



# National Low Rainfall Tree Improvement

- Workshop Proceedings

Held at the Woodhouse Rymill  
Conference Centre,  
Adelaide  
November 3-5<sup>th</sup> 1998

**A report for the RIRDC/LWRRDC/FWPRDC  
Joint Venture Agroforestry Program**

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## Foreword

Australian agroforestry is most developed in areas of high rainfall that are close to timber markets and wood processing facilities. Yet it is significantly less advanced in low rainfall areas, including the sheep-wheat belt and pastoral zones, where tree plantations could potentially provide environmental benefits and an alternative source on farm income. At present there is insufficient information about commercial timber tree species which will grow in low rainfall zones.

The National low Rainfall Farm Forestry Tree Improvement Workshop was held to establish priorities and formulate a coordinated approach to low rainfall tree improvement. The workshop discussed key opportunities for commercial timber product for low rainfall areas, including sawntimber, wood panel products, post/poles, craft timbers, biomass for electricity and fuel, firewood, charcoal and eucalyptus oil. As a result of the workshop, a national collaborative research program has been established to produce improved seed for low rainfall zones. The Australian Low Rainfall Tree Improvement Group (ARTLIG) will focus on the breeding of hardwoods, softwoods and short rotation biomass crops for low rainfall zones of southern Australia.

This report, a new addition to RIRDCs diverse range of almost 400 research publications, forms part of the Joint Venture Agroforestry Program, which aims to foster integration of sustainable and productive agroforestry within Australian farming systems.

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### ***Table of Acronyms***

| <b>Acronym</b> | <b>Expansion</b>                                           |
|----------------|------------------------------------------------------------|
| ALRTIG         | Australian Low Rainfall Tree Improvement Group             |
| CaLM           | Dept of Conservation & Land Management (WA)                |
| CSIRO          | Commonwealth Scientific & Industrial Research Organisation |
| AFFA           | Department of Agriculture, Forests & Fisheries, Australia  |
| DNRE           | Department of Natural Resources & Environment (VIC)        |
| FWPRDC         | Forest & Wood Products Research & Development Corporation  |
| JVAP           | Joint Venture Agroforestry Program                         |
| GRDC           | Grains Research & Development Corporation                  |
| LWRRDC         | Land & Water Resources Research & Development Corporation  |
| NHT            | Natural Heritage Trust                                     |
| RIRDC          | Rural Industries Research & Development Corporation        |
| RCB            | Randomised Complete Block                                  |
| RPC            | Regional Plantation Committee                              |
| RWG            | Research Working Group                                     |
| SSO            | Seedling Seed Orchard                                      |
| STBA           | Southern Tree Breeding Association                         |

# Executive Summary

The National Low Rainfall Farm Forestry Tree Improvement Workshop, supported by the Joint Venture Agroforestry Program (JVAP), was held in the Adelaide Hills, 3-5<sup>th</sup> November 1998. The purpose of the meeting was to bring together low rainfall tree improvement stakeholders, from the southern states, to discuss priorities and formulate a cooperative, coordinated approach to low rainfall tree improvement. Time at the workshop was blocked into eight sessions, each covering particular technical and/or administrative aspects..

A summary and discussion of a report commissioned by Joint Venture Agroforestry Program entitled 'An Assessment of Commercial Prospects for Planted Tree Species in the Low Rainfall Zones of Australia' followed the introductory session. The report identified key areas of commercial interest. Opportunities include sawntimber, wood panel products, posts/poles, specialty timber, biomass for electricity and ethanol, firewood, charcoal and activated carbon, eucalyptus oil, fodder and a range of 'niche' markets (eg. bushfood, olives, jojoba). In terms of tree improvement strategy, it was felt that a logical approach would be to divide the areas of opportunity into three groups; softwoods, hardwoods and short-rotation tree crops (including eucalyptus oil crops). It was broadly agreed that the biomass based fuel products would likely be a residual product from other end-uses.

During the course of the invited presentations on the first day (Session 2), a number of areas of common interest were highlighted. It was made clear that eucalypt species such as *Eucalyptus cladocalyx*, *E. maculata*, *E. occidentalis* and *E. camaldulensis* / *E. grandis* and their hybrids are of interest to a number of organisations in the southern states. Softwood species such as *Pinus pinaster*, *P. radiata*, *P. brutia* / *P. halepensis* and other, relatively unknown pines from Mediterranean climates were also a source of common interest. The possibilities for expansion of short-rotation crops, such as eucalyptus oil mallees from Western Australia and the relatively small NSW area to other regions was discussed.

Session 3 reported on *Research Priorities and Information Gaps*. A number of issues and research directions were identified, and the time was taken to reflect on regional scale, long-term implications of tree improvement at the national level. Breeding for physiological resistance to drought, volume and straightness was identified as a priority, particularly for sawntimber programs. The external (or indirect) societal costs and benefits of dryland afforestation were discussed. The need for development of a generic model to identify species by region and enterprise was also mooted. It was argued that new industries should be based on extension of existing industries. The point made in an earlier session - that biomass production will be a residual from other industries, and not require its own breeding program - was reinforced.

The *Trial Design and Reporting* session (Session 4) was led by an overview and discussion of flexible, efficient trial design using modern statistical software, and the possibilities for centralised data storage using the TREDAT database held by CSIRO. The need for selecting the correct design to suit a trial's particular purpose was emphasised, and discussion of the best way coordinate approaches to design and data

collection continued at length. A number of pre-existing sets of criteria that could be used for standardised data collection were identified.

Session 5 - *Tree Improvement Structure and the Implications for Equitable Sharing of Plant Material and Knowledge*, dealt with the planning necessary to the formation of a tree breeding cooperative. A well-structured system of management, and well-defined rights for all parties, at the onset of the program, are essential requisites. Attention was drawn to the fact that organisations must be willing to allow prior research to be ‘written off’ as ‘sunk-funds’ when they donate it to a collaborative program. This is especially pertinent in the likely case that parties form a cooperative with ‘dowry’ contributions that are inequitable. However, there is an equal need for dowered founder members to have well defined, documented rights with regard to the cooperative’s outputs, and what the required joining fees and rights of new members will be. It was broadly agreed that it is important to have a dedicated, enthusiastic person, or ‘champion’ at the head of the cooperative for it to succeed as an entity.

In the *Coordination Approaches* session, (Session 6), it was agreed that a good approach to collaboration, may be to seek funding for a person to collaborate activities across states. This decision was reached after sub-groups were asked to come up with a coordinated approach to breeding for a hypothetical program. These ‘hypotheticals’ served to demonstrate and aid the development of a model for Australian collaborative low rainfall tree improvement. The fact that people would have to be willing to share and effectively release their existing work was brought up. Equitable treatment of those contributing ‘dowries’ was discussed.

Session 7 (*Collaborative Project Development*), gave participants with JVAP funding submissions the opportunity to discuss their proposed directions, in the light of previous workshop discussions. Some participants identified a need to re-work their applications, to include more collaborative effort. RIRDC drew attention to the fact that they have not traditionally funded projects proposing trial work, lacking strong inter-organisational ties, especially those with very long-term horizons for returns. Rather, projects with good strategic outputs are encouraged

The final session was held on the third day of the workshop. Rather than discuss specific projects in detail, Peter Bulman led a session where the structure of national collaborative program was discussed. The group agreed to form a geographically based, five-member *Australian Low Rainfall Tree Improvement Group* (ALRTIG) to guide the direction of collaborative work and mount a proposal for funding in four key ‘modules’. The modules include hardwood breeding, softwood breeding, short rotation biomass crop breeding and a national coordinator. Preliminary membership of steering panels for each module was discussed, and interested parties volunteered membership.

# Session 1. Setting the Scene

(Chair Peter Bulman, PIRSA)

## *1.1. Welcome by Peter Bulman*

The workshop was opened by Peter Bulman, who welcomed the participants and invited them to introduce themselves, and say a little about their area of interest. A list of participants and their details is included in Appendix 1. Sharon Davis from RIRDC was then introduced.

## *1.2. RIRDC perspective*

(Sharon Davis, RIRDC)

Sharon Davis gave a summary of the Joint Venture Program's purpose and budget. Key points are as follows:

- The Joint Venture Program was established in 1993 and is comprised of RIRDC, LWRRDC, and FWPRDC with funding contributed by the Murray Darling Basin Commission, AFFA, and NHT.
- The program has received a total of \$4 million from NHT to be administered by RIRDC and FWPRDC.
- RIRDC manages \$2.5 million, to assess new tree crops and integrate farm forestry into sustainable systems, with an emphasis on medium to low rainfall areas.
- \$1.5 million managed FWPRDC, concentrating on timber production elements of agroforestry and sustainable management and use of private native forests and woodlands.

There are a series of objectives, defined by the Joint Venture, that the money will be used to address:

- Targeted strategies for implementation of more sustainable management of natural resources
- More sustainable management of natural resources
- Optimised productivity of crops and pastures
- Optimised direct returns from tree products
- Cost effective multi-purpose agroforestry systems
- Effective communications

Agtrans Research were commissioned to supply RIRDC with a report identifying opportunities, in terms of 'best-bet' species for low rainfall areas from an economic perspective.

The objectives of the Agtrans report were to:

1. Assess the commercial opportunities for growing a range of tree species and
2. to establish priorities by commercial product and species type to assist resource allocation

The JVAP is hoping to get the following outcomes from this workshop:

- Agreement on the most promising species for low rainfall farm forestry
- A framework for collaborative research to assess low rainfall farm forestry options

### *1.3 Summary of presentation: 'Opportunities in Low Rainfall Farm Forestry'*

Agtrans research was commissioned by RIRDC to assess the main commercial opportunities in Australia's medium to low rainfall (400-600 mm) zone. Peter Chudleigh presented an overview of the study's findings, many of which are detailed in Appendix 4. He emphasised the product group approach that was taken. Natives were emphasised more than exotics, and priorities were set by commercial products and species type.

### *1.4 Summary of Discussion – Session 1*

A number of questions ensued after Sharon Davis' presentation, concerning the scope of the NHT program and implications for low rainfall tree improvement. The need to make the best possible use of existing trials and resources was emphasised, as a means of making rapid progress in the short-term.

The overview of the Agtrans Research report, delivered by Peter Chudleigh, stimulated a vigorous discussion round. Debate was centred on three main topics; on-farm value adding, effluent irrigation and biomass energy production. The main points are summarised below:

- On-farm value adding is becoming an important factor with sawn timber production. Things like small-scale milling - leading to higher recovery – and particularly drying systems, will strongly influence economic analyses.
- The economic implications of on-farm value adding were discussed. One view was that on-farm value adding simply shifts the distribution of benefits to the landholder, while total societal benefit remains unchanged.
- It was also argued that total societal benefit increases due to lower total production costs. There was some discussion about the efficiency of on-farm processing relative to traditional, off-site processing.

#### **1. Effluent irrigation**

- It was argued that the use of effluent to irrigate biomass production may be good option – it has dual benefits in that a town can simultaneously produce electricity and deal with its effluent problems. The advantage over rain-fed plantations for power generation is that the high nutrient load may be continuously removed from the site, rather than building up and making its way into the environment at large.
- To produce 5000 tonne per annum of biomass around 250 ha of plantation might be needed – which works well for a town of around 2000 people.
- A counter-argument for effluent irrigated plantations concerns opportunity cost. Effluent is a potentially valuable resource, and using it for biomass production may not be an efficient allocation. Cropping or fish farming may be economically attractive alternative uses.

## 2. Biomass energy production

- Agtrans estimate that electricity producers could feasibly pay up to \$22 per tonne (delivered) for biomass fuel. The price of biomass fuel would need to be higher than \$22 per tonne, to support a stand-alone industry. However, if biomass is produced as a residual by-product from another activity (such as sawn wood milling), the industry is likely to be.
- The above point was recognised in the Agtrans report, where it was assumed biomass energy production would be generated from eucalypt oil residue (whole aboveground biomass).
- No transport costs, were built into the Agtrans \$22 price estimate. It was assumed that by positioning the energy plant at a sawmill or an oil distillery, you could then process the residue, as an integrated operation, without any transport cost. The price received for biomass based fuel would obviously be sensitive to transport costs.

## **Session 2. Low Rainfall Tree Improvement – Directions and Opportunities**

**(Chair Peter Bulman, PIRSA)**

This session consisted of seven invited presentations, each with question time. The topics included:

1. CSIRO program, including seed service to Regional Plantation Committees  
(Roger Arnold & Tim Vercoe)
2. South Australian program - Farm Tree Improvement & South-East Projects  
(Peter Bulman & David Bush)
3. Victorian program  
(Charles Hajek)
4. Western Australian program: Broad genetic screening, non-wood products/leaf oils & other projects  
(John Bartle)
5. Mediterranean pines: Aleppo group and others  
(David Spencer)
6. Maritime pine  
(Trevor Butcher)
7. Western US conifers  
(David Boomsma)

During the course of workshop discussions, Des Stackpole presented results of work carried out by CFTT in Victoria. A paper discussing this work is included in Section 4.

## ***2.1 Tree improvement for the low rainfall zone - CSIRO Forestry and Forest Products' program and associated support to Regional Plantation Committees***

**R.J. Arnold and T.K. Vercoe**, CSIRO Forestry and Forest Products, PO Box E4008, Kingston, ACT 2604, Australia

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Tree Improvement Workshop, Adelaide, November 3-4 1998.

### **Abstract**

CSIRO Forestry and Forest Products is undertaking collaborative tree improvement programs for a range of tree species well adapted to low rainfall areas of southern Australia, for both wood and non-wood products. Species-provenance trials, investigations of wood quality and climatic modelling have helped identify a suite of native species with plantation potential, including *E. benthamii*, *E. camaldulensis*, *E. cladocalyx*, *E. occidentalis*, *E. sideroxylon* and *Corymbia* species. One of the challenges in this work is to judge the appropriate level of improvement effort, relative to both the establishment areas and end-use or product value, for each species of interest. The programs being pursued for the key species are outlined and involve:

1. assemblage of seed from diverse ranges of provenances and families for evaluation, based on extensive sampling of natural stands by the Australian Tree Seed Centre;
2. establishment of replicated provenance trials and provenance-family trials - since 1994 more than 25 ha of trials across 12 locations have been established on rain-fed sites in temperate low rainfall zones;
3. later conversion of some of the provenance-family trials to seedling seed orchards in order to fast-track the production of genetically improved seed;
4. and, for some species:  
production of intraspecific and interspecific hybrids targeted to specific key environmental niches.

Linked to the tree improvement programs for native species are a range of other research and development activities to enhance the economic and environmental benefits of both commercial farm forestry and other tree planting endeavours. These activities include testing of wood properties, water use studies, climatic modelling and computer based site-species matching and yield modelling. In addition, CSIRO has carried out limited tree improvement work on exotic conifers for low rainfall areas.

Commencing in 1999, CSIRO's research and development activities will be accompanied by a "Seed and Information Support for Commercial Farm Forestry" project to provide scientifically based advice, training and some germplasm to Regional Plantation Committees and other farm forestry groups. This project is being jointly funded by the Joint Venture Agroforestry Program and the Farm Forestry Program. Key aspects of this work include species and provenance selection, design of demonstration and trial plantings, and assisting farm forestry growers and investors (via existing support groups) to make best use of native and exotic species for the sites available and the products required.

### **Introduction**

Exotic species have played the major role in the development of Australia's industrial forest plantation resources to date and a large commitment has been made to breeding and production of improved planting material. However, most of that plantation resource is concentrated in higher rainfall areas. For farm forestry in the lower rainfall areas, the diversity of available sites, planting objectives and growers involved will require the species base to be substantially enlarged. In these lower rainfall areas selecting and matching species to sites and planting objectives is of prime importance and is a major focus of the work currently being undertaken by many farm forestry groups.

This paper outlines tree improvement work for low rainfall farm forestry being carried out by CSIRO Forestry and Forest Products, with a range of collaborators, for lower rainfall sites in southern Australia.

## Species

CSIRO's collaborative tree improvement programs cover a range of native species suited to farm forestry plantings in lower rainfall areas of southern Australia for both wood and non-wood products (see Arnold *et al.* 1996, Vercoe *et al.* 1998). These include *E. benthamii*, *E. camaldulensis*, *E. cladocalyx*, *E. occidentalis*, *Corymbia* species (spotted gums) and *Melaleuca* species (Table 1). Selection of these species was based on growth performance from trials and plantings in Australia and overseas as well as product studies and site matching with natural provenance information. In addition, some work has been carried out on *Acacia* species for a range of applications including wood production (e.g. Searle *et al.* 1998) and for edible seed production (e.g. Maslin *et al.* 1998).

## Tree improvement programs

One of the challenges with tree improvement for farm forestry is to identify the appropriate program intensity for each species relative to both its total establishment area and its end use or product value. Namkoong *et al.* (1980) distinguished three levels of intensity for tree improvement programs. The continuum of intensity ranges from simple selection and use of the best wild provenance, through the establishment of first-generation seed production areas and seed orchards, to intensive breeding strategies which may incorporate controlled pollination, sub-lines and clonal testing and deployment.

At the simple end of the scale, various CSIRO Forestry and Forest Products programs have examined species and provenance variation with respect to adaptation to particular site types, growth and form, and/or end-use suitability. This work has included glasshouse screening for salt tolerance (e.g. Marcar *et al.* 1991, Marcar *et al.* 1995), species-provenance trials (e.g. Vercoe and Clarke 1998), and studies of wood product potential (e.g. Washusen *et al.* 1998). All the trials, seed production areas, seed orchards and associated field plantings involved in CSIRO's programs have been established in collaboration with land owners, private enterprises, extension officers, State Government agencies and/or grower groups. Collaboration is built on discussions of potential benefits and risks and mutually acceptable sharing of investments and returns.

CSIRO's improvement work with *Eucalyptus cladocalyx* exemplifies the simple, low-intensity approach. Representative individual parent tree seed collections were recently made from the entire remaining natural range of this species to supplement provenances already held in store by CSIRO's Australian Tree Seed Centre. Together this material provided 64 individual seedlots representing eight provenances. Samples of all these were then established in a provenance-family trial planted in 1998 near Benalla, Victoria designed to perform multiple roles. In the shorter term this stand will enable identification of the superior natural stand provenances for this environment based on adaptability, growth and form, from where seed could be sourced for plantation establishment. It will also provide some important information on genetic variability in the species. Then in the longer term, selection of the superior trees and thinning to remove poorer-performing families and individual trees will convert the trial into a seedling seed orchard. This orchard should commence production of seed from around the year 2005 which should result in superior growth and form relative to that from the best natural provenances. Provenance trials planted in different environments using CSIRO's provenance collections will help to determine whether this species displays provenance-by-environment interactions.

Greater intensity of activity is being directed towards *E. camaldulensis* and *E. grandis* by CSIRO in the target area. For *E. camaldulensis*, sampling of natural populations has been weighted in favour of provenances with known good performance and trials have been planted on a wide range of sites to enable better evaluation of genetic as opposed to environmental influences on growth. Sites in southern and central NSW, Victoria and WA provide a cross section of the probable planting areas for the species. Joint analysis of the performance of provenances and families across several environments will give an accurate picture of the stability of growth traits and other properties in different environments. Also for *E. camaldulensis*, nineteen outstanding clones from improvement programs in California, USA have been imported in tissue culture via quarantine, with the aim of achieving a rapid lift in the quality of plantable material.

While use of *E. grandis* in the low-rainfall zone will be limited to irrigated/high water table areas, based on experience in South Africa and Latin America there is good potential for its use in interspecific hybrid combinations (see below). It is likely that genetically superior *E. grandis*

individuals will be the best parents for hybrid breeding and CSIRO is pursuing an intensive *E. grandis* breeding program for southern Australian environments (see Matheson *et al.* 1996).

*Eucalyptus camaldulensis*, *E. grandis* and their interspecific hybrid can be propagated fairly readily by stem cuttings, enabling clonal forestry using selected, tested clones. Australia is in a good position to take advantage of the breeding experience developed for these species overseas. The value of this overseas material is being compared and evaluated with a range of Australian material in trials already established. CSIRO's breeding populations of *E. camaldulensis* and *E. grandis* include first and second-generation selections from Australia and overseas, as well as natural-provenance material.

Other CSIRO tree improvement programs are focused on non-wood forest products including improvement of yield and quality of essential leaf oils. A collaborative breeding program for *M. alternifolia* which began in 1993 has already provided seed which should increase tea tree oil yields from new plantations by 50% or more, relative to earlier industry standards (Doran *et al.* 1997, Vercoe 1998). Other *Melaleuca* species and their close relatives have been screened for interesting oils with commercial potential and/or betaine production (Doran 1995). In addition, collection, selection and breeding programs for a number of *Eucalyptus* species known for their oil-yielding potential are being pursued including *E. camaldulensis*, *E. polybractea* and *E. radiata*.

The more conventional aspects of these improvement programs are complemented by work of CSIRO Forestry and Forestry Products' molecular genetics group. They have been developing advanced molecular genetics tools to more efficiently resolve genetic questions related to the breeding of eucalypts, acacias and pines including DNA markers for fingerprinting clones, checking pedigrees, assisting early selection and for inbreeding studies. Their comparisons of different types of DNA markers in some *Acacia* species have shown that microsatellites can detect five times more variation than RFLP markers which, in turn, can detect five times more variation than isozymes (Butcher 1998). In *Eucalyptus nitens* pedigrees, molecular markers linked to frost resistance they have identified offer the opportunity to screen progeny from those families at the nursery stage. Such "marker assisted selection" can improve the efficiency of breeding programs by allowing removal of inferior individuals before field trial establishment (Butcher 1998).

### Hybridisation

In South Africa hybrids of *E. grandis* have enabled eucalypt plantations to be extended into environments previously considered marginal for wood production due to low rainfall, low temperatures and/or poor soils. The most common hybrid combinations used there are *E. grandis* with *E. camaldulensis*, *E. urophylla*, *E. tereticornis* and *E. nitens* (Van Wyk 1985, Denison and Kietzka 1993, Wex and Denison 1997). On marginal sites, growth and survival of the hybrids tends to be superior to the pure species, and some are consistently more resistant to diseases, pests, cold, heat and drought (Denison and Kietzka 1993). Wood density is normally intermediate between that of the parent species (Malan 1993).

CSIRO has commenced a program to produce interspecific eucalypt hybrids (*E. grandis* x *E. camaldulensis* and other hybrid combinations involving these and other species) likely to be well adapted to target environments in the lower rainfall parts of southern Australia. The best trees are being selected from provenance-family trials and other plantings of *E. grandis* and *E. camaldulensis* established by CSIRO and collaborators at several sites in south eastern Australia. These are being grafted and grown in a clone bank in Canberra. Control of environmental conditions and addition of growth regulators will enable early and prolific flowering, thus shortening the breeding cycle and reducing the time taken to provide improved planting stock for growers. Controlled pollination will produce interspecific hybrids, and superior pure-species controls. Seedlings will be clonally multiplied and established in field trials to identify outstanding individual clones well-adapted to difficult site types (e.g. able to tolerate slightly saline ground water) with superior wood properties. Field-tested clones from this program should be available for commercial release within ten years.

### Offshore re-introductions – quarantine issues

The requirement to make rapid progress in the availability of better genetic material for planting has led to great interest in the re-introduction of improved pure species and hybrids from overseas countries. There are two important issues that need to be addressed in consideration of the need to re-introduce.

Firstly, there is potentially immense damage that could be done to native tree and shrub species and ecosystems through the inadvertent introduction of a major pest or pathogen such as guava rust (*Puccinia psidii*). This pathogen, a native of South America, is regarded as the most significant plant health risk to the cultivation of eucalypt species and also occurs as a pathogen on other species within *Myrtaceae*. Coutinho *et al.* (1998) have described *P. psidii* as "...one of the most serious threats to *Eucalyptus* species in the world today". It poses a potential threat to native forests in Australia where entire ecosystems could be damaged (Ciesla *et al.* 1996).

Quarantine rules and restrictions are not always optimal for the detection and/or removal of pests and pathogens in introduced seed or vegetative material. There can be delays in incorporating the latest information on the spread of pests and pathogens overseas into quarantine protocols. Where controls vary according to country of origin, genetic material (especially elite breeding material) originating from a country for which extensive restrictions apply (eg. Brazil) could be brought via a country for which less severe restrictions apply (eg. some African countries), with treatment in Australia carried out only at a level appropriate to the latter. Multi-stage introduction from high-risk countries to Australia may not be done intentionally - it can be very difficult to trace the international movement of breeding material.

Australian Forestry Council Research Working Group 7 is currently considering a revision to the quarantine procedures for tree seed introductions to Australia. The draft protocol is as follows (Mr Jack Simpson, State Forests NSW, pers. comm.):

1. Imported seed should first be washed with sterile water. This water to be autoclaved after use
2. The seed must be surface sterilised in 2.0% sodium hypochlorite solution for 15 minutes. The ratio of seed to hypochlorite solution (w/w) should be not less than 1:20.
3. Next, seed rinsed in sterile water three times for not less than 30 seconds per rinse.
4. Seed dried on blotters.
5. Seed dusted with benomyl or thiabendazole fungicide powder. Both fungicides have systemic capacity.
6. Seed germinated and grown on in quarantine.
7. Seedlings obtained kept in quarantine for a minimum of six months to observe for disease symptoms. If an exotic disease develops plants are destroyed.

This protocol is likely to be adopted for at least the short to medium term. In the longer term, there is potential to adapt existing high temperature seed treatments (especially for *Pinus* spp.) to eliminate seed-borne fungi but research is needed on the suitability of this treatment for a range of Australian native species.

Given the potential hazards associated with pest and pathogen introduction, the second issue with re-introduction is a careful analysis of the usefulness and adaptability of the imported material, to determine whether the expected benefits outweigh the potential risks. This requires an understanding of the selection and improvement process that has been used to develop the material, to determine the likely extent of genetic improvement and therefore how much time and effort would be saved by importing, compared with producing similar material onshore.

### **Other Programs**

In addition to the tree improvement work on eucalypts and other native species, many of CSIRO Forestry and Forest Products' other programs also carry out work of relevance to farm forestry. Together these projects cover the full continuum from seed to final product including silviculture of native forests and plantations, fire behaviour and management, tree harvesting and log transport, and processing into solid timber products, composites, pulp and paper and furniture. Also, substantial work is carried out on tree improvement for *P. radiata* and some work on other exotic conifers.

A booklet to be produced in the near future summarises CSIRO Forestry and Forest Products' recent research results on the benefits and problems associated with tree planting in south eastern Australia with special emphasis on the Murray Darling Basin. This will include work from other CSIRO Divisions, which have undertaken collaborative research with Forestry and Forest Products. Where relevant, references to results from other research providers who are involved in related work will also be included.

### **Seed and information support for farm forestry**

Commencing in 1999, CSIRO Forestry and Forest Products' research and development activities will be accompanied by a "Seed and Information Support for Commercial Farm Forestry" project funded jointly by AFFA and the JVAP. Its primary objective is to enhance the economic and environmental benefits of commercial farm forestry through assisting farm forestry growers and investors to select and make best use of native and exotic species for the available sites and products required (Vercoe *et al.* 1998). It is primarily an extension support project with some research to supplement the extension process. The project's main components are as follows:

1. Technology transfer - scientifically based advisory support will be provided to Regional Plantation Committees (RPCs) and other commercial farm forestry coordinating groups on species and provenance selection, genetic improvement, design of demonstration and trial plantings, and appropriate use of trees for sustainable commercial farm forestry through a variety of means.
2. Extending the knowledge base - the existing knowledge base for commercial farm forestry will be expanded through growth modelling work; enhancement and expansion of the TREDAT tree performance data base; testing of wood qualities (pulp and wood composite products) of promising farm forestry species; and development of climatic profiles for 25 commercially important farm forestry species to assist with definition of suitable sites.
3. Enhanced genetic material - CSIRO will be collaborating with RPCs and other groups both to make seed and other reproductive materials available to farm forestry groups for demonstration plantings and to assist group participation in the breeding and improvement process.

### **Conclusions**

The long term future of commercial farm forestry and other tree establishment endeavours depends to a significant degree on the effective use of up-to-date knowledge and technology as well as on production and availability of better genetic material. CSIRO and its collaborators are pursuing programs throughout Australia for selection of appropriate tree species and provenances and their continuing genetic improvement which, together with improvements in silviculture, management and processing, will provide substantial ongoing benefits to tree growers.

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**Table 1. Some of the farm forestry species for low rainfall areas covered by the CSIRO Forestry and Forest Products' collaborative tree improvement work #.**

| <b>Species</b>                                     | <b>Common Name</b> | <b>Possible use</b>                                  |
|----------------------------------------------------|--------------------|------------------------------------------------------|
| <i>E. camaldulensis</i>                            | river red gum      | sawlogs, posts, firewood, used overseas for pulpwood |
| <i>Corymbia maculata</i> & closely related species | spotted gums       | sawlogs, veneer logs, treated posts                  |
| <i>E. cladocalyx</i>                               | sugar gum          | firewood, posts, sawlogs                             |
| <i>E. benthamii</i>                                | Camden white gum   | firewood, possibly sawlogs and posts                 |
| <i>E. occidentalis</i>                             | swamp yate         | firewood, posts and possibly sawlogs                 |
| <i>E. sideroxylon</i>                              | red ironbark       | firewood, sawlogs and posts                          |
| <i>E. polybractea</i>                              | blue-leaved mallee | essential leaf oils                                  |
| <i>Acacia</i> species                              | wattles            | edible wattle seeds, firewood                        |
| <i>Melaleuca</i> species                           | tea tree           | betaines, essential leaf oils                        |

# Much of the work on the different species is carried out collaboratively with other organisations.

**Table 2. Some of CSIRO Forestry and Forest Products' collaborative trials and seed orchards in lower rainfall areas of southern Australia.**

| Location #       | Mean annual rainfall (mm) | Species                                                     | Type of Trial ##        | Area (ha) | Material                  |
|------------------|---------------------------|-------------------------------------------------------------|-------------------------|-----------|---------------------------|
| Deniliquin, NSW  | 410                       | <i>E. camaldulensis</i>                                     | provenance-family       | 2.2       | 30 prov.'s - 99 families  |
| Wellington, NSW  | 620                       | <i>E. camaldulensis</i>                                     | provenance-family / SSO | 2.6       | 30 prov.'s - 99 families  |
| Dubbo, NSW ###   | 620                       | <i>E. camaldulensis</i>                                     | provenance-family / SSO | 0.5       | 10 prov.'s - 28 families  |
| Bunbury, WA      | 870                       | <i>E. camaldulensis</i>                                     | provenance-family / SSO | 2.0       | 20 prov.'s - 85 families  |
| Albury, NSW ###  | 680                       | <i>E. camaldulensis</i>                                     | family trial / SSO      | 1.7       | 1 prov. - 72 families     |
| Albury, NSW ###  | 680                       | <i>E. camaldulensis</i>                                     | provenance-family       | 2.2       | 29 prov.'s - 108 families |
| Holbrook, NSW    | 625                       | <i>Corymbia</i> species                                     | provenance-family / SSO | 1.1       | 9 prov.'s - 77 families   |
| Benalla, VIC     | 670                       | <i>E. cladocalyx</i>                                        | provenance-family / SSO | 1.3       | 8 prov.'s - 64 families   |
| Kowen, ACT       | 475                       | <i>E. benthamii</i>                                         | provenance-family / SSO | 3.0       | 1 prov. - 54 families     |
| Shelford, VIC    | 490                       | <i>E. occidentalis</i>                                      | provenance-family / SSO | 3.0       | 17 prov.'s - 90 families  |
| Wangaratta, VIC  | 640                       | <i>E. sideroxylon</i>                                       | provenance              | 1.0       | 10 prov.'s                |
| Barnawartha, VIC | 650                       | <i>E. sideroxylon</i>                                       | provenance              | 1.0       | 8 prov.'s                 |
| Bendigo, VIC     | 550                       | <i>E. sideroxylon</i>                                       | provenance              | 1.0       | 9 prov.'s                 |
| Wangaratta, VIC  | 640                       | <i>E. benthamii</i> , <i>C. maculata</i> & <i>E. dunnii</i> | species-provenance      | 1.0       | 3 species - 9 prov.'s     |
| Benalla, VIC     | 670                       | <i>E. benthamii</i> , <i>C. maculata</i> & <i>E. dunnii</i> | species-provenance      | 1.0       | 3 species - 14 prov.'s    |
| Kowen, ACT       | 475                       | <i>Acacia</i> species                                       | species-provenance      | 1.9       | 26 species - 64 prov.'s   |
| Uriara, ACT      | 700                       | <i>Acacia</i> species                                       | species-provenance      | 1.9       | 26 species - 64 prov.'s   |
| Wellington, NSW  | 620                       | <i>Acacia</i> species                                       | species-provenance      | 0.7       | 12 species - 22 prov.'s   |
| Wellington, NSW  | 620                       | <i>Acacia</i> species                                       | species-provenance      | 0.6       | 10 species - 18 prov.'s   |

# Locations are only approximate.

## SSO: seedling seed orchard.

### These sites are irrigated.

## 2.2 South Australian Low Rainfall Tree Improvement Program

### 2.2.1. South Australian Farm Tree Improvement Project

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Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Tree Improvement Workshop, Adelaide, November 3-4 1998.

#### Introduction

The Department of Primary Industries and Resources of South Australia (PIRSA) has been actively engaged in research into farm forestry since 1990, the year the first simple provenance trials were established in the Murray Mallee. Progressively since then, as a part of the *South Australia Farm Tree Improvement Project*, a more systematic (but far from comprehensive) series of trials, including four seed orchards<sup>1</sup>, have been designed and established on the key tree planting site types in the agricultural areas of South Australia.

**The SA Farm Tree Improvement Project aims to:**

- systematically evaluate the performance of different seed sources for a range of species and sites
- provide genetically improved seed for on-farm use of sugar gum and flat topped yate

The search has been for provenances with the 'most desirable characteristics' to more effectively enhance agricultural productivity by improving:<sup>2</sup>

- shelter for soils, crops and stock
- surface and ground water management
- rehabilitation of degraded lands
- income from plant products.

Generally, the 'most desirable characteristics' are:

- good health and vigour eg tolerance to difficult sites, extra height for shelter, water use and productivity
- good form eg straight trunks for timber or numerous straight stems for broombush

A report was compiled in 1994 outlining the aims of the project and describing the locations and layouts of all trials established to that date.

This report summarises the same information with interim assessments of those trials.

It is important to highlight that all the trials are less than 10 years old and the better performing species and provenances may not maintain early growth trends.

Recognising this limitation, but not wishing to withhold the interim results, long-term species suitability has been assessed by incorporating general experience of the species suitability for the site type with the early trial results. Species suitability assessments have made for each site type.

Although these early results cannot be used in a definitive way, after carefully matching species to site (and planting objectives) it makes sense to use the more promising provenance(s) and avoid the least promising ones.

Many of the original seed lots for the research trials were obtained from the Australian Tree Seed Centre (CSIRO) in Canberra. However, it is envisaged that there will be a number of commercial sources of cheaper seed and that availability will improve as demand increases.

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<sup>1</sup> The first seed is expected to be collected summer 98/99.

<sup>2</sup> Locally collected seed of the native species is recommended for conservation projects and roadside revegetation. Locally collected seed is generally represented at each of the trial sites to enable a comparison between seed sources.

This paper is extracted from a draft ‘Summary of interim results’ report and reviews the site types (growing conditions) and suitable species for each of the sites. It also summarises the most promising provenances of some species.

### Species suitability

A number of methods have been developed for assessing the performance of amenity plantings in an effort to achieve reproducible results with different operators. The *Lay and Meissner Method* is a technique which involves a scoring system with points being allocated for vigour and health; it provides a basis for statistical analysis.

However, the fundamental issue is whether or not a species or provenance is recommended and with what degree of confidence. Most agreed that a simple system (not intended for statistical analysis) using the two classifications, 'suitable' and 'not suitable', each further divided into two categories, is reproducible and meaningful:

| Score   | Description                                                                                        | Recommendation                                                                                                |
|---------|----------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|
| 0 = ✕   | May persist for a number of years but generally expected to fail                                   | Not suitable                                                                                                  |
| 1 = (✕) | Generally will survive but not thrifty; healthy individuals are the exception rather than the rule | Not suitable except for unusual circumstances such as a favourable site or the need for a short rotation crop |
| 2 = ✓   | Reliable performance - only occasional failures                                                    | Suitable                                                                                                      |
| 3 = ✓✓  | Exceptional health, vigour and reliability                                                         | Highly suitable—should grow well                                                                              |

### Form assessment

Rod Bird's PVI tree form assessment is used (with permission) as a simple and reproducible way to arrive at a score for a tree or trees, which gives an indication of stem form in relation to capacity to produce a log suitable for sawing (ie a straight 6m log).

Scoring is as follows:

**“1”**

Stunted or grossly bent **or** heavily branched and stunted—not suitable even for firewood

**“2”**

Two or more main stems from 1m **or** less from ground (if extra stems are minor, class as “3” or even “2”) **or** total loss of main leader (basket) **or** grossly malformed—but still useable for firewood

**“3”**

Stem not straight enough for saw log **or** forked above 1m from ground **or** heavy branching on lower 6m stem section (if the stem is to be pruned, the branching can be ignored)—not a sawlog but would make a good shelter tree or firewood

**“4”**

Fairly straight stems of at least 6m, (or those which will most likely make 6m with age) and which have light branching (if the stem is to be pruned, the branching can be ignored )— suitable for a sawlog

**“5”**

Erect straight stem (or most likely to be so with or without pruning) with light branching—high-class sawlogs

## THE HIGHER THE SCORE ...THE BETTER THE FORM OF THE TREE

Only trials or parts of trials with trees tall enough for meaningful results have been assessed. These will be presented in the 'Summary of interim results' report.

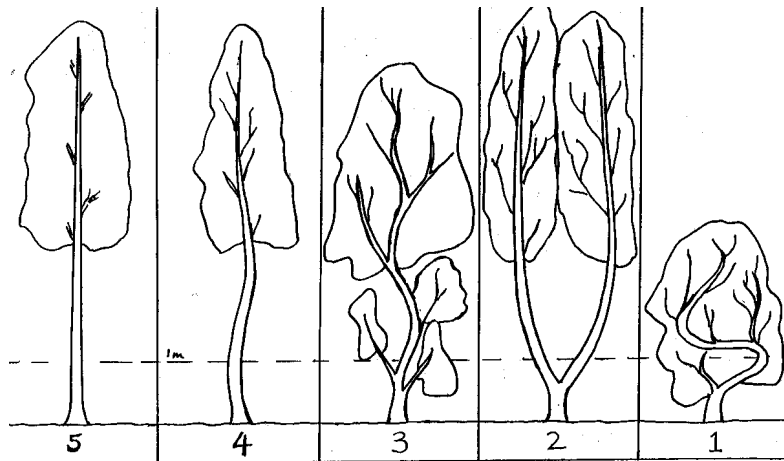


Figure 1: Rod Bird's PVI tree form assessment guide

### Site types

In the Murray Mallee, the Northern Agricultural Districts, the South-East and the Mt Lofty Ranges a number of *site types* have been identified. Sites have been classified principally by using the dominant pre-settlement vegetation except for the Murray Mallee which uses soils (and rainfall factors) to provide the basis for characterising the *site types*.

The more significant *site types* were chosen for trial sites on the basis of widespread distribution or high potential beneficial impact of 'farm tree planting'. The *site types* are briefly described below.

## Summary of site type descriptions

| Site Type                                | Location                                                                   | Rainfall | Soils                                                                         | Vegetation                                                  | Comments                                                   |
|------------------------------------------|----------------------------------------------------------------------------|----------|-------------------------------------------------------------------------------|-------------------------------------------------------------|------------------------------------------------------------|
| <b>Mallee</b>                            |                                                                            |          |                                                                               |                                                             |                                                            |
| Shallow stony & calcareous               | Sherlock                                                                   | 380      | Alkaline (pH 9) shallow stony sandy loam over limestone, 200 – 700mm          | E. leptophylla, Melaleuca lanceolata.                       | Areas of underlying sheet limestone                        |
| Sandy loam                               | Paruna                                                                     | 280      | Alkaline (pH8.5) sandy loam over clay, 600-850mm                              | Callitris preissii, E. anceps, E. cyanophylla               | Swale                                                      |
| Deep sand                                | Peebinga                                                                   | 300      | Alkaline (pH8) deep sand >1m                                                  | Callitris preissii, Leptospermum coriaceum<br>E. incrassata | Relatively infertile, widespread                           |
| Sandy loam                               | Pinnaroo                                                                   | 340      | Alkaline (pH9), sandy loam over clay, 200-600mm                               | E. socialis, E. gracilis, E. anceps                         | Flats                                                      |
| Sandy loam                               | Murray Bridge                                                              | 340      | Alkaline (pH9) sandy loam over clay, 200-700mm                                | E. odorata                                                  |                                                            |
| Sandy loam                               | Lameroo                                                                    | 380      | Alkaline (pH8-9) sandy loam over clay with some pure sand patches 200 - 600mm | E. socialis, E. gracilis, E. anceps                         | Prime cropping land                                        |
| <b>Mid North</b>                         |                                                                            |          |                                                                               |                                                             |                                                            |
| Saline                                   | Redhill                                                                    | 400      | Alkaline (pH8.5) brown loam over clay, 200-350mm                              | Sea Barley Grass, saline spp.                               | Some saline seeps and salt scalds                          |
| Treeless                                 | Mannanarie                                                                 | 360      | Alkaline (pH9) brown loam, 200- 350mm                                         | Native grassland                                            | Mainly treeless                                            |
| Mallee Box                               | Appila                                                                     | 380      | Alkaline (pH8) brown loam, 200- 350mm                                         | E. porosa?                                                  | Compacted                                                  |
| Mallee Box?                              | Mt. Bryan                                                                  | 438      | Neutral (pH6.5) shaly red brown loam, 200-400mm                               | Grasses, possibly E. porosa                                 | Rolling hills, northerly aspect                            |
| Blue Gum <15m?                           | Browns Hill                                                                | 400      | Acidic (pH6) shaly red brown loam, 200-350mm                                  | E. leucoxylon/pruinosa woodland                             | Rolling hills, easterly aspect                             |
| Blue gum >15m                            | Bundaleer                                                                  | 500+     | Neutral (pH7) red brown loam, 200- 400mm                                      | E. leucoxylon, E. cladocalyx                                | Tall forest form E. leucoxylon                             |
| <b>Adelaide Hills</b>                    |                                                                            |          |                                                                               |                                                             |                                                            |
| Stringybark/Pink Gum 12–20 m.            | Montarra                                                                   | 820      | Acidic (pH5-5.5) brown clay loam, 200 - 400mm                                 | E. obliqua, E. fasciculosa, some bracken                    | Rolling hills, upper to lower slope, north-easterly aspect |
| Blue Gum >15m?                           | Gumeracha—Robinia pseudoacacia/E globulus/Grevillea robusta/ mixed species | 850+     | Acidic (pH5.5) brown clay- loam, 200- 500mm                                   | E. leucoxylon                                               | Mid-slope, variable aspect                                 |
| Blue Gum >15m?                           | Cudlee Creek                                                               | 900+     | Acidic (pH 6) brown clay- loam, 200- 450mm                                    | E. leucoxylon, E. camaldulensis                             | Mid-slope, moderate fertility                              |
| Red Gum Site (poorly drained)            | Gumeracha—A. melanoxylon                                                   | 850+     | Acidic (pH6) sandy loam over clay/gravel, 300-900mm                           | E. camaldulensis                                            | Valley bottom, poor drainage                               |
| Red Gum Site (well drained)              | Gumeracha—E. cladocalyx/mixed species                                      | 850+     | Acidic (pH 5.5-6) brown clay- loam, 400-600mm                                 | E. camaldulensis                                            | Lower slope, northerly aspect                              |
| Tall Stringybark >15m.<br>Tall Manna Gum | Lenswood                                                                   | 950+     | Acidic (pH6) brown clay- loam, 200- 400mm                                     | E. obliqua (tall), E. rubida, E. viminalis                  | Steep slopes, sheltered valleys, northerly aspect          |

| <i>Site Type</i>                              | <i>Location</i>                                     | <i>Rainfall</i> | <i>Soils</i>                                                                                              | <i>Vegetation</i>                                                        | <i>Comments</i>                                                 |
|-----------------------------------------------|-----------------------------------------------------|-----------------|-----------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------|
| <i>S. East.</i>                               |                                                     |                 |                                                                                                           |                                                                          |                                                                 |
| <i>Saline</i>                                 | Woolumbool                                          | 500             | On salty area, alkaline (pH 9) sand over clay >1m. Off salt, neutral (pH 7) sand > 1m.                    | <i>E. fasciculosa</i> , sea barley grass.                                | Low lying, restricted drainage, some salt scalds                |
| <i>Treeless Plains (black cracking clays)</i> | Struan                                              | 580             | Alkaline (pH 8.5) black clay, 150 - 400mm                                                                 | Treeless grassland                                                       | Black cracking clay, sometimes inundated, exposed               |
| <i>Pink Gum—deep sands</i>                    | Coombe                                              | 470             | Neutral (pH 7) deep sand, >1m.                                                                            | <i>E. fasciculosa</i>                                                    | Deep infertile dune sands                                       |
| <i>Pink Gum /shallow water table</i>          | Willalooka                                          | 485             | On rise neutral (pH 7) sand over clay, 200 - 300mm on low flat acidic (pH 6.5) sand over clay 300 – 400mm | <i>E. fasciculosa</i>                                                    | Undulating: some rises ,some low lying with restricted drainage |
| <i>Medium Stringybark Site &lt;12–20 m</i>    | Coonawarra                                          | 650             | Acid (pH 6- 6.5) deep sand, > 1m.                                                                         | <i>E. baxteri</i> / <i>E. obliqua</i> , <i>Acacia mearnsii</i> , bracken | Low dunes amongst shallow swamps, relatively infertile          |
| <i>Red Gum Site (mod. well drained)</i>       | Kalangadoo—main trial<br>Kalangadoo—Blackwood trial | 760             | Acidic (pH 5.5) sand over clay, 400 - 900mm<br>Acidic (pH 4) sandy clay, 300 – 400mm                      | <i>E. camaldulensis</i> , <i>Acacia melanoxylon</i>                      | Most mod. well drained, some swamps, excellent grazing land     |

Species suitability according to site type

| Species                             | Saline<br>(Mid N<br>/SE) | Mallee           |             |       | Mid North     |               | .. common to<br>both .. |                | South-east and Adelaide Hills |                       |                                   |               |                                         |                        |
|-------------------------------------|--------------------------|------------------|-------------|-------|---------------|---------------|-------------------------|----------------|-------------------------------|-----------------------|-----------------------------------|---------------|-----------------------------------------|------------------------|
|                                     |                          | Shallow<br>stony | Sand<br>>1m | Loam  | Tree-<br>less | Mallee<br>Box | Blue G<br><15m          | Blue G<br>>15m | Pink G<br>sand<br>>1m         | Pink G<br>sand<br><1m | Stringy<br><15m<br>(Hills/S<br>E) | Tree-<br>less | Red G<br>mod<br>drain<br>(SE/<br>Hills) | Red G<br>well<br>drain |
| Acacia melanoxylon                  |                          |                  |             |       |               |               |                         |                |                               |                       | ✓/(x)                             | (x)           | ✓/✓                                     | (x)                    |
| Acacia salicina                     | ✓/x                      |                  |             |       |               |               |                         | x*             |                               | (x)                   |                                   |               |                                         |                        |
| Acacia stenophylla                  | ✓/x                      |                  |             |       |               |               |                         |                |                               | (x)                   |                                   |               |                                         |                        |
| Allocasuarina fraserana             |                          |                  |             |       |               |               |                         | x*             |                               |                       |                                   |               |                                         | x*                     |
| Allocasuarina luehmannii            |                          |                  |             |       |               |               |                         | x*             |                               |                       |                                   |               |                                         | x*                     |
| Allocasuarina torulosa              |                          |                  |             |       |               |               |                         | x*             |                               |                       |                                   |               |                                         | x*                     |
| Callitris columellaris              |                          | (x)              | (x)         |       |               | (x)           |                         |                | (x)                           |                       |                                   |               |                                         |                        |
| Callitris preissii                  |                          |                  | ✓           |       |               |               |                         |                | (x)-✓                         |                       |                                   |               |                                         |                        |
| Casuarina cunninghamiana            |                          |                  |             | x-(x) |               |               |                         |                |                               |                       |                                   |               | ✓/-                                     |                        |
| Casuarina glauca                    | ✓/✓                      |                  |             |       | (x)           |               | (x)*                    |                |                               | (x)-✓*                | -/x                               | ✓-✓✓          | ✓/-                                     |                        |
| Casuarina pauper (cristata)         |                          |                  |             | (x)-✓ | (x)           | (x)           | (x)*                    |                | (x)                           |                       |                                   |               |                                         |                        |
| Cupressus lusitanica                |                          |                  |             |       |               |               |                         |                | ✓                             |                       | -/✓                               | x             |                                         |                        |
| Cupressus macrocarpa                |                          |                  |             |       |               |               |                         |                | ✓                             |                       | -/✓                               | ✓✓            | ✓/-                                     |                        |
| Eucalyptus anoracea (baxteri)       |                          |                  |             |       |               |               |                         |                | ✓                             |                       |                                   |               |                                         |                        |
| Eucalyptus astringens               |                          |                  |             | ✓-✓✓  | ✓✓            | ✓             | ✓-✓✓                    | ✓-✓✓           | (x)-✓                         |                       |                                   | ✓-✓✓          |                                         |                        |
| Eucalyptus botryoides               |                          |                  |             |       |               |               |                         |                |                               | ✓✓                    | ?/-                               | ?             | ?/-✓                                    |                        |
| Eucalyptus brockwayi                |                          | ✓                |             |       |               | ✓             | ?                       |                |                               |                       |                                   |               |                                         |                        |
| Eucalyptus camaldulensis            | (x)/(x)                  |                  |             |       |               |               |                         |                |                               | ✓                     |                                   | ?             | ✓/-                                     | ✓-✓✓                   |
| Eucalyptus camaldulensis var obtusa |                          |                  |             |       |               |               |                         |                |                               |                       |                                   |               | ✓/-                                     | ✓                      |
| Eucalyptus cladocalyx               |                          |                  |             |       | (x)           |               | ✓-✓✓                    | ✓-✓✓           | x-(x)                         |                       | ✓-<br>✓✓/(x)                      |               | ✓-✓✓/x                                  | ✓-✓✓                   |
| Eucalyptus cladocalyx nana          |                          |                  |             |       |               |               |                         |                | (x)                           |                       |                                   | ?             |                                         |                        |
| Eucalyptus cneorifolia              |                          |                  |             |       |               |               |                         |                |                               | x*                    |                                   | (x)           |                                         |                        |
| Eucalyptus cornuta                  |                          |                  |             |       |               |               | ✓                       |                |                               |                       |                                   | ✓             |                                         |                        |
| Eucalyptus dumosa                   |                          | ✓✓               |             |       |               |               |                         |                |                               |                       |                                   |               |                                         |                        |
| Eucalyptus dundasii                 |                          | ✓✓               |             | ✓-✓✓  | ✓             | ✓✓            | ?                       |                |                               |                       |                                   |               |                                         |                        |
| Eucalyptus famelica                 | ✓/x                      |                  |             |       |               |               |                         |                |                               |                       |                                   |               |                                         |                        |
| Eucalyptus fasciculosa              |                          |                  |             |       |               |               | ✓                       |                | (x)                           | x                     | ✓/-                               |               |                                         |                        |
| Eucalyptus globulus subsp bicostata |                          |                  |             |       |               |               |                         | ✓              |                               |                       |                                   |               |                                         |                        |
| Eucalyptus globulus subsp globulus  |                          |                  |             |       |               |               |                         | ✓✓             |                               |                       | ✓✓/-                              |               |                                         | ✓✓                     |
| Eucalyptus globulus subsp maidenii  |                          |                  |             |       |               |               |                         | ✓              |                               |                       |                                   |               |                                         |                        |
| Eucalyptus grandis                  |                          |                  |             |       |               |               |                         |                |                               |                       |                                   | ?             | ?/-                                     |                        |
| Eucalyptus kondininensis            | ✓✓/?                     |                  |             |       |               |               |                         |                |                               |                       |                                   | ?             |                                         |                        |

| Species                                                   | Saline<br>(Mid N<br>/SE) | Mallee           |             |       | Mid North     |               | .. common to<br>both .. |                | South-east and Adelaide Hills |                       |                                   |               |                                         |                        |
|-----------------------------------------------------------|--------------------------|------------------|-------------|-------|---------------|---------------|-------------------------|----------------|-------------------------------|-----------------------|-----------------------------------|---------------|-----------------------------------------|------------------------|
|                                                           |                          | Shallow<br>stony | Sand<br>>1m | Loam  | Tree-<br>less | Mallee<br>Box | Blue G<br><15m          | Blue G<br>>15m | Pink G<br>sand<br>>1m         | Pink G<br>sand<br><1m | Stringy<br><15m<br>(Hills/S<br>E) | Tree-<br>less | Red G<br>mod<br>drain<br>(SE/<br>Hills) | Red G<br>well<br>drain |
| <i>Eucalyptus largiflorens</i>                            | ✓/?                      |                  |             |       |               |               |                         |                |                               | (*)                   | -(*)                              | ?             |                                         |                        |
| <i>Eucalyptus leptophylla</i>                             |                          | ✓✓               |             |       |               |               |                         |                |                               |                       |                                   |               |                                         |                        |
| <i>Eucalyptus leucoxylon/leucoxylon</i>                   |                          |                  |             | (*)-✓ | (*)-✓         | (*)-✓         | (*)-✓                   | ✓-✓✓           |                               | ✓                     | -/✓-✓✓                            | (*)-✓         | ✓/-                                     | ✓                      |
| <i>Eucalyptus leucoxylon/megalocarpa</i>                  |                          |                  |             | (*)-✓ | (*)-✓         | (*)-✓         | (*)-✓                   | ✓-✓✓           |                               |                       | -/✓                               |               | ✓/-                                     |                        |
| <i>Eucalyptus leucoxylon/pruinosa</i>                     |                          |                  |             | (*)-✓ | (*)-✓         | (*)-✓         | (*)-✓                   | ✓              |                               | ✓                     | -/✓                               |               | ✓/-                                     |                        |
| <i>Eucalyptus leucoxylon/pauperita</i>                    |                          |                  |             | (*)-✓ | (*)-✓         | (*)-✓         | (*)-✓                   | ✓              |                               |                       | -/✓                               |               | ✓/-                                     |                        |
| <i>Eucalyptus maculata</i>                                |                          |                  |             |       |               |               |                         | x**            |                               |                       | x/x*                              |               | x**                                     | ✓                      |
| <i>Eucalyptus obliqua</i>                                 |                          |                  |             |       |               |               |                         |                |                               |                       | -(*)                              |               |                                         |                        |
| <i>Eucalyptus occidentalis</i>                            | ✓✓/✓✓                    |                  |             | ✓-✓✓  | ✓-✓✓          | ✓-✓✓          | x-(*)                   | ✓-✓✓           |                               | ✓                     |                                   | ✓✓            |                                         |                        |
| <i>Eucalyptus ovata</i>                                   |                          |                  |             |       |               |               |                         |                |                               | ✓✓                    |                                   | ?             | ✓/-                                     |                        |
| <i>Eucalyptus porosa</i>                                  | ✓/?                      | ✓✓               |             | (*)-✓ | (*)           | ✓-✓✓          |                         |                | (*)                           |                       |                                   |               |                                         |                        |
| <i>Eucalyptus punctata</i>                                |                          |                  |             |       |               |               |                         |                |                               |                       | ?/-                               | ?             |                                         |                        |
| <i>Eucalyptus saligna</i>                                 |                          |                  |             |       |               |               |                         |                |                               |                       | ?/-                               | ?             | ?/-                                     |                        |
| <i>Eucalyptus sideroxylon</i> subsp<br><i>sideroxylon</i> |                          |                  |             |       |               |               |                         | ✓-✓✓           |                               |                       |                                   |               |                                         | ✓                      |
| <i>Eucalyptus sideroxylon</i> subsp <i>tricarpa</i>       |                          |                  |             |       |               |               | ?                       | ✓              |                               |                       |                                   |               |                                         |                        |
| <i>Eucalyptus tereticornis</i>                            | -(*)                     |                  |             |       |               |               |                         |                |                               |                       | -/✓-✓✓                            |               | ?/-                                     |                        |
| <i>Eucalyptus viminalis</i> / <i>cygnatensis</i>          |                          |                  |             |       |               |               |                         |                | ✓                             | x                     |                                   |               |                                         |                        |
| <i>Grevillea robusta</i>                                  |                          |                  |             |       |               |               |                         | ✓              |                               |                       |                                   |               | x/-                                     |                        |
| <i>Melaleuca cuticularis</i>                              | ✓/✓                      |                  |             |       |               |               |                         |                |                               | (*)                   |                                   |               |                                         |                        |
| <i>Melaleuca uncinata</i>                                 | ✓/✓                      | (*)              | ✓           | ✓     | (*)           | (*)           | (*)                     | ✓              | (*)                           | ✓                     | ✓                                 | x             | x-(*)/-                                 |                        |
| <i>Melia azaderach</i>                                    |                          |                  |             |       |               |               |                         |                |                               |                       | (*)                               |               |                                         |                        |
| <i>Paulownia tomentosa</i>                                |                          |                  |             |       |               |               |                         |                |                               |                       | (*)                               |               |                                         |                        |
| <i>Pinus halepensis</i>                                   |                          | ✓                |             |       |               |               | ✓                       |                |                               |                       |                                   | (*)           |                                         |                        |
| <i>Robinia pseudoacacia</i>                               |                          |                  |             |       |               |               |                         | ✓              |                               |                       | (*)                               |               |                                         | ✓                      |

/ suitability at two sites  
a site  
too young to assess

✓-✓✓ suit. range of diff. prov.      - not represented at  
\* browsing damage      \*\* frost damage      ?

## Relative provenance performance for key species

### *Acacia melanoxylon*

At Montarra in the Adelaide Hills on a Stringybark Site, (*E. obliqua*) Silver Creek (Vic), Fingal (Tas.), Mt. Gambier (SA) and Mt. Mee (Qld) are slightly more vigorous.

In the SE. of South Australia at Kalangadoo on a Red Gum Site (*E. camaldulensis*), the slightly more vigorous provenances are Mt. Gambier (SA), Blackwood Park (Tas.), Burnie (Tas) and Silver Creek (Vic).

There are differences in form between the provenances but due to the young age of the trials, no meaningful form assessment has been made yet.

### *Casuarina glauca*

On salt affected sites (Redhill, Woolumbbool and Willalooka) and non saline sites (Kalangadoo and Mannanarie), most provenances except Coffs Harbour do well.

The trees are still not tall enough to do a stem-form assessment.

### *Eucalyptus astringens*

Differences at this stage are not great between most provenances though Dryandra S.F., Ravensthorpe and Boyagin Rock are generally showing more vigour. Kundip seems to be slightly less vigorous than the other provenances.

### *Eucalyptus camaldulensis*

Relatively vigorous provenances on the highest rainfall site (Gumeracha Red Gum) are Lake Albacutya and Lowan Valley and Lake Hindmarsh. Lowan Valley however performed poorly on a salty site (Redhill).

Six provenances generally performed better than the rest on most sites — Lake Hindmarsh, Wimmera R, Lake Albacutya, Murray Bridge, Lake Coorong and Lake Agnes.

No form assessment has yet been done due to most provenances being below the 6 metre mark.

### *Eucalyptus cladocalyx*

Generally, the fastest growing provenance across the sites is Flinders Chase N.P. from Kangaroo Island, followed by Wilmington and Wirrabara, the latter two having marginally better stem form. The KI provenances would not be expected to be frost resistant. Wanilla lacks vigour and form, is bushy and flowers prolifically.

### *Eucalyptus dundasii*

Dundas blackbutt is an attractive tree, which consistently grows well on most dry (250-400 mm) sites. Though not a vigorous species, its form is generally excellent and its timber reported to be durable.

Although a single seed source was evaluated in the earlier trial, a wider selection of provenances have been recently planted.

### *Eucalyptus leucoxylon*

Generally *Eucalyptus leucoxylon* does not perform well on dry sites (< 400 mm annual rainfall)

Where rainfall is adequate, Kangaroo Island provenance is showing most vigour at a young age, closely followed by Wirrabara, Williamstown and Naracoorte. Form generally is not good though Wirrabara, Williamstown and Kangaroo Island seem to show better formed stems than others. Rushworth is showing promise on some sites.

### *Eucalyptus occidentalis*

On saline sites in the Upper S.E. of South Australia, Pallerup Rock, Katanning and Bremer Bay appear to perform best, whilst in the Mid-North, Ravensthorpe, Katanning and Broomehill are the fastest growing.

On non-saline sites, Grass Patch, Bremer Bay and Katanning seem to perform well in most areas.

Generally, the best performing provenances have the best form.

*Eucalyptus tereticornis*

Yurammie is showing most vigour at this young age on both trial sites.

*Melaleuca uncinata*

Broombush does not like compacted soils, for example old sheep runs (Appila Springs), or the dry tops of deep sand dunes (Peebinga), other wise where conditions are more suitable, both the Lameroo and Kangaroo Island provenances grow best.

Generally it would seem that the Kangaroo Island provenance has better form (quite noticeably so at Redhill) for brush fencing with very few seed capsules in comparison with the others trialed.

*Eucalyptus fasciculosa*

The Meningie and Keith/ Brimbago provenances seem to be more vigorous both in the Adelaide Hills and Mid-North of SA. Growth is not rapid on the deep sands of the Upper SE of the State.

*Eucalyptus porosa*

Golgol and Tailem Bend generally grow more vigorously than the two Mid-North provenances though Yatina – Pekina has done well in the Mallee at Lameroo.

*Eucalyptus globulus*

Rylstone and Bruthen provenances are *E. globulus* subsp. *bicostata*; Cann Valley is *E. globulus* subsp. *maidenii*. The other 7 seedlots (Police Pt, Dover, Denison Valley, Lorne, Huonville, Lake Leake and Otway Range) are *E. globulus* subspecies. *globulus*. Generally *E. globulus* subsp. *globulus* is more vigorous and has better form than the other subspecies but there is generally little apparent difference in vigour of the *globulus* subspecies seedlots.

*Grevillea robusta*

Differences between provenances are small at this early stage of growth.

Contact Jeff Fairlamb on 08 8539 2113 for a full copy of the summary of interim trial results and detailed trial site information if required.

## 2.2.2. South-East SA Low Rainfall Tree Improvement Program

David Bush, ForestrySA, PO Box 162, Mount Gambier, SA, 5290, Australia

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Tree Improvement Workshop, Adelaide, November 3-4 1998.

### Overview of activities

The dryland tree improvement program in the Mid-Upper South East of SA has been running for two years. The objective is to establish trials to assess the suitability of a number of species, for commercial dryland afforestation. The program has ties with and complements other research in SA (eg. see Bulman, S. 2.2.1 in these proceedings). The focus to-date, has been on areas receiving 500-600 mm rainfall per annum. This will be expanded into the 400 - 500 mm rainfall zone in winter 1999. Sites in the Mid-Upper South East are of variable soil type, including sandy ridges and uplands, and heavier clay soils in lower lying areas. Lower rainfall areas may also be subject to waterlogging during winter, which is a somewhat unusual problem in dryland forestry. Currently there are four dryland trial sites established. Another site receiving 700 mm rainfall per annum is used for comparative purposes (Table 1). Note that the sites are of three types; deep sands ('sandy'), and 'heavy' rendzinas and clay-loams.

Table 1. Site characteristics

| Site         | Mean annual rainfall (mm) | Soil type [Northcote, 1974 class]             |
|--------------|---------------------------|-----------------------------------------------|
| Avenue       | 550                       | Sand [Uc1]                                    |
| Broadview Rd | 500                       | Sand [Uc1]                                    |
| Custon Rd    | 500                       | Clay loam                                     |
| Greenways    | 550                       | Rendzina (heavy, shallow clay over limestone) |
| Reedy Creek  | 700                       | Sand [Dy4]                                    |

Over the last two planting seasons, trials of both softwood and hardwood species have been established. The first year's planting season was extremely harsh (annual rainfall of less than 500 mm at all sites), and survival on some sites (particularly the Reedy Creek site, which has a hydrophobic A1 soil horizon) was generally poor. This was especially the case for the clonal eucalypt hybrids, and open rooted *P. pinaster*. A list of material being trialed is given (Table 2).

Table 2. List of trees being trialed in mid – upper south east

| Species                                            | Provenance/ subsp               | Site types      | Comment                                                                                                                                                                                                                   |
|----------------------------------------------------|---------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>E. camaldulensis</i> x <i>grandis</i> clones    | 20 clones                       | Heavy & Sandy   | Failed on rendzina post contact with limestone (lime induced chlorosis)                                                                                                                                                   |
| <i>E. camaldulensis</i> x <i>grandis</i> seedlings | 20 full sib families            | Sandy           | Good survival @ P+4 months despite drought                                                                                                                                                                                |
| <i>E. globulus</i>                                 | Ssp globulus Pelterata (TAS)    | Sandy           | Subsp. globulus significantly better height and diameter growth than bicostata at P+10 months                                                                                                                             |
| <i>E. globulus</i>                                 | Ssp globulus Flinders Is. (TAS) | Sandy           |                                                                                                                                                                                                                           |
| <i>E. globulus</i>                                 | Ssp bicostata Mt Cole (VIC)     | Sandy           |                                                                                                                                                                                                                           |
| <i>E. globulus</i>                                 | Ssp bicostata Nullo Mt (NSW)    |                 |                                                                                                                                                                                                                           |
| <i>E. globulus</i>                                 | Ssp globulus Seymour (TAS)      | Sandy           |                                                                                                                                                                                                                           |
| <i>E. viminalis</i>                                | Var. cygnetensis                | Sandy           | Poor form, all sites @ P+14 months                                                                                                                                                                                        |
| <i>E. robusta</i>                                  | Nowra                           | Heavy           | Failed on rendzina post contact with limestone country-rock                                                                                                                                                               |
| <i>E. grandis</i>                                  | Buladelah SF (NSW)              | Sandy           | Good early height and diameter growth                                                                                                                                                                                     |
| <i>E. saligna</i>                                  | Batemans Bay (NSW)              | Sandy           |                                                                                                                                                                                                                           |
| <i>Pinus radiata</i>                               | Cedros Is. half sib             | Sandy           |                                                                                                                                                                                                                           |
| <i>Pinus radiata</i>                               | Guadalupe Is. half sib          | Sandy           |                                                                                                                                                                                                                           |
| <i>Pinus radiata</i>                               | STBA seed orchard               | Sandy           | Guadalupe outperforms other radiata at P+10 months                                                                                                                                                                        |
| <i>Pinus pinaster</i>                              |                                 | Sandy           | V.good initial growth in '98 plantings                                                                                                                                                                                    |
| <i>Cupressus macrocarpa</i>                        | Longwoods (New Zealand) SPA     | Heavy, Sandy    | Both casuarina and cypress spp. doing well on rendzina, clay-loam and sands. P+10 month measures indicate that performance is better on heavier sites. Casuarina is brittle and has suffered from bird and animal damage. |
| <i>C. lusitanica</i>                               | Lismore (New Zealand) SPA       | Heavy, Sandy    |                                                                                                                                                                                                                           |
| <i>Casuarina obesa</i>                             | Lime Lakes (NSW)                | Heavy and sandy |                                                                                                                                                                                                                           |
| <i>C. glauca</i>                                   | Tuross Lakes                    | Heavy and sandy |                                                                                                                                                                                                                           |

While it is too early to gauge long term prospects for these species, the following observations can be made:

1. All of the eucalypt material established on rendzina soils has failed after promising initial growth, due to chlorosis caused by root contact with the limestone country-rock. The casuarinas and *Cupressus* spp. have grown extremely well under these conditions, and are showing promise.

2. *Eucalyptus globulus* is growing well at the two sandy sites, and is around 2 m tall at P (time of planting)+14 months. Thus far, the Tasmanian Flinders Is. and Pelverata provenances of *E. globulus* subsp. *globulus* are significantly outperforming the mainland provenances (*E. globulus* subsp. *bicostata*), in terms of volume growth, which is normal on higher rainfall sites in South Australia. However, the Tasmanian provenances may be less drought resistant in the long term, based on the rainfall of their natural ranges. It is not expected that any *E. globulus* subspecies would perform well at sites receiving below 500 mm average annual rainfall, or where soil depth is low. *E. saligna* is also performing very well on the sandy sites, though volume growth is not as good as *E. globulus*.

Despite the very harsh planting season in 1997, the radiata pine was established with less than 5 % mortality. At P+10, the Guadalupe half-sib material was significantly outperforming the seed orchard and Cedros Island half-sib material, in terms of volume growth, at all three sites where it is being trialed. This is a surprising result, and this trial will be monitored with interest in future.

### Future

Expansion of the trial program is planned for 1999. This will include selection of drier sites (400-500 mm) and expansion of the range of species selected. On the drier sites, selections of *E. cladocalyx* and *E. occidentalis* will be established, as well as *P. pinaster* and *P. brutia*. It is likely that joint trials with DNRE will be carried out in the Wimmera, close to the South Australia - Victoria border. Other selections of eucalypts, including *E. cladocalyx* and *E. occidentalis* will be tried on the rendzinas, in the hope of identifying species tolerant of the high pH associated with this soil type.

### Reference

Northcote, K. H., (1974). *A Factual Key for the Recognition of Australian Soils* (4th Edition), Rellim Technical Publications, Glenside, South Australia, pp.123

## 2.3 Victorian Low Rainfall Tree Improvement Program

### 2.3.1 Low Rainfall Farm Tree Improvement in Victoria

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

C. Hajek, Department of Natural Resources and Environment Victoria

#### 1. State Policy: The big picture

In 1998 in response to the national goal of trebling Australia's plantation area, the Private Forestry Council of Victoria, in conjunction with the Department of Natural Resources and Environment, produced "Private Forestry in Victoria : Strategy towards 2020".

This document sets out the State's;

**Vision** - *"By the year 2020, Victoria will have developed a major market driven commercially and environmental sustainable private forestry sector with strategically placed concentrations of plantations comprising suitable species."*

**Target** - *"To increase the effective area of private forestry in Victoria between 1998 and 2020."*

**Strategy** - *"Industry and government sector will collaborate to create an environment conducive to investment in commercial tree growing that will enhance Victoria's agricultural sector, its forest industries, and the contribution made by the sector to the State and regional economies and rural communities, by ....."*

*"The development of the private forestry base will compliment the production from the public native forest resource. While the major focus will be on fast growing eucalypts and radiata pine, **the industry should be encouraged to grow other tree species to meet a range of market requirements.**"*

#### 2. Key players

Within the sub 600 mm areas of Victoria there are a number of private and government organisations concerned with farm forestry research and development. Of these, the ones with a major emphasis on tree improvement are the Department of Natural Resources and Environment (NRE) and Melbourne University.

Within NRE projects concerned with farm tree improvement are being undertaken by research staff located at one of three institutes as well as extension staff in NRE's Catchment and Agricultural Services division. Generally speaking extension staff projects tend to have a greater emphasis on demonstration and applied research, in contrast to the more formal trials of the research staff, however there is a high degree of collaboration between the two.

The three NRE research institutes have historically concentrated upon quite different areas, but have found common ground recently in the field of farm forestry. These institutes are;

- Pastoral and Veterinary Institute (PVI) - PVI is located at Hamilton and has a Farm Forestry Section which concentrates on combining tree species and management practices with agriculture to maximise sustainable production. Their study area covers the Glenelg, Southern Wimmera and Western Districts of Victoria.
- Centre for Forest Tree Technology (CFTT) - CFTT is based in Melbourne and works across the whole state. In the past they have worked mainly in either native forests, radiata pine and Blue gum plantations in the higher rainfall zone or irrigated plantations, however they are looking to increase their activity in the lower rainfall zone.

- Centre for Land Protection Research (CLPR) - CLPR is based at Bendigo and has a Native Vegetation Unit which is interested in the role which farm forestry can play in addressing land degradation issues. Although they operate in many parts of the state their farm forestry activities have concentrated in the North Central Region of Victoria to date.

In addition to the traditional research bodies of the Department, a significant role is also played by the Catchment and Agricultural Services (CAS) division. CAS is NRE's field based extension arm and in conjunction with a number of community groups has been successful in obtaining Federal assistance to provide farm forestry extension programs in a number of areas. These include the Wimmera, North Central and North East regions of Victoria which contain significant areas of sub 600mm annual rainfall.

### 3. Activities Past and Present

The various efforts being made in Victoria to improve the genetic stock of farm trees is best described on an area basis. Most of the sub 600mm annual rainfall zone is located in the North West of the state (see fig 1 & 2) with some small pockets caused by rain-shadows on the Western plains and in Gippsland. However, excluding irrigated woodlots, most of the activity is in the 400 - 600 mm annual rainfall area which forms a belt about 200 - 300 km wide running East West across Northern Victoria through such towns as Horsham and Bendigo.

#### 3.1 Wimmera

A number of early species and provenance trials were established by the former Forests Commission of Victoria during the 60s and 70s. Unfortunately the monitoring and recording of these was very poor and as a consequence the level of information that can be derived from these sites is far less than it should be. Most of the early trials concentrated upon selecting suitable species for firewood production on sandy soils. The full extent of the species trialed is unknown, but *E. astringens*, *E. occidentalis* and *E. cladocalyx* were determined to have the optimum growth and survival and consequently became the favoured plantation species in the region. Another early trial of note is a provenance trial of *Pinus brutia* established on two sites in 1971. Great variation is now evident between the different provenances and the sites, and we are currently attempting to ascertain the seedlot details.

During the 90s the emphasis shifted towards higher value, small scale woodlots for clearwood production and a number of programs were initiated by Wimmera CAS and PVI Farm Forestry staff which led to the following outcomes;

- Greening the Wimmera - five large scale formal species trials were established on different soils, and several small scale demonstration woodlots containing one or more "best bet" native species were established.
- Glenelg Farm Forestry Project - Establishment of numerous small demonstration farm woodlots and a number of provenance trials of such species as *Callitris gracilis*, *Corymbia maculata*, *E. sideroxylon* and *A. mearnsii*.
- DPIE Small Scale Farm Forestry Project - Further establishment of small scale farm woodlots with an emphasis on best bet native species in areas not covered by the above projects and trials to examine the potential of *P. brutia*, *P. pinaster* and *E. grandis x camaldulensis*.

Early indications are that the indigenous species such as *E. camaldulensis*, *E. leucoxydon*, *E. tricarpa* and *Allocasuarina verticillata* along with *E. cladocalyx* and *E. occidentalis* have the greatest reliability in terms of survival and growth across a range of sites. However some higher rainfall species such as *C. maculata* and *E. globulus* can perform well under certain conditions. All of these sites are currently being monitored by Wimmera CAS and PVI staff.

### 3.2 North Central

Work by CLPR and CAS staff has concentrated upon narrowing the field of species and examining the performance of different provenances for a select group of “core” species. As most of this work commenced relatively recently species selection has involved assessment of species in the field on various land systems and market prospects. Consequently there has been a strong emphasis on *E. tricarpa*, *E. leucoxydon*, *E. microcarpa*, *E. occidentalis* and *E. cladocalyx*. Currently provenance trialing of two species has commenced with more intended.

### 3.3 North East

A series of provenance trials containing *E. sideroxylon*, *E. tricarpa*, *E. cladocalyx* and *E. benthamii* have been established in the 500 - 650 mm/yr areas between Bendigo and Barnawatha this year.

### 3.4 Corangamite

CAS has commenced a program to promote *E. cladocalyx*, *A. mearnsii* and *E. occidentalis* for firewood production in their lower rainfall regions between Lake Bolac and Ballarat. Activities include the establishment of an *E. occidentalis* seed orchard and growth trials with the above three species.

### 3.5 Gippsland

During 1999 Gippsland Forest Plantations will be establishing demonstration/trial sites in the 500 - 650 mm/yr rainfall zone however the species to be used are still to be determined.

## 4. Conclusion

There is no designated farm tree improvement program in the low rainfall regions of Victoria as such, and responsibility and involvement in this area has tended to evolve and develop rather than then be clearly structured and delegated. However there is a high degree of communication and interaction between the various interested parties and a high degree of commonality in our approach and objectives.

In the main, research has concentrated upon identifying a small number of best-bet species for which provenance trialing is then commenced. Most of this work has occurred this decade, and in many cases has not progressed far enough to yield a great deal of information. There is however, a common shortlist of species emerging upon which most parts of the state are concentrating. These are;

|                                |                   |
|--------------------------------|-------------------|
| <i>E. cladocalyx</i>           | sugar gum         |
| <i>E. occidentalis</i>         | swamp yate        |
| <i>E. tricarpa/sideroxylon</i> | red ironbark      |
| <i>E. leucoxydon</i>           | yellow/white gum  |
| <i>A. mearnsii</i>             | late black wattle |

*E. camaldulensis*, *E. microcarpa*, *A. verticiliata*, *C. maculata*, *C. gracilis*, and *P. brutia* are being studied to a lesser extent.

Selection of these species has been based on their proven ability to perform well under a range of conditions, growth rates, form and perceived potential to yield a commercial product.

Other characteristics of farm tree improvement in Victoria are;

- a tendency to combine extension with research by placing an emphasis on establishing small (less than 2 ha) trials which can also be used for demonstration purposes.
- a strong emphasis on integrating farm forestry into the agricultural system so as to improve sustainability.
- a strong emphasis on higher value clearwood production from small woodlots.

It is also worth mentioning that an equal or greater amount of resources has been invested in other complimentary projects, which impact on the selection of suitable species and thus farm tree improvement. These include;

- a farm forestry economic feasibility study for the Wimmera and North Central regions.

- a study of the milling and processing properties of low rainfall farm trees by CSIRO.
- an *A. mearnsii* feasibility study in Western Victoria.
- trials concerning spacing, management and site preparation.
- Farm forestry extension.

### Contributors

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Figure 1. Victoria: Average annual rainfall zones



### 2.3.2 Some Prospective Low Rainfall Species for Use in Low Rainfall Zones: Performance at Several Victorian Irrigated Sites

Paper submitted to the proceedings of the Joint Venture Agroforestry Program Low Rainfall Tree Improvement Workshop, Adelaide Nov 3-4 1998

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#### Introduction

A series of trials were established in Northern Victoria in 1993 where the combination of climate and adequate reuse and ground water supplies appeared suitable for tree growing, to test the most promising species, and some provenances within these. A further group of species not considered as good was also tested, the performance of which is described here. These notes are presented to give some indication of Victorian experience with low rainfall eucalypt species under saline conditions. The experience may be of some assistance in the new ALRTIG hardwood breeding module.

This report describes the establishment and early growth on four sites established under the Trees for Profit (TFP) program, of *Eucalyptus occidentalis*, *E. cladocalyx*, *E. sideroxylon*, *E. viminalis*, *E. brookeriana*, *E. maculata*, *Casuarina cunninghamiana*, *C. glauca*, *Acacia melanoxylon* and *A. mearnsii*. At most sites, several provenances of each species were included. At Shepparton, the main seedlots of *E. globulus*, *E. grandis*, *E. saligna* and *E. camaldulensis* were incorporated into the trial as benchmarks of relative performance.

#### Method

Four irrigated sites were planted to a series of species in 1993. The species planted at each site are indicated in Table 1. The experimental design adopted is indicated in Table 2. The sites were irrigated with groundwater or municipal effluent (salt content in electro-conductivity units  $\mu\text{S cm}^{-1}$  indicated in Table 2).

Volume derived from diameter and height measurements were used to compare between species and seedlots within species on ranked performance. The tendency of seedlots to fork was also assessed.

Stem volume was the main analysis variable. Plot means were compared by the least significant difference. Shepparton fork scores were regressed against stem diameter to determine if any relationship existed between growth rate and forking. For instance, an average fork of one indicates that all trees were single stemmed at 1.3 metres height. A score of 1.5 indicates that 50% of trees have single stems at 1.3 m, and 50% have two stems (or somewhat fewer than 50% if some of these have three or more forks).

#### Results

Survival differences were highly significant at all sites. At Shepparton survival was very high, and those species with lower figures were *E. globulus* (due to heavy Autumn gum moth attack which set them back in their first winter), *E. maculata* (frost damage), and *Acacia mearnsii* (weak seedlings). Volume comparisons on a site were highly significant, except at Timmering, where no difference could be discerned between the saline and fresh irrigated plots. Tatura survival results were quite variable and rendered reliable comparisons impossible. Shepparton was the best trial from the viewpoint of successful establishment; at this site all species have had every opportunity to display their full potential. Results for Shepparton are listed in Table 3, along with those of Nathalia.

#### Stem form

The regression of fork score against individual tree diameter at Shepparton was not significant, hence no relationship was discernible between tree size and its tendency to fork. Therefore mean species fork scores could be allocated equivalently to all size classes. This feature has implications for the maintenance requirements of fork prone species. Note that *E. occidentalis*, *E. maculata*, *E. cladocalyx* and *E. sideroxylon* had from 1.14 to 1.74 stems at breast height. Most of these fork results appear to be due to the species natural habit; in the case of *E. maculata* the forks appear to be the result of epicormic stem growth in response to frost damage at the growing tip.

Excepting one poorly formed seedlot, *E. viminalis* had 1.1 or fewer mean stems. The best performers, with mean stems per tree of 1.04 or fewer, were *E. globulus*, *E. viminalis*, and one seedlot of *E. saligna* and *E. grandis*.

### Comparison between sites

Only four seedlots are common to all sites. Replicate means for these were combined and analysed at the site then at the seedlot level (Table 4). The analysis of common seedlots revealed a strong site difference ( $p < 0.005$ ), which was expected and is explainable by the greatly superior performance of the Shepparton site. This result masks any subtler differences due to soil type or irrigant salinity.

Of the salt tolerant species, *Casuarina glauca* and *Eucalyptus cladocalyx* had high survival, whereas *E. occidentalis* survival tended to be poorer and much more variable. This is probably related to the quality of seedlings; the species appears unsuited to plug propagation methods due to its sprawling habit as a young seedling. The survival of *E. occidentalis* at Shepparton was much better (98-99%). This is probably due to their better stage of development as a seedling at the time of planting. At all sites, *E. occidentalis* was superior in growth rate once established than either *E. cladocalyx*, *E. sideroxylon*, or *C. glauca*.

## Discussion

The following discussions consider the success of species over a range of sites.

### *E. occidentalis*

Poor survival of all *E. occidentalis* seedlots at the three sites planted in the winter of 1993 has confounded results. Seven seedlots from the Calyerup creek provenance planted at Timmering and Tatura displayed high variability in both establishment and volume growth. The three seedlots (OCCID100, 200 and 300) common to all trials, when planted at Nathalia also displayed very low survival (Table 3). The seedlings used for these sites were relatively small and poorly developed at planting, but despite the losses showed satisfactory growth once established. The same three seedlots were planted much later at Shepparton. These were sturdier seedlings and conditions at planting were better. This resulted in high establishment percentages and good early growth. Thus, at Shepparton performance of *E. occidentalis* can be confidently compared. Volume production of OCCID100 was significantly better to OCCID300, whilst OCCID201 was ranked between, and not significantly different to either (Table 3). The stem form of these *E. occidentalis* provenances were consistently poor, as are the seven Calyerup Creek families.

### *Casuarina glauca* and *C. cunninghamiana*

*Casuarina glauca* at both Timmering and Tatura showed consistently high survival, but had a tall slender habit and very low volumes. Two *Casuarina cunninghamiana* seedlots were planted at Nathalia and Shepparton. Survival ranged from 99 to 97%. As for *C. glauca*, while plants were very consistent in height, they were very slender and produced little volume. They may be slow to establish, and later inventories should monitor for a change in the situation.

### *E. cladocalyx*

*E. cladocalyx* displayed high establishment rates at all sites, and consistent, though comparatively slow development. As both *E. cladocalyx* seedlots were sourced from plantation sources in Victoria, the possibility of prior inbreeding may have restricted their growth rate.

### *E. sideroxylon*

At Nathalia the Murrungowar provenance of *E. sideroxylon* was significantly superior to the Bendigo seedlot in survival, basal area, height and volume growth, yet at Shepparton they were almost identical (Table 4). This difference may once again be due to differences in the quality of seedlings. A seedlot from the Killawarra forest was also planted at Nathalia, and ranked in between the others.

### *E. maculata*

Only one seedlot, from planted trees (provenance unknown) was available for planting at Nathalia. Three seedlots from native stands were later established at Shepparton. Survival was 86% and volume rank 9th at Nathalia, and ranged from 86 to 96% at Shepparton. Establishment conditions at Shepparton were very good and it is considered likely that seedlots had every opportunity to perform well. All *E. maculata* seedlots at both sites suffered tip damage due to frosts in the winter following planting. This has without doubt restricted growth, and caused many trees to fork by recovering from several epicormic leaders. Volume growth at Shepparton ranged from 5.88 m<sup>3</sup> to 3.25 m<sup>3</sup> ha<sup>-1</sup>, with MACUL230 (Kangaroo State Forest) ranked 16th overall, MACUL610 19th, and MACUL260 last. Differences between these were not significant. A more recent trial at Undera incorporating further provenances and families of *E. maculata*, (Supplied by CSIRO FFP) will enable much better evaluation of frost resistance variation.

### *Other Species*

*E. brookerana* (BROOK800 Triabunna) ranked fourth outright at Shepparton for volume, seventh in height, third in basal area, and in the best survival group. At Nathalia it was 8th for basal area, 9th in height, and 13th in volume. Its survival of 75% was still within the top (but variable) bracket. The performance at Shepparton is indicative that it may be suited to lower salinity sites.

One *Acacia mearnsii* seedlot AMEAR900 (Natal seed orchard) was planted two sites. At Nathalia it ranked highest overall ( $p < 0.001$ ) for height, basal area and volume growth, and was clearly well suited to the site at two years of age. The plants were characterised by butt sweep, and heavy branching, probably due to the dominance the plants had over their neighbours. At Shepparton they were large plants as well, but the species only ranked tenth.

One seedlot of *Acacia melanoxylon* AMELA100 (Warrenbayne) was planted at Nathalia ranked lowest overall for height and volume growth, producing a stout, compact but single stemmed tree. Its foliage colour is healthy and appears to tolerate the moderately saline conditions.

*E. botryoides* at Nathalia (Table 3) had patchy survival between 68 and 86%, and volumes from 2.4 to 1.0 m<sup>3</sup> ha<sup>-1</sup>. BOTRY300 (Narooma), ranked second over all seedlots, and BOTRY110 (Termeil) fifth. BOTRY900 (Tildesley) ranked ninth and was significantly poorer than the other two. BOTRY900 was also represented at Shepparton, ranking eighth in volume at 9.88 m<sup>3</sup> ha<sup>-1</sup>. It was superior but not significantly so to BOTRY350 (Bithry inlet, 13th, 6.83 m<sup>3</sup> ha<sup>-1</sup>). Survival of both was very close to 100%.

At Shepparton *E. viminalis* (VIMIN850 Otway) was outright tallest of all seedlots, although with a smaller basal area. It thus ranked third overall for volume, at 14.85 m<sup>3</sup> ha<sup>-1</sup> behind two *E. grandis* lots. Its stem form was excellent and branches fine. VIMIN390 (Ellery, 11th, 7.85 m<sup>3</sup> ha<sup>-1</sup>) was also tall and slender relative to other seedlots. VIMIN090 (Scone, 14th, 6.03 m<sup>3</sup> ha<sup>-1</sup>) exhibited somewhat poorer form than the other two. VIMIN850 was significantly superior to the other two, which were not significantly different to each other. Survival of all seedlots was high, with no significant differences. General observations indicate that all these *E. viminalis* seedlots are preferred to other species by the leaf grazing insect *Paropsis* spp. larvae and adults. At Nathalia survival ranged from 65 to 75% (NS), with Ellery third overall (2.24 m<sup>3</sup> ha<sup>-1</sup>), Otway tenth (0.80 m<sup>3</sup> ha<sup>-1</sup> and Scone 15th (0.49 m<sup>3</sup> ha<sup>-1</sup>). The poorer relative performance of Otway may be attributed to the higher saline irrigation. The Scone seedlot again exhibited poorer relative form than the other two.

### *The benchmark species*

The Shepparton experiment includes two seedlots of *E. globulus* and *E. grandis*, and one each *E. saligna* and *E. camaldulensis*. The *E. grandis* seedlots were outright first and second for volume production. The *E. saligna* lot was fifth, whilst the *E. camaldulensis* lot seventh. *E. globulus* has proven to be the fastest grower of these species in all other trials in the region, and of these GLOBU660 is consistently the fastest grower. In the Shepparton experiment however the larvae of *Mnesampela privata* (Autumn gum moth) heavily grazed the *E. globulus* seedlots in July of 1995. This defoliation led to seedling death rates of 12% in GLOBU660, and 27% in GLOBU200. Recovery of survivors was variable due to the damage levels. Volume at age 26 months was 9.4 m<sup>3</sup> (GLOBU660) and 6.0 m<sup>3</sup> (GLOBU200), under half that of the best *E. grandis* seedlot, with 19.1 m<sup>3</sup> ha. In earlier experiments on the same site under conditions of light grazing GLOBU660 outperformed GRAND300 volume production by a factor of two. Hence the severe impact of insect grazing can be gauged. Note that the Coffs Harbour *E. grandis* performed better in relation to GRAND950. This result is contrary to results obtained in other TFP trials, in which GRAND950 (the Kyabram land race) was superior.

### *Between sites*

Seedlot rank between sites was very inconsistent, and for seedlots with low survival little inference could be made of their prospective performance. Using species mean values we can compare Timmering and Tatura. Tatura was twice as large in basal area increment, 0.6 m better in dominant height, and 0.52 m<sup>3</sup> ha<sup>-1</sup> better in volume than Timmering. As the inventory was at such an early stage it is expected that Timmering will commence to display better figures in the future. Both these sites are very similar in terms of soil and water application.

For Shepparton and Nathalia it was possible to compile a balanced subset of treatments represented at both sites. However, no significant seedlot only effects could be distinguished.

### *Forking*

The tendency to fork should be considered when evaluating the feasibility of treating sawlog stands by removal of forked trees. In such a scenario, all forked stems, and the smaller diameter straight stems in the stand would be removed. Higher degrees of forking (a mean of over 1.2 stems per tree) mean that it may not be possible to obtain sufficient stems for selection as final crop logs. Interpretation of these scores relies on consideration of the likely number of good form stems per hectare that can be achieved at critical stages in stand management.

### **Conclusions**

*E. occidentalis* was healthier and the fastest grower on the more saline sites, though its form left much to be desired. The provenance from Dumbleyung had the best growth rate, and appeared to fork less than other *E. occidentalis* seedlots. *E. cladocalyx* and *E. sideroxylon* were not outstanding by any measure, and typically ranked right at the bottom. Thus, of these hardwood species which are to form the basis of the ARLTIG hardwood module, *only E. occidentalis* appears capable of fast growth under saline irrigation.

Species showing best performance on non-saline sites were *E. viminalis* (Otways), *E. brookerana* (Triabunna), *E. occidentalis* (Dumbleyung), *E. botryoides* (Tildesley), and *A. mearnsii* (Natal). Growth rates were not outstanding in comparison with the benchmark species. Those that came close were the Otway provenance of *E. viminalis*, the Triabunna provenance of *E. brookerana*, and several varieties of *E. botryoides*. *Acacia mearnsii* also produced reasonable growth though its utilisation potential is doubtful. *C. glauca* was superior in form quality, though much slower growing, than most of its eucalypt counterparts.

### *Limitations of trial designs*

The variability in number and composition of seedlots among the four sites restrict the inferences that can be made between them. The fact that irrigation water quality is different between sites, which are physically remote from one another and differing in soil type further restrict the value of between-site comparisons. Lastly, the layout of three of the trials as line plots result in relatively early domination of slower starting seedlots by faster neighbours, which would mask any possible later development by the slow seedlots. The Shepparton trial is however established as 25 tree square plots, which will allow the inner nine trees to develop further with the buffer trees delaying the onset of inter plot competition. Thus this trial's usefulness is likely to continue for several years beyond that of the others.

### *Limitation of early assessment data*

Notwithstanding the above comments, the age of inventory reported here is perhaps a little early to permit full evaluation of all species. This is because at age of 22 months some plots had yet to reach canopy closure, hence inter tree competition had not yet commenced. Secondly, at such an age slower species had scarcely commenced development of stemwood to enable valid volume comparisons. If such trees are indeed "late starters" it will be wise to await future results. The trial sites will be maintained for the foreseeable future, however routine inventories will be phased down. The Shepparton trial has the most potential to continue to provide inference on longer-term growth.

**Table 1. Source of species and seedlots used, and planting location.**

| <i>CFTT seedlot</i> | <i>Species</i>           | <i>Locality</i> | <i>State/country</i> | <i>Nathalia</i> | <i>Tatura</i> | <i>Timmering</i> | <i>Shepparton</i> |
|---------------------|--------------------------|-----------------|----------------------|-----------------|---------------|------------------|-------------------|
| AMELA100            | <i>A. melanoxyton</i>    | Warrenbayne     | Vic                  | Y               |               |                  |                   |
| AMEAR900            | <i>A. mearnsii</i>       | Natal           | Africa               | Y               |               |                  | Y                 |
| BOTRY300            | <i>E. botryoides</i>     | Narooma         | NSW                  | Y               |               |                  | Y                 |
| BOTRY110            | <i>E. botryoides</i>     | Termeil         | NSW                  | Y               |               |                  | Y                 |
| BOTRY900            | <i>E. botryoides</i>     | Tildesley       | NSW                  | Y               |               |                  | Y                 |
| BROOK800            | <i>E. brookeriana</i>    | Triabunna       | TAS                  | Y               |               |                  | Y                 |
| CAMAL540            | <i>E. camaldulensis</i>  | Albacutya       | Vic                  |                 |               |                  | Y                 |
| CCUNN100            | <i>C. cunninghamiana</i> | Wail            | VIC                  | Y               |               |                  |                   |
| CCUNN300            | <i>C. cunninghamiana</i> | Grafton         | NSW                  | Y               |               |                  | Y                 |
| CCUNN900            | <i>C. cunninghamiana</i> | Uriarra         | ACT                  | Y               |               |                  |                   |
| CCUNN901            | <i>C. cunninghamiana</i> | Uriarra         | ACT                  |                 |               |                  | Y                 |
| CGLAU400            | <i>C. glauca</i>         | Wail            | VIC                  |                 | Y             | Y                |                   |
| CGLAU800            | <i>C. glauca</i>         | Unknown         | NSW                  |                 | Y             | Y                |                   |
| CLADO400            | <i>E. cladocalyx</i>     | Wail            | VIC                  | Y               | Y             | Y                |                   |
| CLADO800            | <i>E. cladocalyx</i>     | You Yangs       | Vic                  |                 |               |                  | Y                 |
| GLOBU200            | <i>E. globulus</i>       | Kuark           | VIC                  |                 |               |                  | Y                 |
| GLOBU660            | <i>E. globulus</i>       | Otways          | Vic                  |                 |               |                  | Y                 |
| GRAND300            | <i>E. grandis</i>        | Coff'sHSO       | NSW                  |                 |               |                  | Y                 |
| GRAND950            | <i>E. grandis</i>        | Kyabram         | Vic                  |                 |               |                  | Y                 |
| MACUL100            | <i>E. maculata</i>       | Barwon river    | Vic                  | Y               |               |                  |                   |
| MACUL230            | <i>E. maculata</i>       | Kangaroo SF     | NSW                  |                 |               |                  | Y                 |
| MACUL260            | <i>E. maculata</i>       | Dunedoo         | NSW                  |                 |               |                  | Y                 |
| MACUL610            | <i>E. maculata</i>       | Bateman's Bay   | NSW                  |                 |               |                  | Y                 |
| OCCID151            | <i>E. occidentalis</i>   | Calyerup ck     | WA                   |                 | Y             | Y                |                   |
| OCCID152            | <i>E. occidentalis</i>   | Calyerup ck     | WA                   |                 | Y             | Y                |                   |
| OCCID153            | <i>E. occidentalis</i>   | Calyerup Ck     | WA                   |                 | Y             | Y                |                   |
| OCCID100            | <i>E. occidentalis</i>   | Dumblebung      | WA                   |                 | Y             | Y                |                   |
| OCCID154            | <i>E. occidentalis</i>   | Calyerup ck     | WA                   |                 | Y             |                  |                   |
| OCCID155            | <i>E. occidentalis</i>   | Calyerup Ck     | WA                   |                 | Y             | Y                |                   |
| OCCID156            | <i>E. occidentalis</i>   | Calyerup Ck     | WA                   |                 | Y             | Y                |                   |
| OCCID157            | <i>E. occidentalis</i>   | Calyerup Ck     | WA                   |                 | Y             | Y                |                   |
| OCCID200            | <i>E. occidentalis</i>   | Bremer Bay      | WA                   | Y               | Y             | Y                |                   |
| OCCID201            | <i>E. occidentalis</i>   | Bremer bay      | WA                   |                 |               |                  | Y                 |
| OCCID300            | <i>E. occidentalis</i>   | Esperance       | WA                   | Y               | Y             | Y                | Y                 |
| SALIG970            | <i>E. saligna</i>        | Katunga         | Vic                  |                 |               |                  | Y                 |
| SIDER100            | <i>E. sideroxylon</i>    | Killawarra      | Vic                  | Y               |               |                  |                   |
| SIDER601            | <i>E. sideroxylon</i>    | Murrungowar     | Vic                  | Y               |               |                  | Y                 |
| SIDER900            | <i>E. sideroxylon</i>    | Bendigo         | Vic                  | Y               |               |                  | Y                 |
| VIMIN090            | <i>E. viminalis</i>      | Scone           | NSW                  | Y               |               |                  | Y                 |
| VIMIN390            | <i>E. viminalis</i>      | Ellery          | Vic                  | Y               |               |                  | Y                 |
| VIMIN850            | <i>E. viminalis</i>      | Otway           | Vic                  | Y               |               |                  | Y                 |

**Table 2: Layout of the trials**

| <i>Number</i> |                    |            |          |          |                |       |             |               |                 |
|---------------|--------------------|------------|----------|----------|----------------|-------|-------------|---------------|-----------------|
| Site          | salinity           | replicates | subplots | seedlots | trees per plot | shape | total trees | planting date | measurement age |
| Tatura        | 5000               | 4          | na       | 14       | 7              | 1x7   | 392         | 07/1993       | 22 months       |
| Timmering     | 10000/200          | 3          | 2        | 14       | 12             | 1x12  | 1008        | 07/1993       | 22 months       |
| Nathalia      | 2000               | 4          | na       | 19       | 7              | 1x7   | 542         | 07/1993       | 22 months       |
| Shepparton    | 1000<br>(effluent) | 4          | na       | 24       | 25             | 5x5   | 2400        | 12/1994       | 26 months       |

**Table 3: Survival, Basal area, height, volume and forking score at Shepparton and Nathalia at 2 years**

|          | survival | basal area | height | volume | fork | survival | basal area | height | volume | fork |
|----------|----------|------------|--------|--------|------|----------|------------|--------|--------|------|
| GRAND300 | 99       | 6.21       | 7.40   | 19.12  | 1.09 |          |            |        |        |      |
| GRAND950 | 99       | 5.07       | 7.60   | 15.48  | 1.03 |          |            |        |        |      |
| VIMIN850 | 95       | 4.14       | 8.60   | 14.85  | 1.00 | 75       | 0.55       | 4.0    | 0.80   | 1.06 |
| BROOK800 | 98       | 4.93       | 6.60   | 14.03  | 1.04 | 75       | 0.53       | 3.4    | 0.65   | 1.27 |
| SALIG970 | 100      | 4.33       | 6.60   | 12.28  | 1.02 |          |            |        |        |      |
| OCCID100 | 98       | 4.23       | 5.90   | 10.75  | 1.14 | 36       | 0.46       | 3.5    | 1.29   | 1.43 |
| CAMAL540 | 100      | 4.19       | 5.60   | 10.10  | 1.04 |          |            |        |        |      |
| BOTRY900 | 98       | 3.62       | 6.40   | 9.88   | 1.03 | 86       | 0.81       | 3.6    | 1.00   | 1.19 |
| GLOBU660 | 88       | 3.00       | 7.50   | 9.45   | 1.02 |          |            |        |        |      |
| AMEAR900 | 83       | 3.15       | 6.90   | 9.28   | 1.07 | 89       | 2.51       | 5.0    | 4.15   | 1.23 |
| VIMIN390 | 97       | 2.64       | 6.60   | 7.85   | 1.02 | 72       | 1.26       | 4.9    | 2.24   | 1.23 |
| OCCID200 | 98       | 3.16       | 4.40   | 7.10   | 1.47 | 18       | 0.18       | 4.4    | 1.21   | 2.00 |
| BOTRY350 | 99       | 2.59       | 6.20   | 6.83   | 1.06 |          |            |        |        |      |
| VIMIN090 | 93       | 2.38       | 5.30   | 6.30   | 1.14 | 65       | 0.22       | 2.9    | 0.49   | 1.33 |
| GLOBU200 | 73       | 1.92       | 6.90   | 6.03   | 1.00 |          |            |        |        |      |
| MACUL230 | 96       | 2.09       | 5.40   | 5.88   | 1.20 |          |            |        |        |      |
| OCCID300 | 99       | 2.41       | 4.50   | 5.55   | 1.74 | 11       | 0.05       | 3.6    | 1.21   | 1.50 |
| CCUNN901 | 99       | 1.85       | 5.00   | 4.88   | 1.02 | 97       | 0.23       | 3.1    | 0.37   | 1.00 |
| MACUL610 | 86       | 1.68       | 4.70   | 4.59   | 1.57 |          |            |        |        |      |
| CCUNN300 | 97       | 1.42       | 4.80   | 3.88   | 1.09 |          |            |        |        |      |
| SIDER900 | 96       | 1.40       | 4.00   | 3.43   | 1.46 | 72       | 0.13       | 2.5    | 0.50   | 1.25 |
| SIDER601 | 98       | 1.30       | 4.30   | 3.30   | 1.27 | 100      | 1.26       | 3.4    | 1.99   | 1.75 |
| CLADO800 | 96       | 1.37       | 4.40   | 3.25   | 1.20 |          |            |        |        |      |
| MACUL260 | 75       | 1.26       | 4.80   | 3.25   | 1.27 |          |            |        |        |      |
| BOTRY300 |          |            |        |        |      | 68       | 1.38       | 4.5    | 2.40   | 1.06 |
| BOTRY110 |          |            |        |        |      | 82       | 0.96       | 3.9    | 1.80   | 1.14 |
| MACUL100 |          |            |        |        |      | 86       | 0.26       | 3.0    | 0.95   | 1.43 |
| CCUNN100 |          |            |        |        |      | 97       | 0.57       | 3.6    | 0.67   | 1.04 |
| CLADO400 |          |            |        |        |      | 97       | 0.54       | 3.0    | 0.66   | 1.37 |
| SIDER100 |          |            |        |        |      | 97       | 0.51       | 2.9    | 0.50   | 1.38 |
| AMELA100 |          |            |        |        |      | 100      | 0.29       | 2.7    | 0.42   | 1.13 |
| fpr      | <0.001   | <0.001     | <0.001 | <0.001 | NA   | <0.001   | <0.001     | <0.001 | <0.001 | NA   |
| lsd      | 11       | 1.18       | 0.91   | 4.05   | NA   | 27       | 0.66       | 0.67   | 1.16   | NA   |

**Table 4: Volume and survival of salt tolerant seedlots common to all sites.**

| SEED     | <i>Nathalia</i> |      | <i>Shepparton</i> |       | <i>Timmering</i> |      | <i>Tatura</i> |       | mean volume | mean survival |
|----------|-----------------|------|-------------------|-------|------------------|------|---------------|-------|-------------|---------------|
|          | vol             | surv | vol               | surv  | vol              | surv | vol           | surv  |             |               |
| OCCID100 | 2.6             | 36   | 10.8              | 98[1] | 4.1              | 79   | 3.4           | 100   | 4.87        | 78a           |
| OCCID200 | *[2]            | 18   | 7.1               | 98    | 2.4              | 46   | 2.0           | 64    | 3.83        | 56b           |
| OCCID300 | *               | 11   | 5.6               | 99    | 1.2              | 39   | 4.5           | 90    | 3.77        | 60b           |
| CLADO800 | 2.0             | 97   | 3.3               | 96    | 1.3              | 86   | 2.2           | 100   | 2.27        | 95a           |
| CGLAU400 |                 |      |                   |       | 1.4              | 88   | 3.1           | 93    | 2.25        | 87a           |
| CGLAU800 |                 |      |                   |       | 1.0              | 88   | 3.3           | 100   | 2.15        | 91a           |
| volume   | 2.11b           |      | 6.60a             |       | 1.67b            |      | 3.13b         |       |             |               |
| survival |                 | 40c  |                   | 98a   |                  | 71 b |               | 91 ab |             |               |

[1] Note the very high and consistent survival of *E. occidentalis* at Shepparton

[2] Asterisks indicate not planted at this site

## 2.4. Western Australian Program for the Selection and Development of New Tree Crops

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

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### Introduction

Western Australia's south-west agricultural area extends over 18 million hectares (Table1). The winter-dominant annual rainfall ranges from 1300 mm/year in the south-west corner to the inland wheatbelt/ pastoral zone boundary approximately along the 250 mm rainfall isohyet.

TABLE 1: LANDUSE IN THE SOUTH-WEST OF WESTERN AUSTRALIA

| Land use                                    | Area<br>million ha | % of area within the<br>agricultural region |
|---------------------------------------------|--------------------|---------------------------------------------|
| Agricultural region (>250 mm rainfall)      | 25.25              | 100.0                                       |
| Private land                                | 20.73              | 82.0                                        |
| Private land under agriculture              | 17.98              | 71.2                                        |
| Private with original native vegetation     | 2.75               | 10.9                                        |
| Public land (State forest, reserves, parks) | 4.52               | 17.9                                        |

After Beeston *et al.*, 1994

Agriculture is based on winter growing annuals, cereal and pulse crops in rotation with sub-clover pastures. The pasture phase ranges from 40 to 80% of the rotation period and is grazed mainly by sheep but also some cattle. In the higher rainfall lower south-west corner there is some 2.5 million hectares of native eucalypt forests set aside as State forest or conservation reserves and strongly emerging farm forestry and horticultural industries.

The region produces an estimated average annual value of production of \$4.5 billion, 85% of which is exported. Farms are mostly family-owned and operated businesses and there are some 10,000 farmers in the region. For some decades farm businesses have been under pressure from chronically weak markets for traditional products. Continuing decline in commodity prices, averaging some 4%/year since the 1950s, have not been offset by improved efficiency of production that has run at some 2.5% (Chisholm, 1992). Furthermore, agriculture has been generating substantial internal capital costs in the form of land degradation (principally salinity) and external costs in the form of degraded water resources, wetlands, rivers, biodiversity and infrastructure. In its present form agriculture cannot avoid these costs, nor can it finance a remedy.

The amount of land already damaged by salinity totals 1.8 million hectares, or nine per cent of the region. The Western Australian Salinity Action Plan (1998) estimates that total damaged land will exceed 6 million hectares (32 per cent) within several decades unless urgent remedial action is taken.

The waterlogging and salinisation of the valleys has far reaching consequences. The salt damages water resources (50% of formerly potable south-west rivers are now too saline for water supply), degrades the biodiversity of wetland and riverine habitat, and reduces the amenity value of water bodies. The impact extends along all rivers rising in agricultural land, often over distances of hundreds of kilometres. Extensive waterlogging alters the hydrology of valley floors causing greater average runoff, enhanced water erosion, increased flood peaks. Infrastructure on valley floors is exposed to chronic degradation through saturated and unstable foundations and to risk of increased flood frequency and height.

The only solution is to restore a benign water balance to the agricultural landscape. The State Salinity Action Plan (1998) elaborates the five categories of water management practice that could help bring this about. Four of these are ameliorative in that they will not singly or in combination be adequate. The fifth, extensive use of perennials both herbaceous and woody, is imperative. The Plan foreshadows the need for at least 3 million ha of new tree cover. Bartle *et al.* (1996) assert that such extensive revegetation will only be achieved if the trees are commercially attractive, adopted as an integral component of the agricultural system and are effectively self-financing.

In the western/southern high rainfall (>600 mm/yr) agricultural region of WA there are conventional timber species and industries, especially bluegum (*E. globulus*) for pulpwood, that are currently more profitable than agriculture and can make a major contribution to salinity control.

As part of its commitment to the initial Salinity Action Plan (1996) CALM undertook to create a timber resource based on Maritime pine (*Pinus pinaster*) grown in the 400 to 600 mm rainfall zone. Maritime pine is an established commercial species in wetter areas and has the resilience to be productive in drier areas. The project aims to plant 15 000 ha/year by the year 2000 with a medium term target area of 150 000 ha.

The remaining 60% of the agricultural area (<400 mm rainfall) has no current commercial tree crop option. This area is the focus of major new tree crop development work. Bartle et al. (1996) review the process of selection of species and products for commercial potential and identify several selection criteria. Amongst these market size is paramount. If adoption on the scale of millions of hectares is to be achieved it would probably require several new crops being planted on the order of  $10^5$  ha each. The scale factor in planting and markets means that these crops will probably be producing relatively low priced commodities.

Inevitably new tree crop industries will require considerable long term capital investment especially for R&D. They will certainly struggle to achieve economic viability. Carefully targeted and coordinated investment must be undertaken to address all aspects of industry development including initial selection of most promising prospects, genetic improvement, crop establishment and management, harvest, processing, product and market development.

Especially for previously 'wild' species there is enormous scope for genetic improvement.

The development of oil mallee is the first large-scale wheatbelt tree crop venture to be attempted in WA. Several mallee species are being developed and most of them have never previously been cultivated. This development is a pioneer of its type and therefore makes a useful case study. This paper reviews the investment being made in species selection and genetic improvement of oil mallee in WA.

## **Oil Mallee Case Study**

### ***Background***

CALM initiated the commercial development of oil mallee in 1993. Up to winter 1998 some 9 million seedlings have been established. Oil mallee is a short rotation tree crop with initial harvest at age 3 to 5 years, regeneration by coppice and harvest frequency 1 to 3 years. It will most commonly be grown in alley farming configurations designed to systematically harvest surplus water and nutrients from cropland. The project aims to develop large-scale, low-cost production techniques and new large volume industrial markets for oil and residues. A growers association (Oil Mallee Association) was formed in 1995 and they sponsored the formation of the Oil Mallee Company in 1997. These groups now control industry development.

The development to date has demonstrated that there are no major problems in growing the mallee resource. For example, initial biomass yields to age 3 years reported by Wildy 1996 were modest at less than 5 kg dry weight for each tree in the standard hedge planting configuration (twin rows 2 m apart with a spacing of 1.5 m within rows to give 1333 stems km hedge, survival typically 90%). Subsequent work by McCarthy (1998) showed a strong acceleration in growth in the age bracket 4 to 6 years with average 6 year old trees having 24 kg dry weight of biomass or 29 tonnes/km. Other issues such as pest control and grazing management present no difficulty.

Bartle et al. (1996) have shown that harvest and extraction dominate cost of production. A low unit cost of oil is essential to open access to large volume but low priced industrial markets. There are two main options to reduce oil production cost, i.e. higher leaf oil concentration and lower harvest and processing costs.

Improving leaf oil concentration is therefore the major objective of species selection and genetic improvement. CALM conducts a program of selection, breeding and seed production in partnership with the industry. The industry is still 'pre-commercial' and not guaranteed of success. Hence the program has been designed to establish the foundation of a full scale breeding program, to provide an early stream of improved seed but without incurring the cost of a fully developed breeding program.

### ***Species selection***

Many mallee species have been identified as having high oil content. Although several species have historically been commercially exploited in Australia, *E polybractea* (in NSW and Victoria) is the only one currently used for oil production. There was some small-scale exploitation of WA species early this century. In the mid-1980s Brooker et al. (1988) and Allan Barton (pers comm) undertook a program to reassess the

high oil yielding species of WA. This work confirmed the existence of several WA species with generally high oil contents and guided the initial selection of species for pre-commercial planting.

The major currently used species are:

- The oleosa group i.e. *E. horistes*, *E. kochii* ssp *kochii* and *E. kochii* ssp *plenissima* widely distributed in the central and northern wheatbelt and adjacent pastoral areas.
- *E. angustissima*, south coastal region from Ravensthorpe to Israelite Bay.
- *E. loxophleba* ssp *lissophloia* and *E. loxophleba* ssp *gratae* from the central and southern wheatbelt and adjacent pastoral regions.
- *E. polybractea*, blue mallee currently commercially used in NSW and Victoria.

In order to systematically test species performance across the range of wheatbelt environments CALM commenced a species testing program in 1993. Some 20 sites were planted in 1993, a further 12 in 1994 and 2 or 3 sites annually since then.

A species reconnaissance program is conducted to identify new potentially commercial species. There are two objectives in reconnaissance, firstly to find new species with high average oil content and secondly, to screen species with moderate oil content, but with potentially useful adaptations such as tolerance of salinity, waterlogging or acidity.

Species trials (Wildy 1996 and in press) and visual assessment of operational plantings has revealed strong site preferences by species. Local or regional taxa are usually the best performers. For example, the oleosa group taxa (*E. horistes*, *E. kochii* ssp *kochii* and *E. kochii* ssp *plenissima*) occur in the northern wheatbelt region where they grow well under cultivation, but in the southern wheatbelt and south coast region they perform poorly. The introduced species *E. polybractea* only grows well in the more favourable higher rainfall south-western parts of the wheatbelt but fails in the northern wheatbelt. It has become routine to give priority to local/regional species for planting.

### Systematics

Seed collection and breeding programs must be based on a sound understanding of the systematics of the species. However, mallee taxa in southern WA are numerous and diverse, and in most cases the definition of geographic, morphological and genetic variation is poor. Considerable work has therefore gone into surveying native populations of prospective taxa and delineating boundaries between them.

A ready recognition of the key morphological features separating taxa is essential for parent tree selection and seed collection. This is easily achieved in the oleosa (*E. horistes*, *E. kochii* ssp *kochii* and *E. kochii* ssp *plenissima*) and loxophleba groups (*E. loxophleba* ssp *lissophloia* and *E. loxophleba* ssp *gratae*) where taxonomic description had recently been reviewed. The separation of the geographically adjacent *kochii* and *plenissima* subspecies on the basis of operculum shape was found to be effective although more clinal than indicated by Brooker et al. (1988). Likewise the separation of the *E. loxophleba* subspecies *lissophloia* and *gratae* on the basis of bud and fruit size (Grayling 1996) give an effective separation.

In contrast some taxa in the spathulata group, especially *E. vegrundis*, are of interest because of waterlogging and salinity tolerance but effective morphological separation in the field has proved very difficult (P. White pers comm). Considerable variation in leaf morphology is observed in plantings of *E. polybractea* from seed collected from native populations in NSW and Victoria. Handmer (1970) showed that similar variation in native stands was linked with oil production potential and site characteristics. He identified five 'varieties' in Victoria. No attempt has yet been made to determine the local importance of this variation.

In designing breeding and seed production programs it is desirable to capture the full range of genetic variation, in particular, to determine whether morphologically distinct taxa are actually genetically different and require separation in breeding populations. Byrne (in press) investigated genetic diversity and phylogenetic relationships of the three oleosa group taxa based on nuclear and mitochondrial DNA. She found that while genetic diversity within the group was high there was little differentiation between taxa, and low genetic distance and high gene flow between them. She concluded that they constitute a single large, variable taxon with some provenance variation. On the strength of this work the three taxa are now consolidated into combined breeding populations or seed orchards thus streamlining the genetic improvement program.

The phylogenetic relationships in other related oil mallee taxa will be investigated.

#### Parent tree selection

The aim of parent tree selection is to identify a large number of superior individuals from native populations of each species, to use them as the source of seed for current planting and to form the breeding population for the future. Given the sensitivity of leaf oil concentration in the economics of oil production it is the major parent tree selection criterion. Cineole is used as an indicator of total leaf oil concentration (cineole constitutes some 90% of the oil of most of the species used). The cineole analysis is done by gas chromatography on a small representative leaf sample.

Large natural variation in oil content (commonly 0.5 to 5.0% cineole on a leaf fresh weight basis) is observed in native oil mallee populations (see Table 2).

TABLE 2: TESTED AND ELITE SELECTION LEAF CINEOLE (%FRESHWEIGHT) STATISTICS

| Species                              | Tested sample leaf cineole % |      |     | Elite selection leaf cineole % |      |
|--------------------------------------|------------------------------|------|-----|--------------------------------|------|
|                                      | No                           | Mean | SD  | No                             | Mean |
| <b>E. horistes</b>                   | 1028                         | 2.3  | 0.8 | 68                             | 3.5  |
| <b>E. kochii ssp kochii</b>          | 390                          | 2.3  | 0.7 | 28                             | 3.1  |
| <b>E. kochii ssp plenissima</b>      | 1308                         | 2.3  | 0.8 | 62                             | 3.4  |
| <b>E. loxophleba ssp lissophloia</b> | 816                          | 1.9  | 0.8 | 68                             | 3.3  |
| <b>E. polybractea</b>                | 481                          | 2.0  | 0.9 | 27                             | 3.1  |
| <b>E. angustissima</b>               | 522                          | 2.1  | 0.7 | 30                             | 3.1  |

Seed collection within species is therefore biased to elite high oil content trees. Random selections are taken from across the geographic range of natural occurrence of each taxon, selections are biased to heavily seeding local populations (for maximum out-crossing) and as large as practical a separation between parents trees is achieved. Trees are permanently marked and a leaf sample returned to the laboratory for cineole analysis. Voucher specimens of some 10% are taken and lodged in the State Herbarium. Elite trees are selected and become the seed collection and breeding population. The elite tree selection threshold is currently set at 2.7 to 3.0% leaf oil content. Some 5 to 15% of random collections qualify and between 30 and 70 elite trees have been located for each of the four local species.

No substantial provenance segregation on the basis of oil content has been noticed during field collection, although disjunct but geographically close populations can exhibit substantially different mean oil content.

*E. polybractea* elite seed has been provided by the CSIRO Seed Centre, Canberra.

#### Seed collection

This seed collection program has the dual objective of providing select seed for current commercial scale plantings as well as superior families for induction into the initial breeding program.

After cineole analysis and selection of elite parents each tree is re-located in the field, whole branches are removed and individual tree collections kept separate through the air drying step.

Seed is collected in spring and most used in the following nursery planting season commencing in December. Seed from several geographically close parent trees is bulked for field planting seed lots. Seed samples from each parent tree are retained in cool storage to be available for the breeding program.

#### Propagation

All forms of clonal propagation have been attempted but all are sufficiently problematic to eliminate the prospect of operational clonal plantings and even to limit the use of clonal seed orchards.

Germination has been a particular problem with some species. *E. polybractea*, for example, has an extended germination period of more than six weeks. Many dormancy breaking treatments have been tested but none are completely satisfactory.

### *Progeny trials*

Establishment of progeny trials commenced in 1993. The objective of these progeny trials was to provide information on genetic parameters as well as being able to be readily converted to open pollinated seedling seed orchards to provide an early source of out-crossed seed from selected parents. This dual objective was adopted because there was no certainty that the development of an oil mallee industry would be successful and a maximum of opportunity had to be opened for a minimum of expenditure.

One or more trials replicated at 2 or 3 sites have been established every year since 1993. The sites are selected to be representative of the environments in which operational planting will be conducted. A few sites were established in higher rainfall areas to test the possibility that greater rainfall would improve seed yield.

Table 3 gives detail of species, number of families and number of sites.

TABLE 3: OIL MALLEE PROGENY TRIALS AND OPSS ORCHARDS

| Planting Year | Oleosa group            |                         |                         | <b>Eucalyptus loxophleba ssp lissophloia</b> | Eucalyptus <b>angustissima</b> | Eucalyptus <b>polybractea</b> |
|---------------|-------------------------|-------------------------|-------------------------|----------------------------------------------|--------------------------------|-------------------------------|
|               | <b>horistes</b>         | <b>plenissima</b>       | <b>kochii</b>           |                                              |                                |                               |
| <b>1993</b>   | 3 sites,<br>20 families |                         |                         |                                              |                                | 3 sites,<br>30 families       |
| <b>1994</b>   |                         | 4 sites,<br>20 families |                         |                                              |                                |                               |
| <b>1995</b>   |                         |                         |                         | 3 sites,<br>25 families                      |                                |                               |
| <b>1996</b>   | 3 sites,<br>36 families | 2 sites,<br>28 families | 2 sites,<br>28 families | 3 sites,<br>30 families                      |                                | 3 sites,<br>36 families       |
| <b>1997</b>   | 2 sites,<br>30 families | 2 sites,<br>30 families | 2 sites,<br>30 families | 2 sites,<br>30 families                      |                                | 2 sites,<br>30 families       |
| <b>1998</b>   | 2 sites<br>78 families  |                         |                         | 2 sites,<br>28 families                      | 2 sites,<br>28 families        | 2 sites,<br>28 families       |

Leaf oil concentration is measured at age 3 when full expression of oil yielding potential can be expected (Barton et al 1991). Bud formation commences in year 3 to 5 (depending on species and site) and careful observation of the flowering period of all individuals is made. Progeny leaf oil data is analysed to provide breeding values for all individuals in each trial.

### *Seed orchards*

Once breeding values are available progeny trials are converted to seed orchards in an attempt to get improved seed into operational planting as quickly as possible. The first small amounts of seed from the 1993 progeny trials were harvested and used in 1998.

Culling is based on several factors:

- within plot replication: 3 tree plots were used up to 1995 and thereafter single tree plots were used. All 3 tree plots are reduced to a maximum of one in the culling procedure.
- breeding value: is the primary selection criterion at all levels i.e. within plots, within families and between families.
- form and vigour: any obviously unthrifty or deformed individuals are culled.
- spacing: large gaps in the orchard are avoided.
- diversity: families with generally poorer breeding values are more heavily culled but not entirely removed from the orchard

Culling provides the opportunity to collect data on coppice vigour. Hence culled individuals are not killed. They are cut to ground level, coppice data is collected within 12 months at which time the coppiced stems may be removed.

Seed production and oil yield estimates are being prepared for each orchard. Seed production depends on the density of retained trees, site quality, flowering synchrony, number of capsules formed and seeds per capsule. Oil yield estimates can be prepared after culling is completed. These parameters will be varied to ensure supply of an adequate volume and quality of seed to operational planting. It is expected that the bulk of operational planting will be provided with orchard seed by 2001.

### Acknowledgments

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## 2.5. Mediterranean conifer species suited to temperate low rainfall forestry in Australia

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

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### Introduction

As part of the strategy to reafforest large areas of rural Australia, expanding plantations into the drier areas is an attractive prospect. Within these drier areas there will be many requirements for tree species, including conifers, for niche plantings such as degraded landscapes and recharge sites or other areas on farmland, windbreaks to mitigate soil erosion and protect pastures and amenity plantings which also carry a substantial social benefit. This will require a substantial re-evaluation of both coniferous and native species capable of meeting those goals. For softwoods in plantations, species other than radiata pine will have to be considered as radiata plantations, in most circumstances, are not an economic proposition below the 650mm rainfall isohyet and availability of new land area suited to radiata is diminishing. However, the land area in temperate Australia between the 400-650mm isohyets that could become available for plantations is substantial, given the availability of well-adapted species. The main focus will be on the Mediterranean conifers, *Pinus halepensis*, *P. brutia*, *P. eldarica* and *P. pinaster*, which have a potential role for this purpose as they have been trialed in Australia and many other dry areas in the world and have demonstrated reasonable growth and survival.

One major contender is *P. pinaster*, an important economic species in its native occurrence of SW France and Portugal, and as an exotic in the wheat belt of Western Australia where CALM (Dept. Conservation and Land Management) has made a large investment in selecting, breeding, and improving the growth capability and wood quality of *P. pinaster* over the last 30 years, especially in adaptation to low rainfall areas.

Trials in the Mediterranean region (not including *P. pinaster*) indicate that *P. brutia* and *P. eldarica* have better stemform and growth than *P. halepensis* with provenance having a strong influence. Some Eastern provenances of *P. halepensis* are almost as good in growth and form as some of the better *P. brutia*. In the SE of Turkey in areas away from the coast, *P. brutia* trees are straight and offer good growth however, close to the coast trees are of poor form and slower in growth. In the same trials, provenances from Syria and North Iraq have also shown good growth and straight stems.

*P. eldarica* in its natural habitat (Transcaucasus region, USSR) has good form with growth rates similar to *P. brutia*. Trials of Eldarica in New Mexico USA have shown outstanding growth with very little variation according to seed source. This species has a high initial growth rate that tapers off to normal after the first few years. This ensures high survival rates. It has deep roots and tolerates alkaline soils (among others) but does not like heavy, wet soils.

From the above examples it is clear that the issue of what to plant where is not simple. The object of this paper is to draw a brief outline on the potential of a few exotic conifers that have shown acceptable adaptability to the low rainfall areas in Australia. The presentation is in four parts:

- Planting what where
- Data from Australian plantings
- Reports from overseas trials.
- The way ahead

### Planting what where

**Zone for planting.** The focus area is the 400 - 650 mm rainfall belt of the temperate areas of SE Australia which, although not continuous, covers a range of soil types and fortunately, are adjacent to many areas of higher rainfall with existing plantations and forest operations infrastructure. Much of this chosen zone is occupied by sheep grazing and grain crop farming with little of the original vegetation existing. In NSW this zone includes most of the natural stands of *Callitris glaucophylla* occur which are managed for timber production.

**Soil types** Throughout this rainfall zone soil types can vary over short distances. Most soils are reasonable in structure, fertility and are amenable to tree growing, water often being the limiting factor. Within these areas are some poorer soils. Clays, as a broad generic description, often occur on denuded, exposed sites with the sands (generically) occurring on the less undulating areas and being aeolian or marine in origin. The common factor is that most are nutritionally deplete and easily degraded.

**Soil pH** Most soils in the plant/tree growing range have a pH in the 5.5 - 6.5 range. Unfortunately within the 400 - 650 mm rainfall zone there are many large areas with alkaline soils due in part to denudation, degradation and rising water tables or underlying limestone parent material. These are problem areas for most species but can be revegetated with selected species screened for tolerance. Expecting growth in terms of a commercial forest is unlikely on such sites.

### Available species

Throughout the world there a considerable number of conifer species that grow in areas with rainfalls lower than the 400 mm considered here. What is common is that they mainly exist at very high altitudes and undoubtedly receive sustenance through fog/mist/clouds etc. In Australia we are looking for species better adapted to low rainfall at low altitudes. There are some exotic cypresses (eg *Cupressus dupreziana*, *C. arizonica*, *C. atlantica*) and conifers (eg *P. halepensis* and *P. brutia*) which occur naturally in dry regions in other parts of the world that have been introduced to dry regions in Australia and have shown remarkable adaptability. Conifers which produce edible seeds (*P. cembroides*, *P. edulis*, *P. pinea*) occur naturally in the drier areas of several countries and may be able to contribute to the social/amenity benefits on properties in Australia.

Listed are some of the species considered as having potential for the 400-650 mm zone in the temperate areas of Australia. Not all species listed are commercial propositions. With each species are a few brief notes by way of explanation of choice. There is no significance in the order listed.

***Pinus halepensis*** Aleppo pine. Common in the Western end of the Mediterranean right across to the East side of Greece and from Morocco to Libya in North Africa. Provenance form improves from West to East. Grows from sea level to 1500 m. Very tolerant of calcareous soils. High yielder of resin. Makes good pulp due to long fibre. Wood considered resinous (c.f. *P. radiata*). Potential as timber species if grown at 1100 - 1300spha. Trees can be found throughout the dry areas of Australia (down to 300 mm rainfall). Used mainly as windbreaks due to early crown break in open situations.

***Pinus brutia*** Brutian pine/ Brutia/ Red pine. Common in the East end of the Mediterranean through NE Greece, Black Sea, Turkey, Crete, Cyprus, Syria and Lebanon. Distribution narrower than *P. halepensis*. Grows from sea level to 1500m. Reasonably strong apical dominance. Stemform much better than Aleppo pine. Provenance effect on form very strong. Withstands cold, high temperatures and drought. Has been successfully grown as plantation trees in the 400 mm rainfall zone at Wirrabara, South Aust. Performs well at wide spacing (50 stems/ha) as well as at closer spacing (1100 stems/ha). Good pulping species.

***Pinus eldarica*** Eldar pine. Closely related to *P. brutia* with a narrow distribution further East in the southern USSR across to Afghanistan. Rainfall 200 -250 mm/ann. Grows from sea level to 1500 m in environs with temperature ranges of -20°C to 40°C. Foliage is denser than Brutia, multinodal branching habit (Av.7 whorls/ann) and retention of lower branches in open situations. Wood properties similar to *P. radiata*. Good survival capacity and fast initial growth. Seed difficult to obtain.

***Pinus pinaster*** Maritime pine. Occurs throughout Spain and Portugal, SW Atlantic coast of France, NW Italy on the coast, South France and in North Africa from Morocco to Tunisia. Considerable provenance variation. Leiria provenance of Portugal has been selectively bred in WA for growing on sandy soils. More recent breeding has aimed at adaptability to low rainfall sites. Moroccan race has straight stems, well adapted to summer drought, tolerant of limestone, but not very vigorous in growth. Important economic species in SW France (1.0M ha) and Portugal, and in Western Australia (50,000 ha) where there is a very high level of genetic improvement. Plans exist to enlarge this species' land base in WA by a further 60,000 ha by 2002 by expanding plantations within the 400-600 mm rainfall belt. Wood is processed routinely with radiata in WA with both having similar properties for the building market. This species is used in southern France (AFOCEL) for papermaking. In SA., *P. pinaster* has been grown by ForestrySA (formerly Woods & Forests) as a plantation species near the coast on sandy soils since the early 1960s and is processed without difficulty by local industry.

***Pinus canariensis*** Canary Island pine. Naturally occurs on the dry slopes of the Canary Is. at altitudes of 1000 - 2000 m. Has adapted well to low altitude in Australia and this species can often be found growing in public areas, often in low rainfall areas. Good form and, although slow in growth, very drought tolerant. Least fire susceptible of all conifers.

***Pinus pinea*** Stone pine. This species has a wide distribution throughout Spain and Portugal and across the north Mediterranean to Lebanon. Drought tolerant. Slow growth. Used mainly as an amenity species and a source of edible seeds. Has an unusual cultural niche in Australia's history and is often fondly remembered by many folk as being the "nice shady tree in the school grounds". Many isolated trees still exist in old school grounds.

***Pinus torreyana*** Torrey pine. Restricted distribution around San Diego, California, USA. Low winter rainfall (245 mm), low altitude. Virtually no genetic variation. Deep rooting. Drought tolerant. Sparse crowns. Tendency to break crown early unless form pruned. Stiff needles decompose slowly (mulch advantage). 70 year old trees have outgrown adjacent *P. radiata* in the ACT. Wood density slightly less than *P. radiata*.

***Pinus cembroides*** Mexican nut pine. A short tree (7 m) that grows mainly in the dry areas of north Mexico and southern Arizona at altitudes of 1300 - 2650 m. Has value as an amenity tree as well as a producer of edible seeds if the right environment to induce flowering can be found.

***Pinus edulis*** Two leaved nut pine/Pinyon pine. Wider distribution than *P. cembroides* across the southwest USA and into northern Mexico. Trees grow on alkaline soils in the semi desert areas with low rainfall and hot summers. Similar altitudinal range. Trees grow to 15 m very slowly. Potential as a revegetation and amenity species with the ability to produce edible seeds.

***Callitris glaucophylla*** White cypress. Conifer native to SE Aust. Grows naturally in the drier regions of Australia (mainly 400 -650 mm zone) on the sandier soils. Growth is slow - rotations to commercial grade are about 30 years first thinning, 100 years for full rotation. On better sites will reach 30 m height. Excellent wood properties.

***Cupressus dupreziana***. Saharan cypress. This is a rare tree growing on the fringes of the Sahara desert. Almost extinct. Very drought tolerant. Quite a few planted in Tunisia but genetic diversity of individuals unknown. Seed may be difficult to obtain.

***Cupressus atlantica*** Atlas cypress. Endemic to the Moroccan Atlas mountains. Well adapted to semi-arid conditions. Tolerates a wide range of temperature conditions. Vigorous growth and produces good quality wood. Species under threat and seed not readily available.

***Cupressus arizonica*** Arizona cypress. Native of the USA. Occurs from Texas across to SE Arizona, Sth California and New Mexico. Drought tolerant. Grows on most soils and is not severely restricted by low fertility. Grown as a commercial species in Africa. Often seen as amenity and windbreak plantings.

***Cedrus atlantica*** Atlas cedar. Natural distribution in NW Africa (Algeria and Morocco) at altitudes between 1000 - 2000m. Found in many gardens in Australia. Can tolerate droughts when established. Initial growth as a seedling is reasonable. Used in afforestation programmes on the barren areas of Mediterranean. Wood durable.

***Cedrus libani*** Lebanese cedar. Natural occurrence in Syria, Lebanon and Turkey at altitudes of 1300 - 2100m. Tough species which likes calcareous soils. Growth very slow. Wood of good quality. Main benefit as an amenity species or planted in small plots at wide spacing.

### Data from Australian plantings

Very few trials consisting of only dry conifer species have been planted in Australia. Dry conifer species were sometimes included as an adjunct to the main trial of usually *P. radiata*, but unfortunately not replicated. The better trials which were replicated are few however, they do exist in Western Australia (CALM), South Australia (ForestrySA) and New South Wales (CSIRO). This general lack of structured trials has left a legacy of growth data with no meaningful value from across a wide range of sites. The best information that can be gleaned is usually the age of the stand/plot, sometimes seed origin, and survival. The survival alone is worth having as an indicator of adaptation to the site and its unique soil and climatic conditions.

Some problems that have been encountered include the following

Not well replicated across sites. Rarely do you find seed from the same origin planted across a range of sites so that valid comparisons can be made.

Too much variation within sites. Lack of adequate statistical design annuls differences in growth between provenance sources which makes it difficult to identify with confidence the better seed sources.

Survival. Not so much of a problem as the surviving trees attest to their fitness for the specific site. Poor survival can be attributed to many factors, not just ability to stay green.

Soil type changes. Variation of soil type across the trial planting is not uncommon. This would have been unintentional but more than likely due to inexperience. Good designs can accommodate this type of problem.

Management. Often the cause of many a good trials' demise. Planting a trial is often complex but quick. It is the long-term commitment to maintenance that is difficult. Usual causes are lack of staff continuity and enthusiasm, lack of long term funds, loss of records and not that frequently, poor establishment.

Growth data not reliable. Mainly due to poor design initially. Over the term of a trial many different teams will carry out measurements of one sort or another. Consistency between data sets becomes uncommon and hence unreliable. Identification labels may have unchecked errors (provenances mixed) or map locations/diagrams too sketchy.

### **Reports from overseas trials**

The information that can be readily accessed today via the Internet is substantially greater than a decade ago. Libraries are documenting published papers electronically and as they progress they include some often “obscure” papers which may have been totally neglected. These published reports are often an excellent source of information about species and their growth habits and useful for making comparisons. However, one should not forget that climate and soils are vastly different in Australia.

Species distribution. Most published papers and reports on trials of dry country conifers in the Northern Hemisphere have excellent detailed information on seed provenance, climate, soil type, and growth characteristics. The reports produced by the staff of FAO on species distributions are often very detailed and well illustrated. These types of reports often give a better “feel” for the conditions under which a selected species occurs naturally. Since the focus is on the Mediterranean conifers, species distribution maps for *P. brutia*, *P. halepensis* and *P. eldarica* are included in Figures 1 & 2.

Provenance variation. Any information on provenance variation prior to designing a trial will help make better decisions on what material to include. Often you cannot include everything and being able to focus on the “best bets” will yield more useful results. It is best not to rely on any one set of results so that trends or patterns can be discovered.

Examples are:

Longitudinal variation moving from west to east. *P. halepensis* growth and form improves in this pattern in European trials.

Altitude variation. *P. brutia* from the elevated region near the SW coast of Turkey has better form and growth than that on the coastal strip (Arbez 1974).

Rankings are often similar but growth rates differ. Eccer *et al.* (1982) demonstrate a good example of this in replicated trial sites across Italy where seedlings from the same individual provenances of *P. halepensis*, *P. brutia* & *P. eldarica* were planted. Two sites with similar characteristics and close to each other just near Rome had the same rankings for the provenances but quite different growth rates.

Conflicting information. It is essential that information from many trials is evaluated before making decisions about seed sources. A good example of conflicting information relates to Brutian pine. Most reports published have indicated that the provenances from the higher altitudes have the best form and growth. In Israel they have found that the coastal provenances have the better performance (Weinstein 1989).

Performance indicators. Published results which compare species are often valuable providing the differences in climate, soil and other variables are recognised. For example, when the height growth of *P. brutia*, *P. eldarica* and *P. halepensis*, grown in New Mexico (USA) and irrigated (500 mm max) (Fisher, 1985) is compared to similar age material planted in a dry area of Australia (Palmberg 1975), you can see similar growth patterns but you also note that initial growth is vastly improved by a little supplemental water in the early stages. Species comparisons for parameters such as survival, height, DBH, whorls/ann on the same site and subject to the same variables in environmental effects, give an idea as to what is happening at the trial site. It is only when you determine the coefficients of variation (%) within species that you can get an appreciation of what is happening between species. This is well illustrated in Fisher *et al.* 1986. Evaluating the biomass production of a new species against more familiar species (eg, Haygreen and Bowyer 1982) will help put the overall performance of the targeted species into a fuller context.

### **The way ahead**

#### *Short term*

Establish a national database. Having complete, accessible records of what has been established, where, and site characteristics makes planning for the future easier and with a higher level of confidence.

Encourage testing of selected species as amenity plantings. Whilst such plantings may not contribute scientifically, many individuals have a greater chance of planting a wide range of species under just as varied conditions. These plants will give an indication of adaptability which may otherwise never be known.

Establish larger yield plots (2.0ha) across a range of sites. Large yield plots have the advantage of providing enough material to test a range of genotypes as well as providing the flexibility to manage the plot as a commercial stand (thinning, selection and pruning). Such plots also provide a better visual guide (field days etc.) to management approaches than small experimental plots of a few trees. Critical to success are sound, uncomplicated management plans for a possible long period. Guaranteed long-term support is also valuable.

Figure 1. natural range of *P. halepensis*

(a) *P. halepensis*

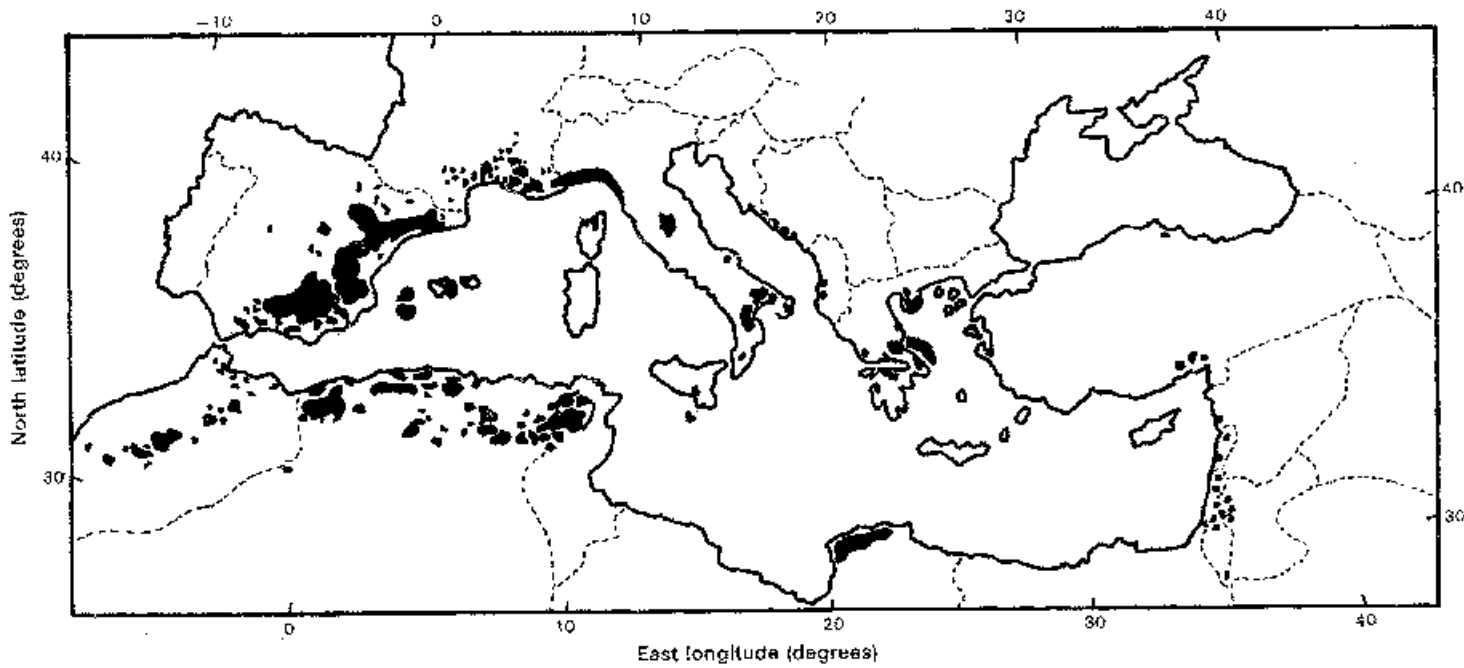
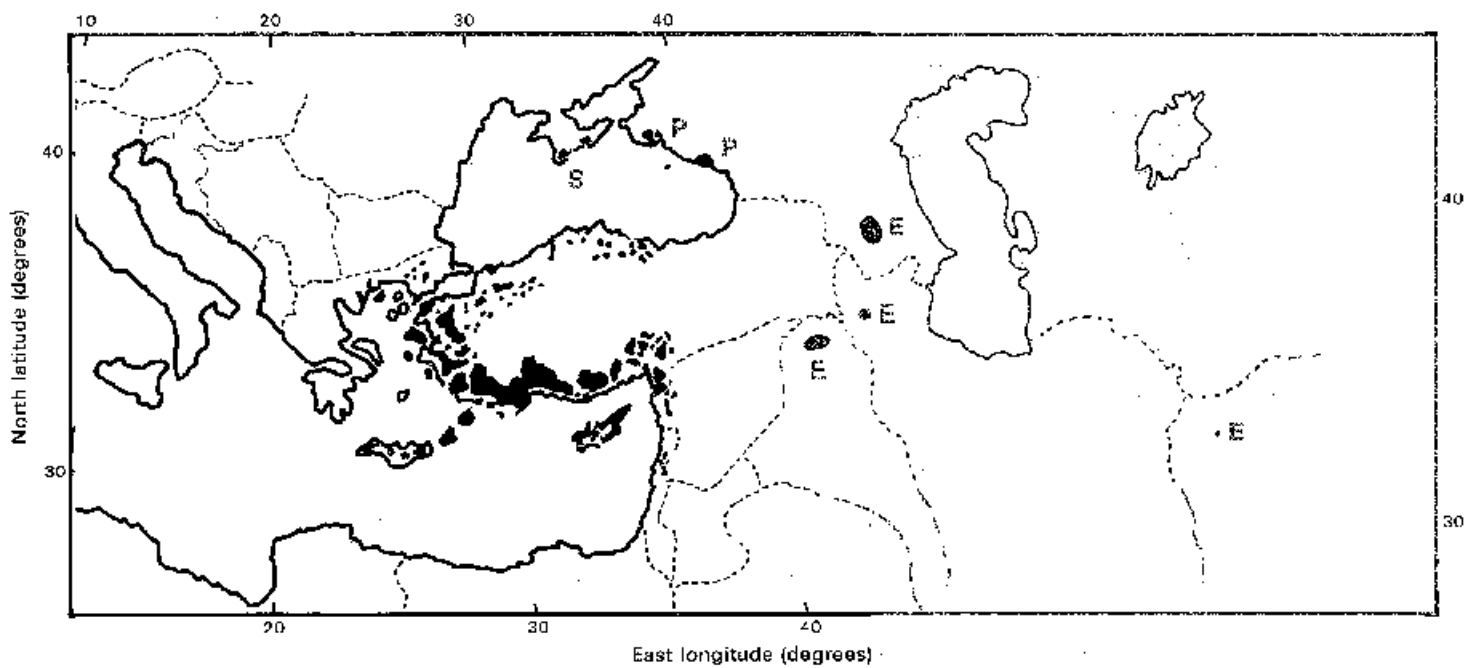


Figure 2. Natural range of *P. brutia* subspecies; E = *Pinus eldarica*, S = *P. stankewiczii*, P = *P. pithyusa*

(b) *P. brutia*



#### *Longer term*

Evaluate provenances of potential species. Once target species have been identified, the breadth of the genetic diversity of the species should be examined principally to ensure that the best provenance/s are selected for commercialisation and that an adequate gene pool is available for future breeding. Such evaluations should be in well designed trials with practical, long term management plans across wide range of sites (soil and rainfall)

Continue with yield plots. These types of plots offer the best guide to commercial potential and will often influence a grower as to whether the species is worth pursuing as a venture on his/her property.

Develop a breeding strategy. An essential step in the successful development of any species.

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## 2.6. *Pinus pinaster* in Western Australia.

Paper presented to Joint Venture Agroforestry Program National Low Rainfall farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

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### Summary

*Pinus pinaster* (maritime or cluster pine) is a major plantation species in Western Australia with a current area of about 28,000 ha. This species has become significantly more important with the planned establishment of more than 150,000 ha in low rainfall areas of the wheatbelt to reduce salinity effects while providing a commercial crop.

Maritime pine is a major alternative pine species for southern Australia and the successful breeding program in Western Australia has produced a useable tree that has ready markets. A big advantage is that the harvesting and milling infrastructure already exists in certain areas. Maritime pine can be planted on marginal low rainfall areas unsuitable for *Pinus radiata* and will improve the viability of the local wood processing industry. Planting of a vigorous well formed and drought tolerant pine tree for the rehabilitation of degraded soils, rivers and wetlands in the agricultural region will have very significant ramifications for Australia's rural industry.

### Natural Distribution

There are more than 4 million hectares of *Pinus pinaster* forest in southwestern and Mediterranean Europe, and northern Africa. The species consists of five major races, based on tree vigour and phenotypic appearance (Destremau *et al.*, 1982). 1) Atlantic group, occupying the coastal plains and seaboard of the Atlantic coast from Lisbon (Portugal) to Nantes (France). 2) Mediterranean coast from Tarragona (Spain) to Tivoli (Italy). 3) Corsican group restricted to islands of Corsica and Sardinia. 4) Continental group of the Iberian mountain regions and includes the Atlas mountains in Morocco. 5) North Africa coastal group, in Algeria and Tunisia.

There are 1.8 million hectares of *Pinus pinaster* forest in France with 1 million in the Aquitaine (Landes) area, 90% of which is privately owned. The 10% public forest includes the protection forest on the Atlantic coast dunes that was first established in 1774. Swamps were drained and 600,000 hectares of maritime pine were established during the reign of Napoleon's Second Empire. 25% of France is forested; 45% of Aquitaine is forest where it is the principal industry employing 30,000 workers. Maritime pine is the principal species used in France for forest regeneration with 18,000 ha planted each year. Average productivity is 9 m<sup>3</sup>ha<sup>-1</sup> and this increases to 15 m<sup>3</sup>ha<sup>-1</sup> in the fertile area of southwest France. They harvest some 6.5 million m<sup>3</sup> of wood per annum. One third goes to pulpwood, 60% of harvest is as sawlogs and 6% as peelers. Because of poor form of the Landes race, log lengths are very short, 1.5 m. Sawn timber recovery is 50%.

In Portugal, there are 1.3 million hectares of *P. pinaster*, or about 44% of the forest area. It extends to the Spanish border all over Portugal north of the river Tagus. Only 30% of the total area, or about 300,000 ha belong to the State. Most of the area belongs to absentee landowners in very small lots of 1 to 2 ha and is poorly managed. The Leiria forest extends for 11,000ha along the Atlantic coast between latitude 39°42'N and 39°53'N and was first planted some 700 years ago. 81% of area is production forest and is managed on 80-100 year rotations. Remaining 19% is protection forest. *Pinus pinaster* is used for almost everything that wood can be used for in Portugal although trees from the Leiria forest are used essentially for high quality timber products. Resin tapping during last 3 years of the rotation is still practiced.

In Spain, there are more than 1 million hectares of *Pinus pinaster* forests covering an extreme range of climate and edaphic conditions. Maritime pine is found on the Atlantic coast in northern Spain (>1000 mm rainfall), central Spain and in southern and southeastern Spain (100mm rainfall). Soil types also vary from sands and dunes to shallow rocky soils. Seed zones for commercial and native forests have been delineated for all areas of Spain. 780,000 hectares were afforested between 1940 and 1982, for production and protection plantings on the Mediterranean coast and on the high plains of the Teleno - Ona Region.

## Western Australia

*Pinus pinaster* was first planted in trials in Western Australia in 1896. Plantations at Gnangara on the northern Swan coastal plain were commenced in 1923 using *P. pinaster* seed originating from France. Seed source, or provenance trials were planted in 1926 using seed from Portugal (Leiria), France (Landes and Esterel) and Corsica. They were conclusive in showing *P. pinaster* from Leiria having the best growth rate and reasonable form for southwestern Australian conditions (Perry, 1940). Since 1942, all *P. pinaster* plantations used seed collected from the forest of Leiria in Portugal. Subsequent testing of seed sources from Portugal, Spain, France, Corsica, Italy and Tunisia has confirmed the vigour superiority of the Leirian provenance (Hopkins, 1960; Hopkins and Butcher, 1993). Nicholls *et al.* (1963) assessed wood properties of Leiria, Landes, Corsica and Esterel races of *P. pinaster* and concluded that Leirian provenance had higher basic density, good fibre length and superior vigour and form compared with the others. Hopkins (1971) in a glasshouse study showed Leiria provenance seedlings to have good drought tolerance. Hopkins and Butcher (1993) confirmed this result from field trials. Butcher (1976) reported areas planted with *P. pinaster* of 21,400 ha in Western Australia, 6,000 ha in South Australia, 1,400 ha in Victoria, 100 ha in New South Wales and 31,500 ha in South Africa. The South African estate has not been replanted to *P. pinaster* because of problems with the pine woolly aphid (Butcher, 1999).

## Breeding Plan

In the late 1950s, maritime pine was the major plantation species in Western Australia and a future planting of 80,000 ha was envisaged. This would provide a major wood source for development in the State and a sound use for otherwise unproductive land on the coastal plain. A breeding program was initiated by Hopkins in 1957 with the objective of improving stem and branch quality, and vigour within the Leirian provenance of *P. pinaster*. Western Australian plantations, older than 30 years, were searched for plus trees but this constraint limited the search area to only 400 ha and a small number of trees suitable for orchards resulted. As a consequence, the Western Australian Forests Department sent Dick Perry to Portugal in 1964 to select plus trees in the Forest of Leiria - this was recognised as the best and quickest route to the improvement of maritime pine for Australia. Forest services in South Australia, Victoria, New Zealand and the Commonwealth Forestry and Timber Bureau provided financial support. Scion material of these Portugal selections was dispatched to breeding centres in Western Australia, South Australia, Victoria and New Zealand as part of the agreement. However, with the exception of Western Australia, grafting was a total failure. Subsequently, scion material was collected from our clonal archive and sent to collaborating centres and also to South Africa. Importation was an outstanding success! More than 85 phenotypes were introduced to the WA program as scions, seed and pollen in 1966 (Perry and Hopkins, 1967).

More local plantations were searched in 1972 to 1974 and increased the number of local selections to 86. Pollen and seed was exchanged with the South African breeding program at this time. Another 110 plus trees were added to the Breeding Population in 1996 following an extensive search in mature age, unimproved plantations in WA. These trees were grafted and established in clonal archives.

Western Australia is the only centre actively involved in the genetic improvement of the Leiria provenance of *P. pinaster*. AFOCEL in France has an active program with the Landes provenance because of its frost tolerance and the Corsican race because of its good stem form. WA trials planted in 1966 and 1967 have shown the best of the Landes from the French program to be inferior in vigour and form to the routine Leirian source. Our hybrid crossing with Leiria increased vigour of the Landes and Corsican tree but the hybrid was significantly less vigorous than the improved Leiria tree. The French used Leiria pollens from our program in 1979 to create hybrids with Landes parents. Severe frosts in 1984 to 1986 killed some 60,000 ha of Portugal origin stands in France, however, the young hybrid trees survived and were the top ranked families for volume and form at age 15 years (Butcher, 1999). This shows the hybrid Landes-Leiria tree to be frost resistant. Hybrid crossing in France with Corsica race *P. pinaster* has significantly improved the stem and branching quality of Landes race *P. pinaster* without reducing vigour or frost resistance.

The WA Base Breeding population consists of 304 individuals, selected in Western Australia (196), Portugal (85), South Africa (20) and South Australia (3). This base is currently being expanded with the selection of plus phenotypes in Leiria origin plantations that have demonstrated an ability to survive severe drought conditions. *Drought resistant* trees will be grafted and held in quarantine glasshouses until released for breeding crossing.

The Western Australian *Pinus pinaster* pedigree seed database contains 830 control cross families. They are planted in a minimum of 2 trials and are usually represented with 50 trees in each trial. In the early 1970s, full-sib and polymix seedlots from the WA program were sent to Forest Services in Victoria and South Australia, CSIRO in Canberra, New Zealand, Turkey, Portugal, South Africa, Morocco and Oklahoma USA. This series would provide information on performance of the WA improved *P. pinaster* across a range of environments.

Some 97 breeding trials covering an area of 203ha and 216,000 trees are established in Western Australia to provide the base population for future breeding and database required to quantify genetic parameters of *Pinus pinaster*. Clonal seed orchards were established in 1963 at Joondalup (14 ha) and 1970 at Mullaloo (11 ha) to provide seed for plantations. All *P. pinaster* plantations have used improved seed from clonal orchards since 1971. New and improved seed orchards were planted at Manjimup (7 ha) in 1986 to replace existing orchards and this now provides seed for the plantation program. The Manjimup CSO was designed to meet land use objectives of the Swan Coastal Plain, water and timber production (Butcher, 1977). Breeding traits were cylindrical volume and form of the 10 m sawlog with reduced size limbs to minimise rainfall interception. Because stem and branch diameter is correlated, gains in volume have been reduced.

The WA maritime pine tree breeding program objective is to improve the quantity, quality and uniformity of wood produced for industrial use per unit of land area and time. Silvicultural characteristics that are the focus of selection include survival, growth rate, stem and crown form and wood properties. CALM's advance generation breeding program is mainly based on selections made at an early age (8 to 10 years) in progeny trials for growth rate, stem and branch quality. In the early stages of the program, wood density of new selections was also assessed and the tree was cloned for breeding and orchards if it was average or above average density for the population. Siemon (1998) reported on a CALM Timber Technology study that showed whole tree basic density of 25 year-old trees to be similar for both orchard origin and unimproved trees although the mean ring width of orchard trees was greater. We have not had to include resistance to diseases and insects although we are aware of threats imposed by frost, insects (*Matsucoccus feytodi*, *Thaumetopoea pityocampa*, *Dioryctria sylvestrella*, *D. splendidella*, *Hylobius abietis*, *Pineus pineus* and *Pissodes notatus*) and fungi (*Fusarium subglutinans* f. sp. *Pini*, *Melampsora pinitorqua*, *Fomes annosus*, *Armillaria*, *Ceratocystis* and *Rhizina*) (Butcher, 1999).

### **Gains from the breeding program**

Yield trials were planted in 1973 at Gnangara and Yanchep. 18 year-old trees gave 10% more diameter growth (36% more volume) for Joondalup orchard seed when compared with the routine unselected seed source that was used for planting. Even greater gains were achieved in stem form and branch quality that significantly increases the utilisable volume (Butcher and Hopkins, 1993). Progeny tests have been planted north of Yanchep, east of Mundaring, at Busselton and Pemberton in the south, with a consistent family response over these environments (Butcher, 1974). The seed and vegetative propagules we are developing will be suitable for all medium rainfall sites. More recently, seedlings from 200 second generation selections were planted in large trials (10 ha) in the 400-600 mm rainfall agricultural zone in high and low evaporation areas.

For the orchards planted at Nannup (2 ha) and Manjimup (2 ha) in 1992, it is calculated that genetic gains in diameter have increased to 15%. This is a 50% increase over our first seed orchard gains. Clones used in these orchards had a greater selection weighting for vigour and a reduced emphasis on stem and crown form so that more industrial wood could be produced at first thinning. Silvicultural manipulation would control the potable water objective. For the CP and OP orchards planted at Manjimup (13 ha) in 1996, TBIMS (Butcher, 1993) has computed a breeding value of 22% for diameter (equivalent to 70% volume gain). This is a doubling of the genetic gains that were achieved from our first seed orchards; tree form gains will be maintained at the same level.

### **Maritime Pine Project**

Western Australia is faced with huge salinisation problems as the result of broadscale clearing of woodland for agriculture since European settlement. To stop the destruction of remnant woodland and low lying farmland by rising water tables, large areas of deep rooted perennial crops need to be established to increase water use. *Pinus pinaster* has been selected as the major species to address this problem. It is estimated 3 million hectares of perennial vegetation needs to be planted to reduce watertables in the intermediate rainfall zone (400-600 mm) and 500,000 ha is considered as suitable for *P. pinaster* (Shea, 1998). This needs to be done quickly to have an impact and arrest salinisation in this area. The Maritime Pine Project was announced by the Premier of Western Australia late in 1996 and is a significant component of the government's salinity strategy

(Agriculture WA *et al.* 1996). The Government in partnership with private landowners plans to establish 150,000 ha of *Pinus pinaster* over the next 10 years to demonstrate to the private sector, the capacity for the commercial viability of this species as an alternative land use. The demand for wood fibre is to be used as a tool to drive the rehabilitation of degraded soils, rivers and wetlands in the agricultural region by effectively integrating tree crops into farming systems.

To provide for this huge increase in planting, an additional 25 ha of advance generation clonal seed orchards were established in 1995 and 1996 in the Manjimup region. A number of strategies were used. Small clonal blocks were planted for prolific flowering parents having good breeding values for volume and tree form. These ramets are shaped at a young age to control height growth and then used for control pollination with very high breeding value pollens. This allows for immediate use of any new outstanding tree from our trials and elsewhere, as pollen. Outstanding parents that would be excluded from conventional orchards because of very poor flowering will be used as pollens. Conventional orchards were also planted using very high breeding value parents but with unknown flowering potential. Our research has shown that seed yield can be increased by 30% using GA<sup>4/7</sup> hormone application and this is now routinely applied to ramets at Manjimup and Nannup.

Vegetative multiplication using juvenile cuttings of *P. pinaster* is a new deployment option that has been developed in CALM by Liz Barbour and John Brealey. This has the advantage of immediately overcoming our shortage of improved seed but more importantly, the best genetic stock from the breeding program can be used. Pollination programs in recent years have concentrated on making these elite crosses for cutting development and deployment as well as for advancing the breeding population.

## Conclusion

Maritime pine is an important plantation species in Western Australia with a current area of about 28,000 ha but its importance has changed significantly with the planned establishment of more than 150,000 ha in low rainfall areas of the wheatbelt to reduce salinity while providing a commercial crop.

History shows that the planting of the Leiria forest in Portugal in the 14<sup>th</sup> century, the huge plantings of Les Landes in the 19<sup>th</sup> century and central and Mediterranean Spain in the mid 20<sup>th</sup> century were successful. These were with maritime pine and each had a land rehabilitation objective, driven by a commercial tree crop planting (timber and resin). This was a colossal effort, even by today's standards! In order to appreciate the magnitude of this planting, Australia has established 750,000 ha of pine plantation over the last 75 years. Perhaps the proposed maritime pine planting of 500,000 ha in the low-rainfall zone of southern Western Australia over the next 40 years will also place this in the history books as an outstanding land rehabilitation achievement.

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## 2.7 Conifers of Western United States Of America and Mexico

Paper presented to Joint Venture Agroforestry Program National Low Rainfall Farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

**David Boomsma** Southern Tree Breeding Association, 2 Eleanor St. Mount Gambier SA 5290

### Introduction

The purpose of the topic was to review the coniferous tree species which grow in the temperate regions of western USA which have similar climatic conditions to southern Australia.

In particular the focus will be on those species which grow in the dry conditions defined for this Workshop, namely, less than 600 mm of annual rainfall. This climatic restriction can be represented by the 500 mm rainfall isohyet for the western USA as depicted in Fig.1. Once you move past the coastal fringe of the western USA and over the mountains, annual rainfall drops to 250 mm. As you move further east of Utah and Arizona, rainfall increases to 500 mm/an

There are a large number of coniferous genera and species endemic to the broad rainfall zone (>250 mm/an) and distribution maps of some of these species, particularly true pines, are included in the references.

### Conifers from the drier regions of western United States

In order to shortlist the species of potential interest I will refer to the species subjected to intensive breeding in the USA and other places.

The Inland Empire Tree Improvement Cooperative runs breeding programs for six different conifers and Table 1 contains their list of species. The Cooperative is based in Idaho and covers the neighbouring states of Washington and Montana. A total of over US\$7 million is spent annually breeding these commercial forest species.

The natural distributions of these species have been reported by Little (1971).

Table 1 Species bred by the Inland Empire Tree Improvement Cooperative

| Species                      | Common Name    |
|------------------------------|----------------|
| <i>Pseudotsuga menziesii</i> | Douglas Fir    |
| <i>Pinus contorta</i>        | Lodgepole Pine |
| <i>Pinus ponderosa</i>       | Ponderosa Pine |
| <i>Pinus monticola</i>       | White Pine     |
| <i>Abies grandis</i>         | Grand Fir      |
| <i>Larix occidentalis</i>    | Western Larch  |

Jeffrey Pine, *Pinus jeffreyi*, a widespread species in California and reaching into Mexico, is very closely related to *P. ponderosa* but does not appear to be bred commercially.

### Conifers from Western United States currently used in overseas breeding programs

The most notable of these is Monterey Pine (*Pinus radiata*) which is bred in Australia, New Zealand, Chile, South Africa and possibly in Spain. Others include Douglas Fir (*Pseudotsuga menziesii*) and Bishop Pine (*Pinus muricata*).

The most successful commercial plantation pine, Monterey Pine, has a very restricted natural distribution occurring in just 3 locations on the coast of California and upon two islands off the coast of Mexico.

But 4 species with very wide natural distributions - Douglas Fir, Lodgepole Pine, Jeffrey and Ponderosa Pine - should have provenances which show potential for an Australian low rainfall tree improvement program.

### Secondary conifers

Of course there are many other conifers growing in the drier regions of the western US, but because they have not been seen as candidates for tree breeding programs I have relegated them to a secondary status. (See Table 2 for a list of secondary species). It is possible that these secondary species were bypassed for breeding

programs for reasons of inherent slow growth rates or problems with utilisation. Such reasons may not be of significance when they are assessed for use as exotics in Australia.

Opportunity exists to review the performance of these species in Australia by examining records of state and commonwealth agencies, notably CSIRO Division of Forestry & Forest Products and State forest services.

*Table 2 A list of secondary species of interest for low rainfall regions in Australia.*

| Species                 | Common Name    |
|-------------------------|----------------|
| <i>Pinus flexilis</i>   | Limber Pine    |
| <i>Pinus coulteri</i>   | Coulter Pine   |
| <i>Pinus albicaulis</i> | Whitebark Pine |
| <i>Pinus sabiniana</i>  | Digger Pine    |
| <i>Pinus torreyana</i>  | Torrey Pine    |
| <i>Pinus attenuata</i>  | Knobcone Pine  |

### **Conifers from 250-500 mm rainfall zone in Mexico**

North western, northern and central Mexico have annual rainfall, which ranges from 250 mm and upwards from 500 mm. As you move south into Mexico the climate becomes humid and moist.

Three of the very widely distributed conifers of western US occur also in Mexico, they are Douglas Fir, Ponderosa Pine and Lodgepole Pine. Monterey, Bishop and Knobcone pine have restricted occurrences in Mexico as well as the western US.

Other species to occur in the drier sub-humid zones of Mexico are shown in Table 3.

*Table 3 Pines of sub-humid zones of Mexico*

| Species                   |
|---------------------------|
| <i>Pinus strobiformis</i> |
| <i>Pinus leiophylla</i>   |
| <i>Pinus chihuahuana</i>  |
| <i>Pinus lumholtzii</i>   |
| <i>Pinus engelmannii</i>  |
| <i>Pinus arizonica</i>    |
| <i>Pinus greggii</i>      |

Some plantings of *P. greggii* are being planned for Queensland and Tasmania.

### **Discussion**

There are a number of conifers from the western US and Mexico, with both restricted and widespread distributions, which have been domesticated and have potential for use in low rainfall areas.

However, due to the spread of Pitch Canker on Monterey and other pines in coastal California and Mexico any further importation of seed from these region would need to be very carefully controlled if it could be considered at all.

It would appear from the performance of the island provenances of Monterey Pine in the ACT and at Wirrabara, SA, that there is potential for further breeding with this species.

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Figure 1. Annual rainfall distribution for western USA and Mexico (after Critchfield & Little 1976)



## 2.8 Summary of Discussion – Session 2

### Discussion (*Pinus pinaster* Breeding Strategy)

Discussion focused on the wood properties of *P. pinaster* relative to those of *P. radiata*, and its acceptability in the market-place. These factors have been researched by CALM, who have a goal to establish 500 000 ha of pinaster plantations.

- *P. pinaster* has slightly higher density than *P. radiata* and has similar stress-grade properties
- It is envisaged that a number of silvicultural options, including integrated operations, could be used to manage WA's large-scale plantations. Outputs will include both sawlog and pulpwood
- Of the 500 000 ha planned, the WA State Government has a commitment to establish around 150 000 ha, over ten years, to create a sound industry base

### Discussion (Mediterranean Pines)

David Spencer answered questions about what he considers to be 'best-bet' Mediterranean species. Along with *P. brutia*, Iranian *P. eldarica* seed sources may have potential. The possibilities and problems associated with sourcing seed from native stands in the Trans-Caucasus region was also discussed.

### Discussion (Western American Conifers)

The Western American conifer presentation by David Boomsma, stimulated discussion on two main themes:

#### 1. *Hybrid superiority*

In general, strong hybrid superiority has not been widely demonstrated in the Western American conifer group, by comparison with the well-known *P. elliottii* x *carribaea* hybrid (of south eastern American origin – widely planted in Queensland). Boomsma pointed out that whilst the combinations were made during the 1930s at Placerville, and nothing with really significant commercial applications discovered, this should not discourage people from re-visiting the possibilities.

One hybrid from the W. American conifer group with minor commercial significance, is *P. radiata* x *attenuata*. This hybrid is used to fill a niche in high altitude applications in America, where 'straight' *radiata* can't be planted. Bob Boardman and Don McGuire (ForestrySA) have trialed the hybrid in South Eastern South Australia during the last 10 years. Their data indicate the hybrids are intermediate between the two species, and unfortunately, are multi-stemmed. However, they may have acceptable growth in dry country.

#### 2. *Possibility of importing already improved material from America*

David Boomsma mentioned some cooperative breeding programs based in America during his presentation. The idea of importing already-improved material suited to arid conditions was discussed. It was agreed that it would be worth inquiring about recent developments in the US, and at least contacting the relevant organisations regarding genotype-environment interactions they are aware of. Problems with quarantine, involved in the importation of live genetic material, were briefly talked about.



# Session 3. Research Priorities & Information Gaps

(Chair: David Bicknell)

## 3.1 Overview of session

The aim of the session was to consolidate the information presented in prior sessions, with particular regard to information gaps, research priorities and key opportunities for collaboration. Bicknell set the following tasks for the group -

### Identify:

- Major problems or opportunities that are driving the need for research and information
- The desired outcomes at a strategic level (the big picture changes being aimed for)
- Discrete objectives that will be part of the process to achieve desired outcomes.

### Outputs

The group as a whole set the issues and objectives. The workshop then split into three smaller groups to discuss the issues more thoroughly, for approximately half an hour. Bicknell suggested that the Agtrans report and Peter Chudleigh's presentation may be an appropriate topic to discuss in the first instance. After the group discussions, the workshop reconvened as a whole, and each group reported its work. Group 2, chaired by Mark Stewart (Bird, Boomsma, Butcher, Hajek, Spencer ) focused on issues contained in the Agtrans report. Group 1 (Chaired by Chris Harwood with Arnold, Boardman, Bush, Stackpole and Underdown) and Group 3 chaired by Nuberg (Bartle, Bicknell, Bulman, Clark, Davis, and Vercoe) discussed a broad range of issues.

### Priorities identified in the discussion by groups 1 and 3 were:

- Breeding for drought resistance, big, utilisable trees, and salt and sodicity tolerance is a fundamental issue
- Water use efficiency is a critical consideration, either where water tables are rising (possibly causing salinity problems) or where they are falling (causing competition for ground-water resources)
- Planting must be on a large scale to have an effect on water tables
- To make a short list of commercial tree crops for dryland forestry, we need data on which tree crops and/or industries will give greatest returns to society on their investment. These data are not available, making the list hard to formulate.
- Commercial focus should not be the sole issue. Environmental benefits of dryland afforestation can be substantial, (economic benefits exist, but are often relatively long-term and unrecognised 'externalities') and this should drive research and tree improvement programs.
- Biodiversity is not an issue in terms of tree breeding programs.

- The scale of markets needs to be taken into consideration when setting priorities. A large nearby market may make expansion into dryland feasible if products can be fed into the existing market.
- Hybrids – imported versus local research. Our programs are juvenile, but we risk disease problems when we import
- A good quality, well kept database / repository for trials across Australia is needed
- Tredat could potentially fulfil the database/repository role
- Long versus Short rotation systems should be recognised
- Opportunity costs are important (eg. displacement of agriculture).

**The following are information gaps that were identified by group 2.**

*Agtrans report identifies fodder as possible market.*

**Gap 1.** Comprehensive data are needed to support this claim

*Electricity may be an important opportunity for dryland farm forestry (Agtrans). However, fuel needed to support it would need to be derived as a by-product of another major industry.*

**Gap 2.** The major industry must be identified

**Gap 3.** The economic benefit of the combined industries need to be thoroughly assessed jointly

**Gap 4.** The research needed to increase efficiencies in the biomass fuel industry need to be identified

**Gap 5.** Research needed to quantify societal benefits and sustainability issues of biomass fuel industry

**The following are assessment criteria for research identified by Group 2.**

- Cost
- Risk (technical, market, financial)
- Sustainability
- Societal benefit
- Level and rate of adoption required

### **3.2 Conclusion**

Many participants remarked that they found this session rather hard work, and this is not surprising given the scope of subject matter that was laid down for discussion in the agenda. The group discussions were a valuable source of subject matter and ‘big picture’ reflection. In retrospect, this was needed to drive later sessions (which focused on more detailed technical or tactical planning aspects). Bicknell’s invitation to examine low rainfall tree improvement at the strategic level provided a much-needed opportunity to examine the long-term planning and regional scale issues intrinsic to tree improvement program planning at the national level.

# Session 4 Trial Design & Reporting

(Chair: Tim Vercoe)

## *4.1 Trial design and data analysis for tree improvement in the low-rainfall zone*

Paper presented to Joint Venture Agroforestry Program Low Rainfall farm Forestry Tree Improvement Workshop, Adelaide, Nov 3-4 1998.

C.E. Harwood and E.R. Williams, CSIRO Forestry and Forest Products, PO Box E4008, Kingston ACT 2604.

### **Abstract**

In genetic trials, we test the significance of differences between seedlots (or clones) for economically important traits such as survival, growth traits, stem form and yield of non-wood forest products. We want to rank the seedlots accurately so that the best ones can be deployed in plantations or used in breeding programs. Good experimental design and correct statistical analysis maximise the precision and accuracy with which we achieve these experimental objectives.

Species trials, provenance trials, progeny trials, clone trials, seedling seed orchards and clonal seed orchards each have somewhat different objectives. Therefore, optimum design layouts differ for these different types of plantings.

Experience with genetic trials in semi-arid areas indicates that between-tree spacing wider than the 3 m x 2 m or 3 m x 3 m commonly used in higher-rainfall zones is required to enable full expression of the growth potential of many species under conditions of low water availability. This wider spacing tends to make trials larger in total area and hence the trial site is more likely to incorporate substantial variation in environmental conditions. Rather than use conventional randomised complete block designs, designs with additional blocking factors (one or preferably two dimensions) are strongly recommended to account for this site variation in the estimation of seedlot effects. Examples are presented to show the higher level of accuracy and precision obtained by incorporating these additional blocking factors in the design.

Results from several similar trials across a range of sites can be analysed jointly using a staged approach, to investigate genotype-by-environment interaction. It is important that the same seedlots be tested across all or most of the different sites to obtain the full benefits from this type of analysis, however experimental designs at each individual site need not be exactly the same.

Software programs for trial design (Alpha+ and CycDesignN) and data pre-processing (DataPlus) are components of an “expert system” which provide flexibility in trial design, link spreadsheet data entry and statistical analysis, enable easy checking of the data for errors which can distort the conclusions reached, and largely eliminate the need to write Genstat code for standard analyses of genetic trials.

## Trial design

In genetic trials, we test the significance of differences between seedlots (or clones) for economically important traits such as survival, growth and form. We want to rank the seedlots accurately so that the best ones can be deployed in plantations or used in breeding programs. Good experimental design and correct statistical analysis maximise the precision and accuracy with which we achieve these experimental objectives, and hence the progress we can make with the limited resources available for tree improvement.

Species trials, provenance trials, progeny trials, clone trials, seedling seed orchards and clonal seed orchards each have somewhat different objectives. Therefore, design characteristics (number of replicates, use of blocking factors, plot size, spacing between trees) differ for these different types of plantings (Eldridge *et al.* 1993, Ch.5, Williams and Matheson 1994, Ch. 2). Table 1 indicates basic features of the designs commonly used for a range of trials.

**Table 1. Common types of genetic trial, and recommended designs**

| Type of trial                            | Replicates <sup>3</sup>                 | Plot size               | Useful life of trial                                                                                                 |
|------------------------------------------|-----------------------------------------|-------------------------|----------------------------------------------------------------------------------------------------------------------|
| species elimination                      | 6 to 8                                  | 6-tree row              | 3-6 years – perhaps longer where growth is slow                                                                      |
| provenance                               | 4 or 5                                  | 25, 36 or 49-tree block | at least ½ rotation                                                                                                  |
| progeny                                  | 4-6                                     | 4-8-tree row            | ½ rotation (systematic thinning if required)                                                                         |
| seedling seed orchard                    | 5-8 (or more, to increase orchard size) | 3-5-tree row            | developed from progeny trial by selective thinning – only pre-thinning assessments give accurate genetic information |
| clone – initial screening of many clones | 4-6                                     | 2, 3 or 4-tree row      | 3-6 years – perhaps longer where growth is slow                                                                      |
| clone – proving best clones              | 4 or 5                                  | 25-tree block           | ½ rotation                                                                                                           |

The plot is the basic blocking unit in field trials – all trees in a plot belong to the same seedlot. In CSIRO Forestry and Forest Products we routinely use multiple-tree plots rather than single-tree plots in our trials, because this ensures that in the analysis of plot means, the impact of missing trees will be minimised (Williams and Matheson 1994, Ch. 3). It also enables calculation of the within-plot variance component, which is very useful in genetic interpretation.

Species elimination trials test a wide range of species and often test more than one provenance of some of these species. The aim of these trials is to screen a large number of seedlots to identify those which do well and merit further testing, and those which are poorly adapted to the trial environment and can be abandoned. At least six replicates of 6-tree to 8-tree line plots are appropriate for such trials. Small plot size is normally used on the grounds of expense and keeping trial area to a practical size, and because many of the seedlots may fail, so large plots would leave big gaps in the trial. Growth rates will vary greatly from species to species, so the trial has a limited useful life. After five or so years (perhaps longer for slow-growing species in dry environments) the faster-growing seedlots will over-top and suppress the slower ones in adjacent plots. These competition effects exaggerate seedlot growth differences. It must be kept in mind that year-to-year variation in climate, particularly rainfall, is high in low-rainfall areas (Brown *et al.* 1997) and it is advisable that species elimination trials run though at

<sup>3</sup> A replicate contains one plot of every seedlot. Sometimes it may be appropriate to include two or more plots of a particular seedlot per replicate, so that we get a more precise estimate of its performance – for example if we are testing a commercial control seedlot against a large number of progenies from a breeding program, we might include three plots per replicate of the control.

least one severe dry year before definite conclusions are drawn. Some fast-growing seedlots may flourish in a series of average or wet years and then die in a drought year, as has been observed with *Eucalyptus globulus* near Albany in Western Australia.

Provenance trials, and species/provenance trials testing provenances of a few closely related species, have a longer working life. Provenance trials are generally only planted when we are confident that the species to be tested is well-adapted to the target environment and is a serious candidate for operational planting. Differences between seedlots are smaller than in species elimination trials, so we need larger plot size to accurately rank the provenances. Also, we want to see how each provenance develops as a stand, over at least half a rotation. Four or five replicates and square plots of 25, 36 or 49 trees are commonly used. Rectangular plots (eg. 4 x 8 trees) may also be used if spacing between and within rows is different, so as to achieve a square plot shape. Thinning may be required to enable proper stand development – if this is anticipated, 36- or 49-tree plots would be preferable to 25-tree plots. As the trial develops, competition between adjacent plots of faster- and slower-growing provenances starts to affect their performance, and it is then advisable to analyse only the net plots (eg. the inner 16 trees in 36-tree plots) which will be less affected by such competition.

Progeny trials in tree breeding programs test many progenies, so large plots would make the trials overly big and expensive (eg. 100 progenies x 4 replicates x 36-tree plots at 3 m x 3 m spacing = 13 hectares). Around 20-25 trees per progeny will enable us to rank the families with a fair degree of accuracy (Cotterill and James 1984). A good arrangement is 5 replicates of 5-tree line plots. Often, we convert progeny trials into seedling seed orchards by thinning down to one tree per plot (to minimise inbreeding) and removing some or all plots of the worst families. Such selective thinning reduces the quality of genetic information we can obtain at later ages because we no longer have a random sample of progeny from each family. Progeny trials designed to be converted to seedling seed orchards usually have larger numbers of replicates, depending on the area of orchard required, and fewer trees per replicate (eg. 8 replicates and 3-4 trees per plot).

Clone testing is usually done in at least two stages (Walker *et al.* 1996). Initial screening trials rank a large number of candidate clones. Because there is no genetic variation among the individual plants (ramets) of a clone, only 8-12 ramets per clone are required to rank the clones with fair accuracy. Four replicates of 3-tree plots, or 5-6 replicates of 2-tree plots would be a good arrangement. We then test a smaller number (say 15-20) of the best clones in clone proving trials with larger, square or rectangular plots – four replicates of 25-tree plots would normally be sufficient. These later trials provide estimates of volume production for the different clones grown as monocultures.

At least two external perimeter rows around any designed trial are advisable to minimise edge effects which are often produced by solar aspect, prevailing wind, absence of competition in the outermost rows, and other site factors. These perimeter rows should use one of the seedlots in the trial, known to display good growth and survival.

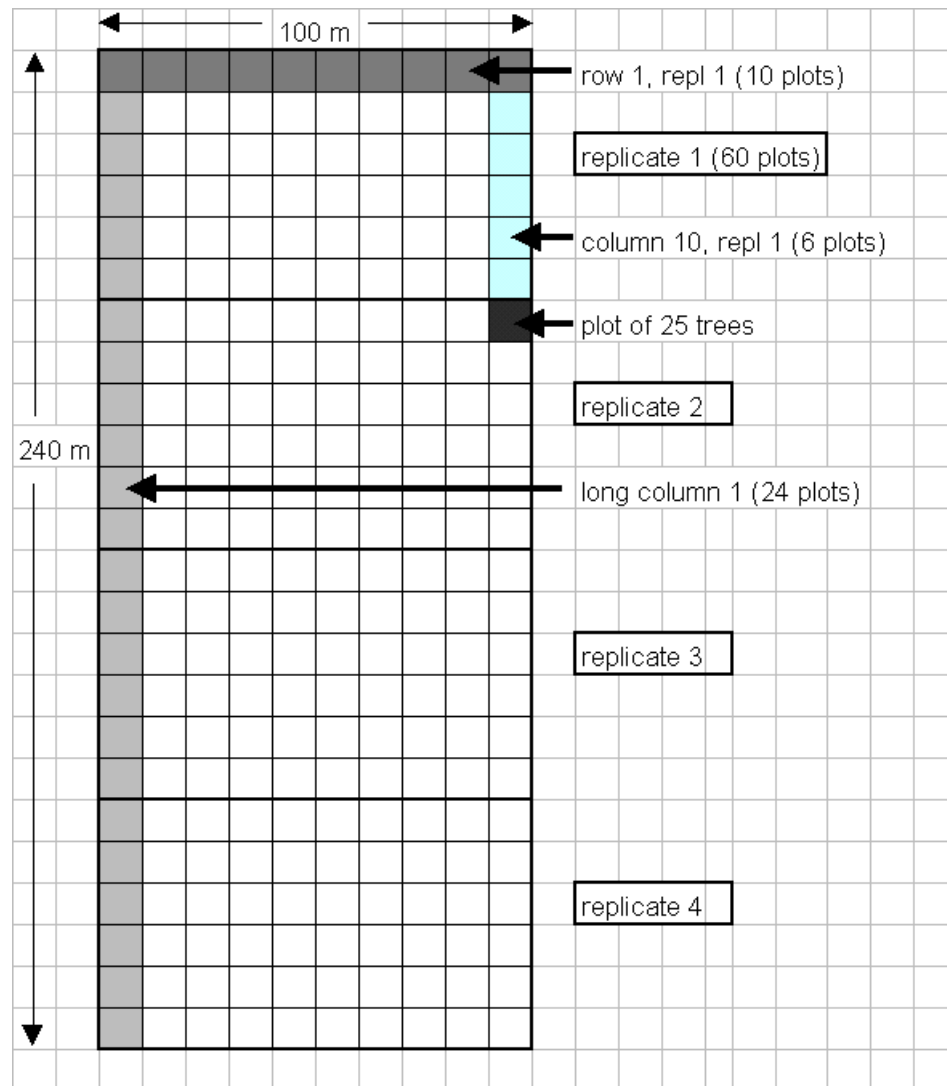
### **Use of additional blocking factors to account for field trends**

The hallmark of a successful genetic trial is not so much whether it detects a significant difference among the treatments (although we would normally anticipate this when testing genetically different seedlots) but the precision with which it estimates seedlot mean values. This precision can be summarised in the form of the coefficient of variation (Snedecor and Cochran 1989, p. 36), which is directly related to the standard error of the difference (s.e.d.) of the means expressed as a proportion of the site mean.

Experience with genetic trials in semi-arid areas indicates that between-tree spacing wider than the 3 m x 2 m or 3 m x 3 m commonly used in higher-rainfall zones is desirable to enable full expression of the growth potential of many species under conditions of low water availability. For example, in semi-arid Niger, spacing wider than 4 m x 4 m has been recommended for Australian acacia species (Harwood 1994). This wider spacing tends to make trials larger in total area and hence the trial is more likely to extend across an area with substantial variation in environmental conditions. Rather than using conventional randomised complete block (RCB) designs, designs with additional blocking factors (one or preferably two dimensions) are strongly recommended to account for this site variation and remove it in the estimation of seedlot effects. Using these additional blocking factors in the design enables a higher level of accuracy and precision to be obtained for a given trial area and seedling resource, thus improving the cost-effectiveness of genetic research.

As an example, a provenance trial of *Casuarina equisetifolia* at Weipa in north Queensland tested 60 provenances using a latinised row-column design with 4 replicates, 10 columns and 6 rows per replicate. Plot size was 25 trees (5 x 5) and spacing between trees 2 m x 2 m. This gave overall trial dimensions of 240 x 100 m (Figure 1).

**Figure 1. Latinised<sup>4</sup> row-column design for provenance trial of *Casuarina equisetifolia* at Weipa, north Queensland**



The trial was assessed 18 months after planting, when mean tree height was around 2.4 m. Analysis of tree heights, using replicates as the only blocking factor (ie treating the layout as an RCB design) demonstrated significant ( $P < 0.001$ ) differences between seedlots and provided a standard error of difference (s.e.d.) of the seedlot means of 0.20 m. Mixed-model analysis using REML in Genstat, with replicates, long columns and seedlots set as fixed effects and incomplete blocks (rows and columns within replicates) as random substantially reduced the residual mean square and therefore gave a much lower s.e.d. of 0.061 m for the comparison in seedlot means –provenances were ranked three times more precisely, at no additional cost (Williams *et al.* 1998).

<sup>4</sup> As a consequence of the latinised feature of the design, no seedlot occurs more than once in any long column (Williams and Matheson 1994, p. 127).

Where the number of seedlots is low (below about 12-15) we generally do not use incomplete blocking factors within replicates, but there are other options such as latin squares or cyclic designs which allow blocking in two dimensions, and are preferable to RCB designs (Williams *et al.* 1998).

### **Analysis across sites**

Analysis of several trials in different environments greatly strengthens the conclusions that can be drawn about the performance of a set of seedlots. When planning genetic tests across a range of sites, it is very desirable to use the same seedlots at every site, so that the extent of genotype-by-environment (G x E) interaction can be investigated. However, it is not essential to use exactly the same trial design at each site. Different designs may be appropriate for particular sites, to accommodate anticipated field trends. The results of several individual trials can be summarised as a two-way table of sites and seedlot means. The statistical significance of G x E interaction can then be tested, using a residual mean square pooled from those of the individual trials. If there is significant G x E interaction, seedlots can be classified as stable (their performance constant across a range of sites) or interactive (growing very differently on differing sites) by the slope of the linear regression lines for individual seedlots (Williams and Matheson 1994, Ch. 5).

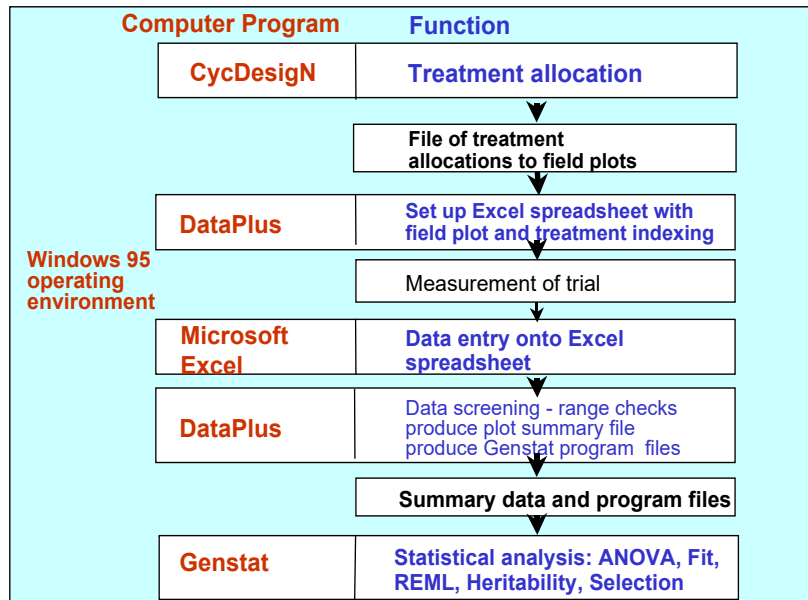
### **Importance of outlying data values**

Data recording, entry into the computer, checking and statistical analysis are time-consuming operations for genetic trials. However, it is essential that they all be done accurately without introducing errors, so that correct conclusions can be drawn from trial results. Outlying data values (outliers) violate the assumptions of the statistical model (in particular, that residual errors have the same variance, normally distributed about zero). As few as one or two outliers can seriously distort the conclusions we draw. Often, outliers arise from errors in data measurement, recording or entry to the computer – these errors must be detected and corrected during data pre-processing and initial analysis. Outliers can be detected during data entry with DataPlus (see below), from high plot variances in the plot summary file, and from the graph of residual versus fitted values in analysis of variance (Williams and Matheson 1994, page 33). Whether genuine biological outlying values (eg. exceptionally large or small trees) should be included or excluded from a data set prior to analysis is partly a matter of judgement and is influenced by the objectives of the trial. Whilst it may be necessary to exclude data values (and in some cases whole seedlots) from an analysis on statistical grounds, the excluded data should be noted and if appropriate interpreted from a biological viewpoint. For example, interspecific hybrids with superior vigour should certainly be excluded from the analysis of open-pollinated progeny trials which aim to estimate genetic parameters and rank maternal parents for their pure-species breeding values, but may be of great interest to tree breeders and should not simply be ignored.

### **Technical improvements in data pre-processing for statistical analysis**

In recent years CSIRO Forestry and Forest Products has developed an integrated approach to simplify trial design and analysis using personal computers. Software programs for trial design (Alpha+ and CycDesignN) and data pre-processing (DataPlus) are components of an “expert system” (Figure 2) which provides flexibility in trial design, links spreadsheet data entry and statistical analysis, enables easy checking of the data for errors which can distort the conclusions reached, and largely eliminates the need to write Genstat code for standard analyses of genetic trials. Progress to 1994 is summarised in the book “Experimental Design and Analysis for Tree Improvement” (Williams and Matheson 1994). Alpha+ (Williams *et al.* 1993) and CycDesignN (web reference <http://www.ffp.csiro.au/software/cycdesign/>) generate treatment allocations for many classes of designs incorporating blocking factors in one or two dimensions. As discussed above, these designs offer improved accuracy and precision over RCB designs by accommodating field trends and thereby reducing the residual mean square.

**Figure 2. “Expert system” of software programs for trial design and analysis**



The analysis of these more complex designs requires powerful statistical software such as Genstat or SAS, which can handle mixed models. Incomplete blocks are normally analysed as random effects, so that seedlot information can be recovered from the between-block comparisons (Williams and Matheson 1994, Ch. 8). Writing programs to carry out a range of analyses for many trials with differing dimensions and blocking structures requires considerable knowledge of Genstat or SAS programming code and is tedious and liable to error. CSIRO FFP therefore developed DataPlus (web reference <http://www.ffp.csiro.au/software/dataplus/>), a software package for data pre-processing which automatically produces Genstat code for most standard tree-improvement analyses for the particular trial under analysis. DataPlus provides an easy-to-use link between Microsoft Excel (the spreadsheet program commonly used to store trial data) and Genstat for Windows.

The design type (whether randomised complete blocks, row-column, split-plot, etc.) and the dimensions of the trial (number of replicates, dimensions of other blocking factors, number of trees per plot) are entered into DataPlus. The package can also automatically load the treatment randomisation files produced by Alpha+ and CycDesignN, thus eliminating the need to manually dimension and type out the initial Excel spreadsheet for data entry.

Trial assessment data is entered onto the Excel spreadsheet. DataPlus reads the data from this Excel file for initial range checking. It creates a summary file which contains the plot means, and also plot variances and counts if required, and produces Genstat programs to carry out standard analyses (analysis of variance, regression (FIT), residual maximum likelihood (REML) analysis and analysis of nested treatment structure (eg. species/provenance or provenance/progeny). For progeny trials, DataPlus will generate programs for the calculation of heritability and a multi-trait, combined primary selection index (Cotterill and Dean 1990, pages 7 and 40). Blocking factors and treatments can be included/excluded from the analysis as required, and analysis of the gross or net plot (eg. all 36 trees or the internal 16 trees of a 25-tree square plot) can easily be specified.

Scientists and technicians who use this system have obtained several-fold increases of productivity, and we have also found that methods of data analysis are much easier to learn and teach. The decrease in tedious tasks such as writing Genstat code enables workers to concentrate on thoroughly checking their data sets, and running several different analyses of a trial so as to fully explore the results and validate the conclusions that can be drawn.

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#### **4.2 Overview of Session**

The session was comprised of presentations by Chris Harwood, Tim Vercoe and Trevor Butcher. Chris gave an overview of the Tredat software developed by CSIRO, which is used as a repository for trial data.

Vercoe's session gave perspective on the way analyses from diverse locations can be collected at a central repository and used for cross-site comparison. In particular the need for standardised data was emphasised.

Harwood's presentation demonstrated the use of modern software packages to make trial design work easier, and trial analysis much simpler and faster. He also emphasised the importance of designing trials to suit their specific purpose. There are several additional considerations to be made with dryland research.

The session's final presentation was given by Trevor Butcher. He described the TBIMS (Tree Breeding Information Management System) used as a tracking and decision support tool in CaLM's tree breeding programs. The system allows changes to orchards etc to be tracked and is capable of making selections and scheduling operations.

In the discussion following the presentations (summarised below), the need for coordinated design and seedlots in cross-site trials was strongly emphasised. Various guidelines, principles and precedents for achieving standardised guidelines for trials were mentioned.

#### **4.3 Summary of Discussion – Session 4**

Session four stimulated discussion in the following areas:

1. Cross-site analysis
2. Data collection protocols
3. Trial design uniformity
4. Use of common seedlots in cross-site/ collaborative trials

##### **1. Cross-site analysis**

- For cross-site data to be useful, conformity in data capture is needed. Standardised measurement of parameters such as height and forked trees is very important.
- The frequency of measurement also needs to be considered. Early measurements of trials on dry sites need to be treated with caution, as once water becomes limiting, or there is a dry season, a trial that was performing well can collapse.

##### **2. Data collection protocols**

- Standardised procedures will be very important when cross-site analyses are performed. CSIRO have seen published examples of cross-site analyses, where the results are effectively useless, because of the non-standardised methods used to collect and analyse the data.

- Through TREDAT database collation experiences, CSIRO have become aware of the variety of measurement standards that exist, and a lot of time is spent revisiting data sets and questioning organisations to try to establish exactly how measurements were taken.
- There are standard procedures for tree breeding programs. These could be readily adapted for species trials.
- CSIRO have procedure manuals for some species - mostly tropical - that could easily be adapted to dryland species.
- STBA deploy a particular technical officer to all locations during nation-wide series of trial measurements. This ensures standardised measurement procedures.
- Given the likelihood of national coordination of trials for some species, it was decided that guidelines for establishment and standardised measurements of particular species, such as *E. cladocalyx* or *E. maculata* would be beneficial, as an exercise to draw interested parties together.

### **3. Trial design uniformity**

- Many trials in the past have lacked care in the design stage, and consequently have yielded less information than they could have. At the national level, the decision making process for trial design should be coordinated.
- A set of guidelines including pointers to an appropriate trial designer will be necessary.
- CSIRO have a publication entitled '*From Seed to Trial Establishment*' that is currently being updated. This contains standardised guidelines. The update would be suitable and is aimed at RPCs.
- Flexibility in trial design is important. Nationally coordinated designs need not be prescriptive. Local experience will often be the best guide for some elements of trial design.
- In many cases, especially screening stages of a program or for demonstrations, trials need not be set up so that they can be subjected to rigorous analysis using ANOVA or similar.

### **4. Use of common seedlots in cross-site/ collaborative trials**

- The use of common seedlots in cross-site trials, with different designs, was recommended. Otherwise, differences can be difficult to reconcile. This is an extension of the standardised design concept.
- The common seedlot concept was used in radiata breeding programs in the 1970s, where trials throughout Australia included benchmark genetic material.

- There are standard 'recipes' for designing trials with common elements. Generally, the theory is that around 20 % of entries should be common across trials to give proper genetic linkage.
- A list of standard seedlots for a number of species should be developed. The 'standard' seedlot for a species will vary according to a number of factors, such as application, soil type etc.

It will be important to package the information pertaining to standardised seedlots and procedures, in a way that is acceptable to those who are not at the core of the breeding and analytical work.

## Session 5. Tree Improvement Program Structure and Equitable Sharing of Plant Material & Knowledge

(Chair Graeme Clark; Presenter David Boomsma)

### 5.1 Overview of Session

The aim of this session was to discuss the scope and mechanism for sharing intellectual property and materials for low rainfall tree improvement. Boomsma opened the session by drawing attention to the steps needed to form a cooperative breeding program. The experience of the STBA was used as an example. The concept of organisations having to be willing to allow their research to be used by others, without the monetary investment being returned in the short term, or even the long term was raised. This concept of ‘dowry’ contributions formed the basis for a long discussion on equity issues connected with breeding programs.

The Western Australia Oil Mallee and the Tea tree oil cooperatives were used as model structures for discussion by the group.

A synopsis of one of the models – the West Australian Oil Mallee cooperative is given in Box 1.

*Box 1. Cooperative tree breeding program structure proforma prepared by David Boomsma. The details under the headings, were supplied at the workshop by John Bartle and David Bicknell.*

### Oil Eucalypt Cooperative in WA –Summary of Structure

#### Membership

Approximately 400 farmer growers plus CaLM  
Non member growers do exist.  
‘Champion’ membership important

#### Governance

Association and Ltd Company (Limited to Felton, Grimade, Bickford).

#### Mission

To develop a regional scale industry, including establishment, processing and marketing of eucalyptus oil.

#### Technical Direction

Four universities, CaLM, Association and Company form technical group

#### Staffing

3-4 CaLM staff, public interests, operations, regional managers

#### Fees

Operations – funded through Landcare

Administration – Levees and seedling royalty (two cents per plant) plus Membership fees (\$50)

## **IP**

Improved material distributed to all members via regions – centralised  
Information from grower's manual restricted to growers  
CaLM is the major investor

An important point from the box, that stimulated significant discussion, was the concept of a 'champion'. In the context of the case study presented, a large amount of enthusiasm and energy was needed to get the cooperative running, both on the part of John Bartle, and from the head of CaLM who was willing to invest significant sums of money in the scheme to get it moving.

The discussion of model structures from other organisations led on to group discussions concerning the formation of guidelines for a low rainfall tree breeding cooperative. The workshop split into three smaller groups, which using the same proforma given in Box 1, proposed organisational arrangements. The groups all selected *E. occidentalis* as a model species to help focus ideas. At the conclusion, the group reconvened and the ideas were discussed and summarised (Box 2). It was decided during the final synthesis of ideas, to expand the *E. occidentalis* scenario used in the discussion, to include a broader range of species and products. One of the most important concepts arising from this exercise, was that of the interim advisory panel, which would oversee the formation of the cooperative and oversee technical and all other functions in the short-term.

### *Box 2. Ideas on low rainfall farm forestry cooperative structure*

#### **Low Rainfall Tree Improvement Cooperative - Structure**

##### **Membership**

State and Government Agencies  
Industry – adopters (users of products)  
Existing growers and RPCs  
Research providers  
Seed collectors and nurseries

##### **Governance**

Association, initially consisting of mainly state players – though depends on particular species /product type (eg difference between short rotation and long rotation). In first instance governance guided by *advisory panel*.

##### **Mission**

To develop and promote improved genetic material for dryland afforestation and develop markets for the products.

##### **Technical Direction**

A technical coordinator is essential. The function of this person will be to collate and compile information and data and to provide planning direction. Initially the technical coordination role would be through the Advisory Panel.

**Staffing**

Initially the Advisory Panel. When funding available may be possible to retain services for coordination.

**Fees**

NOW: Government funds to be sought to start up program. Possible sources include the JVAP, AFFA, CSIRO, DNRE, ForestrySA etc

FUTURE: Growers fees, Commercial income (royalty from nurseries, seed suppliers, industry), modest membership fees.

**IP**

Issues must be resolved immediately

# Session 6 Coordination – What Approach is Best?

(Chair: John Bartle, CaLM)

## 6.1 Overview of Session

Discussion in the coordination session followed on quite smoothly from the previous session, which focused on mechanisms for coordination. Participants entered the session with an expectation, from the workshop agenda (Appendix 3), that resolutions would be made on a number of points. The points are listed below in bold along with the outcome resolved.

### **How will coordination proceed and would it be appropriate to retain a dedicated coordinator?**

It was agreed that a steering committee or technical panel would be formed, though the detail of membership was not fully discussed. Suggestions that funds be sought, particularly from JVAP, to appoint a person to coordinate low rainfall farm forestry work, were discussed. It was agreed that this would be appropriate. However, it was also argued that it may be possible for people already involved in low rainfall tree improvement to coordinate their own joint activities, or that an arrangement similar to that of the Research Working Groups (RWG), based on voluntary participation, may be effective. However, a majority decision was finally reached that the RWG model would not be effective. Most workshop participants revealed that their own time was already over-committed, and that their personal capacity to volunteer to administer coordinated activities would be low.

### **Is any organisation well placed to administer a coordinated approach?**

After discussion, there was general agreement that CSIRO Division of Forestry and Forest products, situated in Canberra would be best placed to administer the proposed coordination role. This decision was based on locality and availability of suitable technical and administrative resources.

### **What would the role of the coordinator be?**

The group discussed this at some length, and some different views on the specifics of the coordinator's role were proposed. In discussion, the question was turned around, so that it was placed in terms of qualities the coordinator would be likely to need:

- A good grasp of the technical and theoretical aspects of tree improvement
- Good grasp of trial design theory and an ability to analyse trials, and collate data from cross-site experiments
- Good communication skills – it was generally envisaged that the coordinator would spend a large proportion of their time keeping in contact with organisations and facilitating joint arrangements.
- An ability to travel interstate on a regular basis, and to organise time to visit trials, organise technical and management group meetings

From these characteristics, it is possible to draw inference on the type of role the workshop participants had in mind for the coordinator. It was agreed that the coordinator would have an important part to play in providing common material and designs, promoting standard measurements and documenting trial results at the national level. This type of work requires a large amount of liaison, and is quite time consuming. It was suggested that the time consuming nature of setting up joint work over a geographically wide area has been one of the major impediments to cooperative work in the low rainfall zones of Australia to-date.

# **Session 7. Collaborative Project Development – Description of Current Project Proposals Submitted to JVAP**

(Chair: Mick Underdown, ForestrySA)

## *7.1 Summary of Discussion – Session 7*

Discussion following session seven covered the following topics:

- Reconciling the long-term nature of dryland genetics trial work and the need to produce outputs in the short-term, to meet funding body objectives and requirements.
- Ways to collaborate more strongly on proposed trials, including a well coordinated series of trials in all southern states.
- The appropriateness of JVAP funding for trial work *per se*, as opposed to its use for projects with good strategic outputs.
- Ties with other nationally coordinated groups, such as the RWG10 silviculture trials.

The need for projects producing outputs for entry to TREDAT or similar data repositories, which, in turn, can be used to drive predictive models such as PLANTGRO, or other process models.

## Session 8 (Day 3) Cooperative Framework

### 8.1 Overview of session

The final session was optional, though the majority of participants attended. It was led by Peter Bulman. Discussion revolved around refining the arrangement for a cooperative submission to JVAP. Most participants at the workshop agreed that their time was already over-committed and that the extra role of coordination would not be realistic. It was also argued that certain efficiencies might be present if a single person was in charge of coordinating a number of areas.

A decision was reached to form a geographically-based body to oversee the early development of the cooperative program. The group will be known as the *Australian Low Rainfall Tree Improvement Group* (ALRTIG)

It was agreed that coordination of activities would occur, in the following key product/ species areas:

- Hardwood breeding
- Softwood breeding
- Short rotation biomass crop breeding
- Funding will also be sought for a coordinator to facilitate development of these programs.

It was decided that a joint project would be submitted to JVAP with four modular components, corresponding to the preceding data points. These components will deliver working plans for the breeding of a range of species, for the production of several key products. The hardwood and softwood components aim to improve the sawn timber production capability from eucalypt, pine, and other assorted species. The hardwood and softwood modules have been kept separate, based on fundamental biological and technical differences between angiosperm and gymnosperm tree breeding. In the first instance, it was agreed that a small number of species would be selected for each of the hardwood and softwood modules, to be used as models. For the hardwood program *E. cladocalyx*, *E. occidentalis* and *E. camaldulensis* based clones were nominated. For the softwood program, the development of the Aleppo pine complex was seen as suitable, with low rainfall radiata provenance selection and more wide-spread trials of *P. pinaster* also being of common interest. Tim Vercoe was nominated to write the submission with feedback from the group.

The short rotation biomass component is largely focused on the production of cineole oil from several eucalypt and melaleuca species. However, some of the methods and strategies used may also be applicable to other short rotation tree crops such as bush foods, fodder, charcoal and carbon credits.

The meeting strongly supported the appointment of a national coordinator to ensure the breeding and improvement work in different species and geographical areas would benefit sharing of knowledge, skills and, where possible, genetic material. The

coordinator's role would be in the establishment and maintenance of an Australian low rainfall tree improvement network and the procurement, circulation and exchange of information and genetic material around the network and between the network, growers and industrial partners.

The project would support meetings of key stakeholders in each component, field visits for collaborators as well as periodic meetings of all those interested in the technical and applied aspects of tree improvement.

The project is intended to run for three years with on-ground work occurring in all southern states, and periodic coordination and technical meetings in convenient locations across southern Australia. The coordinator would be based at CSIRO Forestry and Forest Products in Canberra with access to the breeding and products technical support base available in the Division.

## Appendix 1. List of Participants

| Last name | First name | Organisation                                 | State |
|-----------|------------|----------------------------------------------|-------|
| Arnold    | Roger      | CSIRO Division of Forestry & Forest Products | ACT   |
| Bartle    | John       | CALM                                         | WA    |
| Bicknell  | David      | Department of Agriculture                    | WA    |
| Bird      | Rod        | Agriculture Victoria                         | VIC   |
| Boardman  | Bob        | ForestrySA                                   | SA    |
| Boomsma   | David      | STBA                                         | SA    |
| Bulman    | Peter      | PIRSA                                        | SA    |
| Bush      | David      | ForestrySA                                   | SA    |
| Butcher   | Trevor     | CALM                                         | WA    |
| Chudleigh | Peter      | Agtrans Research                             | QLD   |
| Clark     | Graeme     | Private Forests Tasmania                     | TAS   |
| Davis     | Sharon     | RIRDC                                        | ACT   |
| Hajek     | Charles    | DNRE                                         | VIC   |
| Harwood   | Chris      | CSIRO Division of Forestry & Forest Products | ACT   |
| Nuberg    | Ian        | University of Adelaide                       | SA    |
| Stackpole | Des        | DNRE                                         | VIC   |
| Spencer   | David      | CSIRO Division of Forestry & Forest Products | ACT   |
| Stewart   | Mark       | University of Melbourne                      | VIC   |
| Underdown | Mick       | ForestrySA                                   | SA    |
| Vercoe    | Tim        | CSIRO Division of Forestry & Forest Products | ACT   |

## Appendix 2. Workshop Proposal

### Joint Venture Agroforestry Program National Low Rainfall farm Forestry Tree Improvement Workshop - OUTLINE

**Keywords: low rainfall, genetics, tree improvement**

#### Background

The scope for low rainfall tree planting in southern Australia is enormous, and interest in re-planting cleared agricultural land is increasing, as the benefits are recognised. The various purposes for low rainfall plantings include rehabilitation of degraded land, shelter for stock, conservation of natural resources and diversification of agricultural income, as well as traditional forest plantations for timber and fibre. Whilst many have recognised the benefits of regenerating cleared sites with plants propagated from local, native seed sources, there is also a need to increase knowledge about 'exotic' material - including Australian trees growing out of their natural range and those introduced from overseas - selected for their potential to produce valuable products. It is a well established fact that carefully chosen exotic species can in many cases out-perform local tree species in terms of their ability to produce specific products. Nevertheless, it can be safely said that knowledge of select genetic material suitable for specific applications in semi-arid Australia is limited and fragmented.

Whilst trials have been established in southern Australia's semi-arid zones, there is scope for coordinated collaboration of research and expertise in low rainfall tree improvement. Consideration and discussion of this issue by key 'knowledge stakeholders' in Australian low rainfall tree improvement is now clearly timely and prudent. In recognition of this fact, funding for this workshop has been approved by the JVAP. If it is felt appropriate by the participants, there will probably be funding opportunities to support further coordination.

#### Topic definition

The focus of the workshop will be low rainfall tree improvement in southern Australia. *Low rainfall* is defined for purposes of the workshop, as those areas typically receiving less than 600 mm of rainfall per annum, including dry temperate and Mediterranean climatic zones, but excluding tropical and sub-tropical regions and irrigated plantations. Experience from ACT, NSW, SA, Tasmania, Victoria and WA will therefore be relevant.

Tree improvement, in the context of this workshop, involves the selection and genetic improvement of tree species to suit particular applications at specific sites. At the most basic level, this means consciously screening and selecting species capable of yielding the desired products for a given site. More sophisticated tree improvement programs might involve production of select clonal planting stock, intra specific or inter specific intensive breeding for desired traits and/or production of special purpose improved seed.

It is envisaged that the main emphasis will be on improvement of trees to be utilised for specific end-uses, including, but are not limited to; timber, fuel, fibre, shelter, essential oil and or niche market commodities. Future uses, such as carbon sinks and petroleum-based fuel substitution may also be considered.

**Expected outcomes**

The main purpose of this workshop is to bring together key knowledge stakeholders to discuss the scope for further collaboration and consolidation of information pertaining to low rainfall tree improvement. By the end of the workshop, it is envisaged that there will be:

- improved knowledge of the current state of low rainfall tree selection and improvement research in Australia, through paper presentations, workshop sessions and informal discussion
- identification of research and information gaps
- an outline of specific research priorities and directions for low rainfall tree improvement in southern Australia
- a resolution on the merit of preferred formats for designing, measuring and reporting on trials (reflecting the trial's objectives)
- a resolution on the merit of the scope and need for increased equitable sharing of knowledge, data and plant material amongst stakeholders
- agreement on the merit of developing and implementing (a) coordinated, cooperative national project(s) on low rainfall tree improvement
- post-workshop production of proceedings, including workshop outcomes and invited papers

# Appendix 3. JVAP National Low Rainfall Farm Forestry Tree Improvement Workshop - Agenda

*Day 1 (Tuesday 3<sup>rd</sup> November)*

## **Session 1: Setting the Scene**

*Chair: Peter Bulman (PIRSA)*

Opening comments from Chair and RIRDC (9.00- 9.10)

Review of low rainfall farm forestry opportunities, by Peter Chudleigh (Agtrans Research) (9.10 – 9.30am)

## **Session 2: Low rainfall tree improvement - perspectives, past & current research**

*Chair: Peter Bulman (PIRSA)*

Invited presentations, *strictly* 25 mins each plus 10 mins discussion time to present an *overview* of current research and indicate *priorities, gaps and recommended future directions* on the following prospective topics:

CSIRO program, including seed service to Regional Plantation Committees (Roger Arnold) (9.30-10.05)

South Australian program —Farm Tree Improvement & South-East Projects (Peter Bulman/David Bush) (10.05 –10.40)

Morning Tea 10.40 – 11.00

Victorian program— (Charles Hajek ) 11.00 – 11.35

Western Australian program: Broad genetic screening, non-wood products/oil & other projects —(John Bartle) 11.35-12.10

Mediterranean pines: Aleppo group/*P pinaster* (David Spencer /Trevor Butcher) 12.10 – 12.45

## **Lunch 12.45 – 1. 45**

Western US and Mexican conifers— (David Boomsma) 1.45 – 2.20

### **Session 3 - Research priorities & information gaps (workshop session)**

*Chair: David Bicknell, CaLM*

This session is to tighten up on the previous session's overview of information gaps and main research priorities.

*Talking points: (Resolutions expected on these points)*

- Areas of greatest opportunity (High value/low volume commodities, niche markets, fuel or fibre—what are we likely to get the best returns on from investment in genetic improvement?)
- What stage are we at? Do we know what genera/species/families/hybrids to concentrate on?
- Importation of genetically improved material versus breeding our own from scratch—costs and benefits, quarantine issues
- Are some areas of Australia ahead of others?
- Where should we be focusing? What activities are an inefficient use of time and money versus what activities represent good use of funds?
- What are the interactions between silvicultural management and genotype?

### **Day 2 (Wednesday 4<sup>th</sup> November)**

#### **Session 4: Trial design and reporting**

*Chair: Tim Vercoe, CSIRO*

*Presentation and demonstration: Chris Harwood (CSIRO)*

Recommendations for trial design for semi-arid forestry

Experience drawn from CSIRO publication “From Seed to Trial Establishment” (CSIRO, 1987); Williams and Matheson’s “Experimental Design and Analysis for use in Forest Tree Improvement” (CSIRO, 1994).

Demonstration of CSIRO software programs Alpha+/CycDesign (trial design) and DataPlus (data pre-processing) which link to Microsoft Excel and Genstat to form an “expert system” for trial design and analysis.

Morning Tea 10.30 – 11.00

## **Session 5: Tree improvement program structure options and the implications for equitable sharing of plant material and knowledge**

*Chair: Graeme Clark, Private Forests Tasmania*

*Presentation: David Boomsma (STBA)*

Talking points: (Resolutions expected on these points)

- Sharing of plant material, including seed, cuttings, pollen
- Sharing of data and records; long-term management
- Formation of consortia for importing advanced material
- Joint collections and trials
- Identification of impediments
- Indications of willingness to share specific materials and info

Lunch 12.30-1.30

## **Session 6: Coordination—what approach is best?**

*Chair: John Bartle, CaLM*

Options and experiences from other coordinated/collaborative projects

Talking points: (Resolutions expected on these points)

- How will coordination proceed (eg. on a project-by-project basis / steering committee / national coordination or major ‘focus project’ located in one region but more broadly applicable)
- Which organisations are well suited to administer a coordinated approach?
- Would it be appropriate to retain a dedicated coordinator with grant funds?
- Who would oversee the coordinator? (eg steering committee)
- What would their role be?

## **Session 7: Projects – Initiate collaborative project development**

*Chair: Mick Underdown, ForestrySA*

Joint Venture applicants will be invited to outline what direction they think would be most gainful for their own projects.

Depending on the previous sessions, this time could be used to begin developing specific collaborative projects, and if a steering committee is formed, some preliminary actions may be outlined. There will probably be a lot of scope for discussion, and it will be carried on to the third day as appropriate.

***Day 3 (optional) - (Thursday 5<sup>th</sup> November)***

## **Session 8: Projects – Initiate collaborative project development**

Collaborative project development (cont.)

For those who wish to use the time to develop projects the facilities will be available.

## **Appendix 4. An assessment of commercial prospects for planted tree species in the low rainfall zones of Australia - Executive Summary**

The study has investigated market and economic prospects for agroforestry enterprises in the low rainfall zone, defined as 400-600 mm average rainfall per annum. A wide range of enterprises was investigated. While focus was on the commercial prospects of these enterprises, sustainability factors were also considered where they were thought to be important.

In general, commercial agroforestry in the low rainfall region of Australia is unlikely to be as profitable as agroforestry enterprises in the high rainfall zone, defined as greater than 600 mm average rainfall per annum. This is due to lower growth rates, less established forestry infrastructure, and, depending on the product form and its value, greater distances to markets.

While there may be some agroforestry enterprises in this rainfall zone that may be considered viable when grown under irrigation (e.g. olives), these were generally given less emphasis. This was because the study was, in the main, targeted at landscape scale change, which dictated dryland agroforestry.

Further, once commercial realities are known, some enterprises in future could be assisted by government/society where sustainability and conservation benefits are significant. Such assistance, if forthcoming and sufficient, could induce investors to pursue agroforestry enterprises that might be 'nearly' commercial. Again, government/society initiatives would likely favour activities where there was potential for 'landscape' or 'regional' change.

The focus in each prospective enterprise analysis was on markets and economics. This required assumptions to be made on the production process, product form and target markets for each enterprise. Information on many of the enterprises was difficult to obtain and for some variables best 'guesstimates' have been made. Hence, the end result in each assessment should be viewed as indicative rather than prescriptive. In particular, the economics will vary from one situation to another and care must be taken in interpreting results of analyses based on one set of assumptions or on one type of production system.

Enterprises which were considered included sawntimber, wood panel products, posts/poles, specialty timber, biomass for electricity and ethanol, firewood, charcoal and activated carbon, eucalyptus oil, fodder and a range of 'niche' markets (e.g. bushfood, olives, jojoba). Full investment analyses were conducted for four of these enterprises: sawntimber, firewood, biomass for electricity, and eucalyptus oil production. Other enterprises were handled in a descriptive manner. In addition, all of the major enterprises were ranked against a set of assessment criteria.

Three prospects that emerged reasonably favourably from the assessment were:

- fodder;
- eucalyptus oil; and

- electricity produced from by-products and residues.

The potential for Australian eucalyptus oil to increase its share of the world market for pharmaceutical use is limited by low production costs in China and, to some extent, in other producing countries. However, there is some limited scope to increase market share based on value adding products in Australia and high quality oil production. However, the solvent market for eucalyptus oil could offer the greatest potential for expanding production from agroforestry, as synthetic products such as trichloroethane have recently been banned for their negative effects on the atmosphere. Estimates indicate that the world market is certainly large enough to support large scale production of eucalyptus oil in Australia. This potential, however, is subject to commercial cost of production being similar to competing products such as limonene and pinene what are by products of orange production and paper making respectively. There may also be potential in supplying to other niche solvent markets, such as hand cleaners, where world prices may be higher.

The economic analysis for eucalyptus oil production, based on planting designs and production systems being employed in Western Australia, was favourable with a benefit cost ratio of 1.14 : 1 and an internal rate of return of 6.9%. This result excluded any sustainability benefits and such benefits could be considerable. The analysis assumed the woody stem co-product would be returned to the field as mulch. If used in alternative uses this co-product could have a higher value. The scale of the eucalyptus oil operation could be significant depending on penetration into the industrial solvent market. The production scale analysed was for 22,900 ha of trees harvested each year and this would require a penetration of the world industrial solvent market of almost 1%.

Wood biomass for electricity also appeared promising if transferred at a low price from other agroforestry enterprises. It would be unlikely that growing biomass specifically for electricity production would prove economic. The economic analysis assumed gasification of wood residue with the resulting gas driving a combustion engine linked to a generator. The scale assumed was for a unit generating about 300kW capacity, sufficient for a small community in rural areas. This would require about 5,000 tonnes of biomass (green) per annum as feedstock. Cogeneration was also considered, with the main application by sawmills and factories already operating in the 400-600 mm zone

In terms of market potential, the Federal Government's mandatory goal of more green power being utilised to produce electricity, combined with the deregulation of the electricity generation and supply markets, should enable 'green power', such as that generated from wood biomass, to compete more favourably with fossil fuel sources of electricity. This is particularly so in rural areas where the cost of delivering electricity is high due to line infrastructure carrying small loads and transmission losses over long distances. The deregulation of the market should mean that supply authorities will attempt to source electricity from the lowest cost source.

Although no economic analysis was carried out for trees and shrubs planted for fodder production in low rainfall areas, this would appear to be an area of considerable promise. Benefits are already accruing from such species as Saltbush and Tagasaste plantings. Native saltbush species have a widespread distribution and survive well in

dry, harsh and saline conditions. Commercial distribution of saltbush seedlings has already commenced in Western Australia for national distribution, with species such as *Atriplex amnicola* and *Atriplex nummularia*. Other native species also offer promise for fodder production. The exotic species *Tagasaste* perhaps offers the greatest economic potential for improved livestock grazing systems throughout much of the drier areas of Australia. Also, the concept of dual purpose fodder trees which can be established and maintained in the normal course of farming, for example, through alley farming systems, offers potential.

Prospects for producing wood for timber are somewhat limited due to the slower growth rates and competition from forestry and agroforestry in the higher rainfall zone. The potential for hardwoods is based on the native species abundance in the lower rainfall zone and unique characteristics of density and appearance of many species. On the other hand while softwood species may have relatively limited opportunities for market differentiation away from *Pinus radiata*, they may still provide an important role in low rainfall agroforestry in some situations.

Production of quality hardwood timber from the lower rainfall areas of Australia would have to compete increasingly with hardwood plantations in high rainfall areas where growth rates would be higher. Low rainfall agroforestry based on hardwood timber production would need to be based on high value and unique type timbers to be the most competitive, such as might be used in the furniture, high value craft and specialty timber markets. In this respect many of the species suited to low rainfall regions are strong and of high density and many have a unique appearance.

An economic analysis based on growing *Eucalyptus maculata* for high quality furniture provided a negative NPV at a 5% discount rate but this assumed no value of the waste timber and sawdust which could amount to about 65% of the volume of total wood produced. This could be used in production of electricity or ethanol, as for the residue for eucalyptus oil. However, planting designs for timber production may need to be based on block designs which may not be as effective for capturing any sustainability benefits that might exist from agroforestry enterprises in a particular region.

Prospects for softwood production in lower rainfall areas are also mixed. There may be particular biophysical niches, particularly in the upper end of the 400-600 mm rainfall zone where certain species may be quite suitable (e.g. *Pinus pinaster*). In addition, there may be some opportunities for softwood species to differentiate themselves and so avoid direct price competition with *Pinus radiata*. Further, where softwood processing infrastructure already exists close to the 400-600 mm zone (e.g. South Australia), this would benefit enterprises focusing on softwood species in the lower rainfall zone. On the other hand, competition from *Pinus radiata* grown in higher rainfall areas (as well as imported material) is generally likely to place a price ceiling on sales of many softwood products. Residues and by products of softwoods, as with hardwoods, could provide feedstocks for conversion to energy products.

There are potential markets for hardwood panel products, particularly laminated flooring and MDF. However, issues of scale, costs of production and processing, and the potential market penetration are still uncertain and could be investigated further with respect to low rainfall areas. Further, agroforestry production for wood panel

products is more likely to be commercially viable if alternative products (e.g. posts, firewood, biomass for electricity) are produced from the agroforestry planting, so as to spread the risk associated with singular markets and to utilise the majority of the wood not used, which can be up to 80% of the log.

The opportunities for gaining commercial value from the production of agroforestry biomass to charcoal initially, and then activated carbon are likely to be promising, and are worthy of further economic assessment. The technology is available and is being pilot tested. The economics of producing activated carbon will be even more promising if its production can be incorporated as part of another agroforestry industry, such as sawntimber or eucalyptus oil production.

Production of firewood, grown in the low rainfall areas of Australia as a sole dedicated product, is not likely to be generally economically viable. The greatest potential for firewood production from this zone could be as a byproduct from other agroforestry systems, such as thinnings from sawntimber production or residues from milling operations. Firewood sold from thinnings is likely to be more profitable than firewood production as a stand-alone operation, because the cost of production is largely recouped by the sawntimber production. In addition, due to potential increasing supply from waste products from high rainfall hardwood stands, the firewood market for low rainfall agroforestry may only be small and localised, centering around rural areas in proximity to large urban centres and where transport costs and competition with high rainfall zone forest waste are minimised. The city markets of Perth and Adelaide may offer potential to low rainfall production as they are located in close proximity to that zone.

There may also be an opportunity for low rainfall agroforestry to produce hardwood fence posts, depending on the extent of any future substitution for steel posts. It is more likely that fence posts would present an opportunity as a product from a multi-purpose agroforestry system, where the risk of the investment can be spread over a number of industries. These fence posts would still be competing against those from remnants and native forests. However, these latter resources may be more sustainably managed in the future, thereby reducing their availability to the fence post market in specific regions.

The market potential for hardwood poles for electricity transmission lines is limited due to competition from underground connections and steel/cement poles, as well as the limited species suitability and lower growth rates to meet the product requirements. Similarly, while the market for vineyard trellis posts could be penetrated by hardwood posts, the market is not large in terms of any landscape scale effects that might ensue. Also, vineyard expansion may have already peaked, and the potential would exist only in replacing existing posts.

The commercial potential for ethanol from biomass was found to be substantial, but subject to the proposed Commonwealth/State Forests of NSW pre-commercial demonstration project substantiating production costs as estimated by Gorton Timber's study. A considerable margin exists between that estimate and the higher current price of industrial grade ethanol, and this latter market may be where the most potential for ethanol from biomass exists. On the other hand fuel ethanol at 48 cents per litre is uncompetitive with petrol and diesel at 25-28 cents per litre.

By reference to the current untaxed wholesale price of conventional petroleum fuels, both diesel and petrol, the blending of ethanol in proportions of 15 and 10 percent respectively may, at the price estimated by Gorton Timber, impose a price premium of the order of 10-15 percent. This may be acceptable to some consumers given the environmental and other benefits associated with replacement of fossil fuel use.

The large scale of operations for ethanol production may be a constraint on using feedstock from low rainfall areas. Electricity production using gasification technology is more suited to a smaller scale of production, and probably more compatible with agroforestry production in low rainfall areas.

Specialty markets for various wood products should be considered as opportunities, albeit somewhat limited. Timber for specialty markets such as musical instruments may be more efficiently sourced from native stands, for as long as this is permitted. This is because long rotation times are required to provide the density and appearance attributes of the timber, which are sought after in specialty timber products. It may not be economically feasible to produce timber over such long periods in an agroforestry situation, and as such, native stands may be the preferred source of timber. If the situation were to change, however, where native stands could not be harvested, opportunities may open up in this area. Specialty timbers for craft uses, such as wood turning and carvings could be supplied from low rainfall agroforestry. There is little doubt that the value of the market could be significant, but it is still likely to be a relatively small volume market compared with other wood markets. Tool handles, which require hardwood timbers with exceptional strength and durability, may provide another niche market for low rainfall agroforestry. While the tool handle market for wood is attractive in terms of the premium prices likely to be received, existing Australian tool handle manufacturers are experiencing intense competition from imported handles, and substitute materials.

The study also considered commercial products from a range of other enterprises. These included carob, cork, jojoba, olives, other essential oils, Guayule (resin/rubber), sandalwood, tannins, trees providing bush food, and trees providing flowers. While all of these markets, due to the market size and the relative scale of plantings required to meet the market, are considered "niche", the enterprises with the most potential include essential oils, olives, carob, jojoba and sandalwood.

Melaleuca species were considered for their contribution to produce essential oil and betaines. One of the more important prospects for Melaleucas in low rainfall areas of Australia could be in the production of betaines produced in *M. bracteata*. The betaines can be extracted and manufactured into crop chemicals. These betaine products, when used on crops, would alter the water efficiency of the plants, so that they become more tolerant of dry conditions.

It is likely that commercial olive production in the low rainfall zone would require irrigation. While there may be geographic niches in the low rainfall zone that are suitable for olive production and where irrigation water is available, it is not likely that olives will provide a significant area of trees unless an extensive olive/grazing system can be developed that integrates livestock grazing and is still able to use harvesting aids or mechanical harvesting.

Even if Australia were to meet 10% of the total world demand for carob bean gum, only 8,750 hectares would need to be planted. This scale of planting is likely to have minimal impact on the total landscape in the low rainfall areas of Australia.

The market opportunity for jojoba could be significant, if the potential world market is ever realised. Australia should have a 10% market share when present plantings peak in production after the year 2000. To reach 50% of current world production would require another 800 hectares or 1 million trees. If the world market for jojoba expanded significantly, it is likely that prices would also need to fall significantly.

The opportunity for plantation sandalwood in low to medium rainfall areas of Australia is typically "niche", due to species suitability, growth rates and limited potential for market expansion.

While there may be commercial opportunities to produce flowers in the low rainfall zone, the size of the market and the need for quality and consistency may drive such production to intensive operations. It is unlikely therefore, that any landscape scale impact would be apparent.

Domestic and export demand for bushfoods is still only small with the initial market developed being in the novelty restaurant sector within Australia. A few of the more promising species are suited to the lower rainfall areas. Most bushfoods are still supplied from native stands. If production of some of the bushfood species were proven to be commercially viable in the low rainfall zones, it is unlikely that large scale plantings could be developed due to the cost of production and the specialised niche markets from which demand currently emanates.

High establishment costs combined with poor rubber prices and low yields, mean that guayule production, under present circumstances, is unlikely to be economic. Significant changes in establishment costs, rubber prices, yields, or changes in a combination of these variables, would need to occur before guayule production became profitable.

Most of the world's tannin production generally occurs in higher rainfall areas. There may be limited potential for tannin as a commercial option for low rainfall agroforestry.

The long rotation and expensive harvesting and processing costs for cork, mean that cork production in Australia is not likely to be significant in the future.

The potential for producing and processing gum arabic in Australia is limited, due to high costs associated with stripping the bark from the trees, high capital costs for processing equipment, competition from other countries with lower labour costs, and competition from synthetic products, particularly synthetic glues.

Carbon credits could provide another market for low rainfall agroforestry. The additional source of income which might be provided from carbon credits could provide the extra return required to ensure commercial viability for any "almost commercial" low rainfall agroforestry products.

In addition, the study has provided an indicative list of suitable species for the low rainfall zone that might be suitable for agroforestry production.

A number of uncertainties exist for low rainfall zone agroforestry which could be the subject of further investigation. These include the threat of species dying after a series of poor seasons. The low rainfall zone is inherently risky in terms of climate. Existing biophysical predictive models mostly do not account for rainfall variability over a series of years and improvements in this regard could be made. Also, limited knowledge is known about how low rainfall species might adapt to a plantation situation. This adaptation could well be related to the planting design and could also be very important in the capturing of sustainability benefits that might be targeted from low rainfall agroforestry.

The study highlights the importance of utilising all of the resulting biomass from agroforestry and therefore targeting multiple products from an individual enterprise. In this regard, future prospects for electricity generation from biomass and production of activated carbon should be investigated further.