoidea* pulp was the easiest to bleach, producing a superior result compared to the A-grade reference sample
- The strength of the kraft pulp produced from *E. muelleriana/E. globoidea* (when bleached using the CEHD sequence), exceeded the tear and tensile index[90] suggested by Rydholm and Gedda (1967 cited by Mamers et al. 1991b) for the manufacture of fine papers;
- The *E. muelleriana/E. globoidea* sample at Kappa number 20, produced an exceptionally high black liquor viscosity and a low swelling volume, which indicates that the black liquors produced during the pulping of *E. muelleriana/E. globoidea* may be more difficult to treat in the pulp mill recovery system, compared to the black liquors of current A-grade pulp mixtures.

Mamers et al. (1991b) ranked the species tested in order of pulpwood quality as *E. sieberi* > *E. macroryncha/E. baxteri* > *E. muelleriana/E. globoidea* > *E. cypellocarpa* > *E. obliqua*.

Given the younger age of the wood sampled for this study, these results are likely to more closely resemble the pulpwood quality of *E. muelleriana* produced in a plantation environment. It is expected that the pulpwood quality of plantation grown *E. muelleriana* may be substantially different again given that pulpwood would be produced from younger (i.e. 15-35yrs) and faster grown trees compared to these regrowth trees (47-77 yrs).

[89] Content of sugar based complex carbohydrates
[90] a paper making strength standard

Hall et al. (1973) confirmed this hypothesis in a study on the effect of species, age and wood characteristics on the quality of eucalypt kraft pulp. The pulping characteristics of eleven species[91] including *E. muelleriana* were evaluated. Species and age classes within species were ranked on the basis of the four perceived economically important variables; burst factor, active alkali per air dry ton of pulp, screened pulp yield and cubic units of wood (ft^3) required to produce one air dry ton of pulp. Three age classes were analysed – young (<26 years), mature (26-64 years) and over mature (>64 years).

Table 22. Relative ranking position for *E. muelleriana* as described by Hall (et al. 1973).

Species	Relative ranking position based on the four most economically important variables (all rankings are out of 33)					
	Burst factor[92] important			Burst – no advantage above av. Penalty if below		
	Y (<26yrs)	M(26-64yrs)	O(>64yrs)	Y(<26yrs)	M (26-64yrs)	O(>64yrs)
E. muelleriana	11	20	32	5	20	32
Mean position of all species for age	13	15	24	12	15	24

Hall et al. (1973) demonstrated that the pulpwood quality of young *E. muelleriana* was markedly superior to the mature and over-mature age classes. Young *E. muelleriana* was ranked better than average on the basis of the four most economically important pulp quality variables. Where there was no advantage to the consumer if the burst factor was higher than the overall average (i.e. they do not need an above average strength paper), the ranking of *E. muelleriana* improved considerably (5 out of 33). This occurred because the high burst factor of species such as *E. regnans* and *E. delegatensis* was counteracted by their relatively high wood requirement to produce a ton of pulp.

This study demonstrates that residual grade *E. muelleriana* grown in plantations over a 30 year rotation has the potential to produce wood pulp comparable in quality to the majority of the species it is likely to compete against for market share. In accordance with this finding, Australian Paper – Maryvale recently stated that they would be likely to purchase plantation grown *E. muelleriana* wood as pulpwood, if it was available (Harvey Crane pers. comm. 2002).

Posts and poles

Because of its high strength and natural durability, *E. muelleriana* throughout its natural range in Victoria and NSW, has been regarded for many years as one of the preferred species for poles, (Boyd 1967). Several references including Bootle (1983), Ozarka (et al. 1999), Cremer (ed. 1990), Brooker et al. (2000) and Costermans (1983) include posts and/or poles as one of the main uses for the species. RTA specify *E. muelleriana* as their preferred species for round poles[93].

The suitability of *E. muelleriana* for posts and poles grown in plantations is not as well known. However Waugh et al. (1997) gave *E. muelleriana* (together with *C. maculata* and *E. saligna*) the highest possible rating as a species suited to the production of round timbers in plantations in a 20-25 year rotation. Barr (1996) noted that unlike many other eucalypts *E. muelleriana* develops durable heart timber very early, suggesting that it would be suitable to use *E. muelleriana* in post and pole applications when grown in plantations. Warden (2002 unpub.) found 3-5 year old *E. muelleriana* posts to be stiffer and significantly stronger than *P. radiata* poles of similar dimension. Chris McEvoy, a director of RTA and Preschem Pty. Ltd., has indicated that the market for posts and poles produced from durable plantation species is likely to expand. Subsequently RTA have

[91] The species tested were *E. regnans, E. delegatensis, E. globulus, E. baxteri, E. cypellocarpa, E. radiata, E. obliqua, E. sieberi. E. muelleriana, E. globoidea* and *E. consideniana*
[92] Burst factor is a measure of bursting strength. Bursting strength is the point to which paper can withstand pressure without rupturing.
[93] Refer to www.radialtimber.com.au

expressed a strong intention to trial plantation *E. muelleriana* amongst other durable species (e.g. *E. sieberi* and *E. globoidea*) for suitability in post and pole applications.

The current demand for posts for vine trellises is estimated at more than 10 million a year (Australian wide)[94] – for around 10,000 hectares of new plantings and to replace existing posts that have been damaged during grape harvesting (CSIRO Forestry and Forest Products 2001). Assuming an average post dimension of 2.4 metres long and 95mm in diameter, 10 million posts equated to ~170,000 m^3 of wood. CCA treated *P. radiata* currently services the majority of this market. However breakage of pine posts at harvest is a significant and costly problem; 5 to 10% of posts broken at harvest (CSIRO Forestry and Forest Products 2001). The superior strength and stiffness properties of young eucalypt posts demonstrate that thinnings from young eucalypt plantations may be a good option as a superior replacement alternative, over pine posts in vineyards.

These findings and developments indicate that thinnings from plantation grown *E. muelleriana* shows good potential for use in post and poles applications. Posts and small diameter poles could be produced during thinning operations from small logs <250mm in diameter. Larger diameter poles may be another market option for sawlogs (particularly small logs) produced in plantations. More work is required to clarify the market demand and the suitability of *E. muelleriana* as a plantation grown post and pole option.

Firewood[95]

Australian households burn between 4.5 – 5.5 million tonnes firewood each year (Dexter 2002). The industry is predominantly based in the cooler southeast and south west of Australia (Dexter 2002). In Victoria it is estimated that 1,035,400 green m^3 of firewood[96] is consumed each year (Sylva Systems P/L 2002). To put this in perspective, approximately 1.15 million m^3 of pulpwood was extracted from Victoria's state forests in 1999 (NRE 2001).

It is estimated that the weighted average price paid for firewood in Victoria is $52.91/ air-dry tonne or $31.68/$m^3$. The value of the firewood market is estimated to be around 32.6 million dollars per year (Sylva Systems 2002). Hardwood pulpwood is usually purchased for $40-50/tonne in southern Australia. It is estimated that 34% of the firewood consumed in Victoria in purchased. The remaining 66% is collected by the consumer (Sylva Systems 2002).

Within the West and EAST Gippsland regions, where *E. muelleriana* is an indigenous species, approximately 83,000 air-dry tonnes (~138,000 green m^3) of firewood is estimated to be consumed per year. This represents 13.5% of Victoria's total consumption (Sylva Systems 2002).

The importance of firewood to the lifestyle of Australians is underestimated. For many Victorians (particularly in regional areas) firewood is a necessity as a major source of fuel for heating and to a lesser extent, cooking. This is particularly the case for those Victorians without access to natural gas– approximately 20% of households (AGA, 2001, cited by Sylva Systems 2002).

The future demand for firewood will be influenced by a number of factors that are summarised by Davies (2002) and Sylva Systems (2002). Whilst this makes it difficult to predict the future long-term demand for firewood, it is unlikely that there will be a change in the level of demand for firewood in the short term (Sylva Systems 2002).

[94] In the article it is not clear what area this demand covers. It has been assumed that it an Australia wide demand.
[95] This section refers extensively to the Victorian Firewood Strategy Discussion Paper prepared by Sylva Systems Pty. Ltd. (2002) on behalf of the Department of Natural Resources and Environment.
[96] This is equivalent to 620,000 air dry tonnes using the conversion rate of 1.67 green m^3/ air dry tonne (Sylva Systems P/L)

Growing firewood in sustainably managed plantations addresses many of the main concerns surrounding the firewood industry and also brings forth the prominent advantages of using wood as an energy source. The major advantages of producing firewood from plantations include:

- Reducing the threat to native forest biodiversity (e.g. leaving dead trees with hollows and coarse ground fuels for food and habitat in native forests). This is particularly important given the huge reductions in areas of native forest available for firewood collection, placing more pressure on areas where firewood collection is permitted
- Using a greenhouse neutral or positive energy source. Providing plantations harvested for firewood are replanted following harvesting, they offset the CO_2 greenhouse gas emitted during burning
- Using a truly renewable energy source (firewood produced in <15years) unlike fossil fuels such as natural gas or coal
- Improves the financial viability of plantations as a sustainable land use, by providing another market option for residual wood
- Indirectly improvements to ecosystem health. Firewood plantations can be established in areas suffering from the consequences of unsustainable land use, such as erosion, salinity, poor water quality, loss of habitat etc.

Historically consumers of firewood have shown a preference for heavy timbers such as Red Gum (*E. camaldensis*) and box/ironbark species. Plantation grown wood has not been as highly regarded as the aforementioned species. However, it appears that perceptions are changing as plantation grown Sugar Gum (*E. cladocalyx*) firewood is gaining widespread acceptance in southwest Victoria (Sylva Systems 2002). Throughout its natural range in Gippsland, *E. muelleriana* is regarded as a good firewood species. The firewood properties of *E. muelleriana* have not been published. However, using the air-dry density of the species as a guide, combined with personal experience, some conclusions can be made.

The air-dry density of *E. muelleriana* grown in native forest conditions is 870kg/m^3, approximately 5% less dense than *E. camaldelensis* – the traditionally preferred firewood in Victoria. Denser species have the advantage of yielding a larger amount of heat per unit volume. However this is counterbalanced by their slower rate of drying (Bootle 1983). *E. muelleriana* has good splitting, ignition and coaling properties and produces no ash (Ozarka 1999).

Plantation grown *E. muelleriana* has a lower air dry density (~646-684kg/m3)[97] than native forest grown wood and therefore the quality of its firewood properties will be reduced. Nonetheless its firewood properties are likely to compare favourably with the principal eucalypt plantation species in Gippsland – *E globulus*, *E. nitens* and *E. regnans*.

Whilst the pulpwood market in Victoria is currently larger than the firewood market, in the long term it is likely to be dominated by preferred species such as *E. globulus*, *E. nitens*, *E. regnans*, *E. delegatensis* and *E. sieberi*. These species are likely to produce inferior firewood from plantations than *E. muelleriana*[98]. Subsequently it could be argued that the there is good potential for residual grade *E. muelleriana* to be sold as firewood in the Gippsland region. However a key consideration when evaluating the suitability of this option, is that only 34% of firewood in Victoria is purchased. For this market option to become a reality, a strategic campaign that educated consumers on the benefits of plantation grown firewood and specifically *E. muelleriana* would need to be undertaken.

Other residual wood options

In the long-term markets for *E. muelleriana* residual wood products may develop in the biofuel, medium density fibreboard (MDF) and particle board industry sectors. Thinnings from *Pinus*

[97] New Zealand data taken from trees =>25 years old
[98] Whilst the density of *E. globulus* will be similar to *E. muelleriana*, the splitting and ignition properties are likely to be inferior.

radiata plantations provide most of the material for particleboard manufacture in Australia and New Zealand, indicating that options to use wood from *E. muelleriana* plantations would be limited.

The Gippsland and southeast NSW regions lack existing composite wood product processing facilities that might provide an alternative market for plantation timber. At this stage there is little information available regarding the existing or potential use of *E. muelleriana* in the manufacture of these products.

Economic considerations

When considering options for the commercial use of residual wood products it is important to explore the potential risk and financial ramifications of being unable to profitably sell residual wood products. If a plantation primarily established for sawlog production is managed appropriately, the bulk of the financial returns will be generated from the sale of sawlogs. Whilst the sale of residual products improves returns in sawlog plantations, the lack of a market for these products in well planned and managed plantations should not dramatically reduce the financial returns from a sawlog plantation venture.

Borough et al. (1997) used STANDPAK[99] to evaluate the financial returns of five different management regimes[100] in *P. radiata*. It was concluded that if no commercial market was available for the thinnings, then a non-commercial thinning regime is preferred as this practice facilitates an acceptable financial return at the completion of the rotation. Table 26 shows the results of the Borough et al. (1997) analysis.

Table 23. Costs and returns from *P. radiata* (Borough et al. 1997)

Regime	IRR %	% Sawlog	% Pulplog	Total costs incurred	Total returns generated
NCT	9.5	79	21	$1950	$24310
Unthinned	7.4	63	36	$1650	$12440
Delayed thinning	8.6	62	38	$1710	$13550
2 thin	10.6	68	32	$1760	$20460
3 thin	11.1	60	40	$1810	$21030

In terms of internal rate of return (IRR) the 2 thin and 3 thin options were more profitable than the non-commercial thinning option. However in the absence of a residual wood market the NCT regime has still produced an acceptable financial return. This is largely because the early NCT resulted in both a higher percentage of sawlogs and a higher percentage of sawlogs reaching larger size classes where a premium is paid.

As previously established, to produce large sawlogs of *E. muelleriana* in plantations within 35 years, NCT is required. This silvicultural operation concentrates growth on fewer stems to produce a high volume of sawlog at the direct expense of residual log volume. Subsequently as shown by Borough et al. (1997) the return generated by residual wood in a NCT regime, is a smaller percentage of the total financial return, relative to common industrial scale sawlog/pulpwood regimes (i.e. 2 or 3 thinnings).

In 2001 and 2002 as part of NRE's Farm Tree Planning Service Woollybutt Pty. Ltd. analysed the projected financial performance of an *E. muelleriana* sawlog plantation on a low rainfall site (~5ha in area) managed under a NCT regime in Gippsland. Table 24 shows the results of the analysis.

---

[99] STANDPAK – is a computer package used to model financial returns generated from different management scenarios in *P. radiata*.
[100] The five regimes were non-commercial thin, unthinned, delayed thinning, 2 thin and 3 thin.

Table 24. Indicative returns from a NCT *E. muelleriana* plantation with or without a residual wood market.

Site	Internal Rate of Return		Total Return		
	Residual market available	No residual market available	Residual market available	No residual market available	% difference
Low rainfall – 690mm/yr	6.22%	5.29%	$21,032	$18,272	13.1

These figures demonstrate that whilst markets for residual products improve financial performance they do not necessarily determine the financial viability of a project. Indeed Borough et al. (997) showed that timely thinning of a sawlog plantation has a far more significant influence on financial performance than the presence or absence of residual wood markets.

Recommendations

E. muelleriana merits further investigation as a sawlog plantation option on suitable sites in south-eastern Australia. The following recommendations have been presented as suggestions to guide any further investigation:

1. Review the current market for *E. muelleriana* wood products. The results could be used as a platform from which to speculate on future market demand for *E. muelleriana*. The reasons behind its demand should be quantified. Also whether these reasons will apply to plantation grown timber should also be investigated
2. That additional stringybark and durable species be further investigated as options for sawlog plantation development in south-eastern Australia. Species that demonstrate good potential include *E. globoidea*, *E. baxteri*, *E. agglomerata*, *E. laevopinea*, *E. macroryncha* and *E. sieberi*;
3. Place a higher priority on researching durable hardwood species for solid wood production (particularly in high rainfall areas). A good starting point would be to:
    a. Measure existing species trials > 10 years of age that contain *E. muelleriana* in East Gippsland and NSW
    b. Re-measure the Mullungdung forest, *Phytophthora cinnamomi E. muelleriana* trial managed by the Forest Science Centre, Vic. Produce a report and distribute the results to relevant Regional Plantation Committee's and government agencies within southern Australia
4. Develop a closer formal and functional alliance between relevant south east Australian forest industry organizations and Forest Research in New Zealand to facilitate better information transfer particularly regarding durable eucalypt species research. In particular the forestry industry in southern Australia should revisit the prospect of becoming a financial or in-kind partners with the Forest Research in their growth and yield trials of eucalypt species with solid wood end-use potential;
5. Conduct a sawing and drying trial that provides some qualitative information about the solid wood utilisation prospects for the species when grown in plantations. This trial should particularly focus on the impact of growth stress and juvenile core on green sawn recovery. Plantations in the Newcastle forest management region of NSW, contain enough trees of suitable age, log size and quality for these trials to be undertaken;
6. Investigate the machining, gluing, finishing and veneer production properties of plantation grown *E. muelleriana*. Seek NET co-operation in this work;
7. A species climatic profile similar to those developed by Jovanivic and Booth (2002) should be developed to assist the correct siting of the species;
8. Develop a tree improvement program that initially targets more extensive provenance testing, so provenances with superior form, growth, frost and *Phytophthora cinnamomi* tolerance and wood properties can be identified for plantation establishment in the short to medium term;
9. Develop a basic establishment regime for *E. muelleriana* that appropriately considers the physiology of the species. Research should target the root configuration of *E. muelleriana* and its impact on weed control and nutritional regimes
10. Conduct a study to better evaluate the relationship between soil type and *E. muelleriana* trial performance in the Hunter Valley, NSW region.

Conclusions

Through the development of a species profile for *E. muelleriana*, this study has investigated the potential of *E. muelleriana* as a plantation option for the production of high value solid wood products. The available quantitative and a large amount of qualitative evidence commends *E. muelleriana* as having good potential as a plantation species for the production of high value wood products.

E. muelleriana offers many benefits as a plantation species managed principally for sawlog production. Evidence shows that *E. muelleriana* has good to excellent utilisation properties. Indeed these properties may become its trademark as a plantation species. The timber of *E. muelleriana* has many desirable attributes that promise to make it suitable for a wide range of products that will be demanded by consumers as high value solid timber products. In southeast NSW, *E. muelleriana* grown in native forest is already the basis of an established and thriving solid timber products industry. In this region, *E. muelleriana* timber products have been developed around the premium features of the timber. Subsequently the retail markets for the species are expanding and have good prospects. These markets for *E. muelleriana* grown in native forest gives plantation developers a ready base from which to work from.

In plantations there are potentially several market options for residual grade wood. However these options require negotiation and further development before they can be regarded as secure. Nonetheless providing *E. muelleriana* plantations have been sited and managed appropriately to produce sawlogs, it can still be a viable investment option, even where markets for residual grade wood are small and/or limited.

E. muelleriana also has good establishment and management attributes where it is sited appropriately. Its emergence as a sawlog plantation species would provide the forest industry with improved diversity in species choice, which could potentially assist to reduce the risk associated with investing in one species.

Being a *Monocalyptus* species *E. muelleriana* also offers some challenges to plantation developers. It is relatively site specific and exhibits significant form problems when established on fertile ex-pasture sites. Adjustments are required to generic establishment regime models that have been developed largely for *Symphyomyrtus* species, to optimise growth rates, tree health and form and to maximise the production of high quality solid wood. Providing a co-ordinated approach is adopted, these challenges can be overcome using methodologies that have already been developed for other plantation species. It is significant that growing *E. muelleriana* in a plantation may prove more challenging than processing it for high value wood products.

Bibliography

Austin, M.P., Cunningham, R.B. and Good, R.B. (1983). Altitudinal distribution of several eucalypt species in relation to other environmental factors in southern NSW. *Australian Journal of Ecology, 8: 169-180.*

Austin, M.P., Nicholls, A.O., Doherty, M.D. and Myers, J.A. (1994). Determining species response functions to an environmental gradient by means of a β-function. *Journal of Vegetation Science, 5: pp215-228.*

Austin, M.P., Nicholls, A.O. and Margules, C.R. (1990). Measurement of the realized qualitative niche: environmental niches of five *eucalyptus* species. *Ecological Monographs, 60(2), 1990, pp.161-177.*

Australian Gas Association (2001). Gas in Victoria. Number 8, February 2001

Barr, N. (1996). Growing Eucalypt Trees for Milling on New Zealand Farms. New Zealand Farm Forestry Association.

Bird, P.R., 2000. Farm Forestry in Southern Australia – a focus on clearwood production of specialty timbers. Department of Natural Resources and Environment.

Bird, P.R., Kearney, G.A. and Jowett, D.W. (1996). Trees and Shrubs for South West Victoria. Agriculture Victoria, Pastoral and Veterinary Institute, Hamilton, Victoria, Australia.

Boland, D. J., Brooker, M.I.H., Chippendale, N.; Hall, N., Hyland, B.P.M., Johnson, R.D., Kleinig, D.A., and Turner, J.D. (1984). Forest Trees of Australia. Fourth Edition. Nelson-CSIRO, Melbourne.

Bolza (1978). The mechanical properties and characteristics of the timber of spotted gum (*Eucalyptus maculata* Hook.) in relation to origin and maturity. Thesis submitted to the University of Melbourne.

Bootle, K. R. 1983. Wood in Australia. Types, Properties and Uses. McGraw-Hill Book Company, Sydney.

Borough, C., Mason, P., and Raymond, D., (1997). Economics of Thinning – Special Liftout Section No. 42 *In.* Australian Forest Grower Summer 1997/98. Vol 20, No. 4.

Boyd, J.D. (1967). The Strength of Australian Pole Timbers – V. Yellow Stringybark Poles. Division of Forest Products Technological Paper No. 50. CSIRO. Australia.

Brooker, M.I.H., 2000. A new classification of the genus Eucalyptus l'Her. (Myrtaceae). Aust. Syst. Bot. 13:79-48.

Brooker, M.I.H., Connors, J.R., and Slee, A.V. 2000. EUCLID. Eucalypts of South EASTern Australia. Revised Edition. CSIRO and Centre for Plant Biodiversity Research.

Clinnick, P. (2002). Dutson Downs Integrated Site Repatriation and Management. *In.* National Low Rainfall Farm Forestry Conference – Proceedings, NRE Victoria.

Costerman, L. (1983 revised ed.). Native trees and shrubs of south-eastern Australia. Reed New Holland.

CSIRO Forestry and Forest Products (2001). Onwood 33 – Winter 2001.

Dexter, N. Dr., (2002). Firewood – a boost to farm forestry. *In.* National Low Rainfall Farm Forestry Conference – Proceedings, NRE Victoria.

Duncan, M.J., Baker, T.G., Appleton, R. and Stokes, R.C. (2000). Growth of Eucalypt Plantation Species Across Twelve Plantation Sites in Gippsland Victoria. NRE, Vic.

Eldridge, K., (1968). Physiological studies of altitudinal variation in *Eucalyptus regnans*. *Proc. Ecol. Soc. Aust.* 3, 70-76.

Forestry Commission of New South Wales (1983). Notes on the silviculture of major NSW forest types. No. 2 Moist Tableland Hardwood Types. For. Comm., Sydney.

Fujii, D.M. (1976) The Nuuanu eucalyptus planting: growth, survival, stand development after 64 years. PSW-318. USDA Forest Research Note.

Hall, M.J., Hansen, N.W. and Rudra, A.B. (1973). The effect of species, age and wood characteristics on Eucalypt kraft pulp quality. *Appita* Vol. 26, No. 5.

Hallam and Read (1989)

Haslett, A.N. 1990. Properties and Utilisation of Exotic Specialty Timbers Grown in New Zealand. Part VI: Eastern Blue Gums and Stringy Barks – *Eucalyptus botryoides* Sm., *Eucalyptus saligna* Sm., *Eucalyptus globoidea* Blakey, *Eucalyptus muelleriana* Howitt, *Eucalyptus pilularis* Sm. Forest Research Bulletin No. 119.

Hamilton, L. (2002). Market opportunities and economic viability of growing firewood plantations. *In.* National Low Rainfall Farm Forestry Conference – Proceedings, NRE Victoria.

Hay, E. and McKenzie, H. 2002. Forest Research Durable Hardwood and Species Trial Note. unpub.

Hicks, C.C. and Clark, N.B. (2001). Pulpwood quality of 13 eucalypt species with potential for farm forestry. RIRDC Publication No. 01/164

Jacobs (1938). The fibre tension of woody stems, with special reference to the genus *Eucalyptus*. Commonwealth Forestry Bureau, Australia, Bulletin No. 22, 37pp

Johnson, I. G. and Stanton, R. R. (1993). Thirty years of eucalypt species and provenance trials in New South Wales – Survival and Growth in trials established from 1961-1990. Research Paper No. 20. Forestry Commission of NSW – Research Division.

Kelly, J. and Turner, J. (1978). Soil nutrient-vegetation relationships in the Eden Area, NSW 1. Soil nutrient survey. *Aust. For.* 41:127-134.

Kininmonth, J.A., Revell, D.H., Williams, D.H. (1974). Utilisation of New Zealand grown eucalypts for sawn timber and veneer. NZ J. For. 19(2): 246-263.

Krilov, A. (1987). Corrosive properties of some eucalypts. *Wood Sci. Technol*. 21:211-217

Krilov, A (1990). Corrosive properties of “stringybark” eucalypts. *Wood Sci. Technol*. Vol 28, No. 3 pp113-121.

Kubler, H. (1987). Growth stresses in trees and related wood properties. *Forestry Abstracts* 48, 131-189.

Laffan, M. (2002). An Introduction to Tasmanian Forest Soils. Course notes. Forestry Tasmania

Maiden, J.H. (1917). Forestry handbook. Part II. Some of the commercial trees of New South Wales. W.A. Gullick, Govt Printer, Sydney.

Mamers, H., Balodis, V., Garland, C.P., Langfors, N.G. and Menz, D.N.J. (1991). Kraft pulping of EAST Gippsland regrowth. *Appita* Vol. 44:6 pp 375-378.

Mamers, H., Balodis, V., Garland, C.P., Langfors, N.G., Menz, D.N.J., and Chin, C.W.J. (1991). An assessment of the kraft pulping properties of residual mature eucalypt roundwood from east Gippsland. *Appita* Vol. 44:4 pp 252-260.

Maree, B. and Malan, F.S. (2000) Growing for solid hardwood products – a South AFRcan experience and perspective. In: The Future of Eucalypts for Wood Products , Proceedings of IUFRO Conference, Launceston, Tasmania, Australia, 19-24 March 2000, pp. 319-327.

Marks, G.C., Fuhrer, B.A., and Walters, N.E.M. (1982). Tree Diseases in Victoria – Handbook No. 1. Forests Commission, Victoria.

Marks, G.C., Kassaby, F. Y. and Reynolds, S.T. (1972). Die-back in the Mixed Hardwood Forests of Eastern Victoria: A Preliminary Report. *Aust. J. Bot.*, 1972, 20, 141-54.

McKinley, R. B., Shelbourne, C. J. A., Harris, J.M., and Young, G.D. (2000). Variation in whole-tree basic wood density for a range of plantation species grown in New Zealand. In: *New Zealand Journal of Forestry Science* 30(3): 436-446 (2000).

Monsanto Tech-Topics, TT 65. Agricultural division, Monsanto Australia Ltd.

Morgan, K.R., and Newman, R.H. (1987). Estimation of the tannin content of eucalyptus and other hardwoods by carbon-13 nuclear magnetic resonance. *Appita* Vol 40. No. 5.

Neave, I.A., and Florence, R.G. (1994). Effect of root configuration on the relative competitive ability of *Eucalyptus maculata* Hook. regrowth following clearfelling. *Australian Forestry* 57,pp49-58

Noble, I.R. (1989). Ecological traits of the Eucalyptus L'Herti. Subgenera Monocalyptus and Symphyomyrtus. *Aust. J. Bot.* 37: 207-224.

Department of Natural Resources and Environment (2001). Private Forestry – Investing in Victoria. The State of Victoria.

Ozarka, B., Thompson, R. Lee, M., Northway, R., Ilic, J., Molenaar, S., Turville, G. and Iskra, B. (1999). The Use of Australian Hardwoods for High Value-Added Wood Products – Yellow Stringybark User Manual. CSIRI Client Report No. 559

Poynton, R.J. 1979. Report to SARCCUS on Tree Planting in Southern Africa, Vol. 2 – THE EUCALYPTS. South Africa Forestry Research Institute.

Radial Timber Australia Ltd. 1999. Radial Timber Australia Ltd. 1999 Prospectus.

Reid, R. and Stephen, P. (2002). The Farmers Forest. Multipurpose Forestry for Australian farmers. RIRDC Publication No. R01/33.

Ryan, M., Hudson, R., Lutze, M., Baker, T. and Bail, I. (1992). Establishment report for intensively managed eucalypt trials at Tamboon, EAST Gippsland. Department of Conservation and Natural Resources, Victoria (Unpublished)

Rydholm, S. A. and Gedda, L. F. (1967). *Paper Techn*. 8:T61

South EAST New South Wales Private Forestry. Treescene – Eucalyptus muelleriana. Infosheet 13.

Shelbourne, C.J.A. (in prep). Domestication of Stringybark Eucalypts: A literature review. Forest Research, New Zealand.

Shelbourne, C.J.A. (2000). Stringybark Eucalypts in NSW Central Coast Forests. Project record no. 8471 (unpublished) December 2000

Shelbourne, C.J.A., Low, C.B., McConnochie, R.M., and Hay, A.E. (2000). Stringybark eucalypts for New Zealand: 6-year results from a provenance/family trial of *Eucalyptus muelleriana* in Northland. *New Zealand Journal of Forest Science* 30(3): 384-400.

Simpson, J., Stone, C. and Eldridge, R. (1997). Eucalypt Plantation Pests and Diseases – Crop Loss Study. Forest Research and Development Division, State Forests of NSW, Sydney.

Stackpole, D. (1998). Thinning eucalypts for sawlogs. Agricultural Note AG0775. Department of Natural Resources and Environment, Victoria.

Stackpole, D. (1998). A suggested stand management regime for eucalypt sawlog rotation. Agricultural Note AG0776. Department of Natural Resources and Environment, Victoria.

Stewart, H.T.L., and Flinn, D.W. (1984). Establishment and early growth of trees irrigated with wastewater at four sites in Victoria, Australia. *Forest Ecology and Management* 8:243-256

Sylva Systems Pty. Ltd. (2002). Victorian Firewood Strategy Discussion Paper. Department of Natural Resources and Environment.

Tibbits, J., and Sasse, J. 1999. An evaluation of the potential to improve spotted gums by breeding. CFTT Report No. 99/029. Department of Natural Resources and Environment, Victoria.

Turnbull, C.R.A., McLeod, D.E., Beadle, C.L., Ratkowsky, D.A., Mummery, D.C. and Bird, T. (1993). Comparative early growth of *Eucalyptus* species of the subgenera Monocalyptus and Symphyomyrtus in intensively managed plantations in southern Tasmania. *Aust. For.* 56: 276-286.

Wang, H., Zheng, Y., Zang, D., Zhang, Z., and Huang, Y. (1999). Species introduction of Monocalyptus to south-western China and its biogeographic implications. *Scientia Silvaue Sinicae* 35(2) March.

Warden, P. G. (2002). Flexural Moduli and Strengths of Small-Diameter Poles Produced from Plantation Thinnings. South EAST NSW Private Forestry.

Yang, J. and Waugh, G. (2001). Growth stress. its measurement and effects. Australian Forestry 64(2) 127-135

Washusen, R.K. (1998). Wood quality of plantation eucalypts from medium rainfall areas of the southern Murray-Darling Basin. Master of Wood Science thesis. Department of Forestry, The University of Melbourne. pp 13-48.

Washusen, R., Waugh, G., and Hudson, I., (1998). Wood products from low-rainfall farm forestry – Final Report. Project PN007.96, Forest and Wood Products Research and Development Corporation.

Waugh, G., Yang, J., and Ozarka, B., (1997). Sawn products from young, plantation-grown eucalypts. Paper presented to IUFRO Division 5 conference, Pullman, Washington State. CSIRO, Australia.

Woollybutt Pty. Ltd. (2002). Savage and Mandaletti – Farm Tree Plan. Prepared on behalf of the Department of Natural Resources and Environment. Unpublished.

Appendix

Appendix A1. Location and site characteristics for the *E. muelleriana* sites in Northland, New Zealand

Site	Location	Latitude[101]	Longitude[10]	Altitude (masl)[103]	Aspec	Slope	MAR (mm/yr)[104]	Average temp[105]	Frost/ yr	Soil Description	Position in landscape	Area (ha)	Previous land use
Thom	Helensville	*36°68'S*	*174°45'E*	0-200	SW	0-10°	*1000-1500*	*14-15°C*	n/a	Subject to seasonal waterlogging	Lower slope	~2ha	Stock grazing
Furniss	Kaukapakapa	*36°61'S*	*174°49'E*	(100)	W		(1800)	*14-15°C*	n/a	Deep clay loam	mid-slope	10 trees	Stock grazing
Pederson 1	Karaki Rd. Parakao	35° 43'S	173° 55'E	135	NE	10-25°	1623	14.40°C	(~20)	Sandstone derived yellow brown earth – "Waitera clay"	Lower slope	1.16ha trial	Dairy
Pederson 2	Karaki Rd. Parakao	35° 43'S	173° 55'E	135	E	15-25°	1623	14.40°C	n/a	Sand stone derived yellow brown earth	Upper slope	~0.5ha	Dairy
Davies Colley 1	Titoki	*35°73'S*	*174°05'E*	60	NE	10°	~1600	*14-15°C*	n/a	yellow brown earth. Slightly podsolised	Lower slope	~1ha trial	Stock grazing
Davies Colley 2	Titoki	*35°73'S*	*174°05'E*	80	E	5-20°	~1600	*14-15°C*	n/a	yellow brown earth. Slightly podsolised	mid-lower slope	~5ha	Stock grazing
Davies Colley 3	Tangiteroria	35°48'S	174°01'E	80	W	10-25°	~1600	*14-15°C*	n/a		mid-slope		
McGee	Warkworth	*36°40'S*	*174°66'E*	(60)	E	10°	(1800-2000)	*14-15°C*	(<10)	Yellow clay over sandstone	Lower slope	<1ha	Stock grazing
Tairua Forest	Whangamata	*37°21'S*	*175°87'E*	100	E	10-20°	1760	*14-15°C*	n/a	Heavy P deficient clay	Lower slope	0.35ha	Ex-pine
Gourley	Tauranga	*37°44'S*	*176°03'E*	100	E	10-20°	*1500-2000*	*13-14°C*	n/a	Kaharoa Ash	Lower slope	~1ha trial	Agriculture

All figures in brackets are based on the records of the landholder.

[101] Latitude co-ordiantes in *italics* taken from www.linz.govt.nz
[102] Longitude co-ordinates in *italics* taken from www.linz.govt.nz
[103] Figures in *italics* taken from the North Is. small scale raster map viewed on www.linz.govt.nz
[104] totals in *italics* taken from www.niwa.cri.nz
[105] Figures in italics taken from www.niwa.cri.nz

Appendix A2. Stand details for the *E. muelleriana* sites in Northland, New Zealand

Site	Establishment[106] and management details							Inventory			
	Est. y	Provenance	Weed Control	SPH	Fertiliser application	Pruning	Thinning	Sample size	Form	Av. dbh	Av. Total tree height
Thom	1996	Waipoua forest	Pre-planting using K herbicides	300-400	-	1-2 lifts	none	10	Mod - poor	21cm	9.7m
Furniss	1992	Proseed	n/a	1600 (2.5x2.5)	100gms/tree	2 lifts	1 to 400sph	8	Good	24.9cm	13.7m
Pederson 1[107]	1994	Provenance trial 7 Aust prov.	Manually weeded twice. Gardoprim post planting?	1234 (2.7x3)	None	none	None	4	Variable – excellent - to poor	31cm	18.2 m
Pederson 2	1988	Not available	Manually weeded twice. Gardoprim post planting	280 (6x6)	None	To 7m	None required yet	2	Excellent – due to form pruning	38.3cm	23.8 m
Davies Colley 1	1992	6 Aust provenances + 1 Proseed import	-	1111 (3x3)	-	1-2 lifts	2 thinnings completed to 670 (1) and 420(2) stocking	15	Moderate, considerable forking	28.9cm	16 m
Davies Colley 2	1992	Not available	-	300 with 3 stems planted per spot	-	-	-	-	-	-	-
Davies Colley 3	?	Not available	-	Pine and YS planted in alternate rows	-	2 lifts	1st thinning recently completed	-	-	-	-
McGee	~1950	Not available	-	Planted as mixed species stand > 2000 sph	None. Prior to planting , least fertile soil on farm	none	Understorey and middle storey removed leaving eucalypts	5	Excellent. Log length ~ 70% total ht.	75.9cm	38.12 m
Tairua Forest	1960	Riverhead & Johnstons	-	-	Blood and bone	none	1 thinning in 1979	5	Excellent. Log length ~75% total ht.	76.2cm	40.1 m[108]
Gourley	1993	6 Aust provenances + 1 Proseed import	-	-	-	-	None. Although severe frost damage in 1994	9	Mod - poor	26.2 cm	14.6 m

[106] All trees were planted into uncultivated ground.
[107] Age 2 and 6 inventory data available in *New Zealand Journal of Forestry Science* 30(3): 384-400 (2000)
[108] Only 3 trees measured for height

Appendix B. Summary of State Forests NSW species trials containing *E. muelleriana* (Johnson and Stanton 1993). MAI data generated from site mean volume per ha figures in Shelbourne (2001).

Trial No.	No. of sites	Est. year	Location				Elevation (m)	MAR (mm/yr)	Geology	Year measured	MAI	MAI ranking
			State Forest	SF N	Latituc	Longitude						
G1213W (1-3)	1	1972	Olney (tucker)	124	33°02’	151°19’	390-410	1190	Triassic sandstone/conglomerate	1993	7.2 m^3/ha/yr	3 out of 3
G1213W (1-3)	4	1972	Watagan	123	33°03’	151°20’	430	1190	Triassic sandstone	1990	8.8m^3/ha/yr	1 out of 17[109]
G1213B (3)	3	1972-74	Bulahdelah	296	32°23’	152°15’	75	1360	Carboniferous sandstone/mudstone	1990	1.1m^3/ha/yr	10 out of 19
G1213C	1	1973	Chichester	292	32°14’	151°46’	370	1350	Carboniferous sediments	1991	11.1 m^3/ha/yr	5 out of 9
G1214W (A-B)	2	1973	Cairncross	183	31°22’	152°43’	50	1280	Carboniferous siltstone	1989	2.7m^3/ha/yr	10 out of 15
SEL32513	1	1974	EAST Boyd	127	37°09’	149°57’	150	850	Devonian rhyolite	1989	-	2 out of 8[110]
SEL32421	1	1978	Nadgee	125	37°23’	149°50’	130	1050	Ordovician siltstone	1988	1.3 m^3/ha/yr	4 out of 7

[109] Equal first with *E. agglomerata*
[110] Ranked second out of eight species for growth not MA I by Johnson and Stanton (1993)