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# **Progress in Breeding Trees for Low Rainfall Farm Forestry**

**– the Australian Low Rainfall  
Tree Improvement Group: 1999-  
2005**

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

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***Progress in breeding trees for low rainfall farm forestry – the Australian Low Rainfall Tree Improvement Group: 1999-1995***

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## Foreword

Growing interest in farm forestry on crop and grazing land in the low rainfall sheep-wheat belt of southern Australia has prompted a cooperative national effort to select and breed trees suited to ‘commercial environmental forestry’ (CEF). CEF aims to simultaneously return growers an income imputed to the environmental benefits of plantations (e.g. salinity or carbon credits for trees that control dryland salinity and/or sequester carbon), and a commercial return from timber or other products. Genetic improvement is expected to improve the commercial returns by increasing yield and product quality. In some cases this will make establishing plantations in the low rainfall zone financially viable where it would not be using unimproved planting material.

The Australian Low Rainfall Tree Improvement Group (ALRTIG) is a cooperative involving State and Commonwealth researchers whose aim it is to ensure that Australia will have the best possible planting stock for a number of low rainfall ‘key species’ through genetic improvement programs. The program has drawn on pre-existing biological and scientific resources belonging to its partners, and pooled them to maximise impact through nationally coordinated research and development.

This report provides an overview of the Australian Low Rainfall Tree Improvement Group’s activities and achievements since its formation in 1999. Early results from trials, as well as a description of extension, commercial opportunities and linkages to industry and other projects are provided. As a result of this project, improved seed is available with more seed orchards due to begin producing in 2007-08.

The report is for use by farm forestry extension and cooperatives, landholders, the plantation industry and policy interested in the availability of improved planting stock, and the status of tree breeding work for improving low to medium rainfall plantation productivity.

This project was jointly funded by the State and Commonwealth project partners, the Natural Heritage Trust, and the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations — Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia, and Forest and Wood Products Research and Development Corporation (FWPRDC), together with the Murray-Darling Basin Commission (MDBC). The R&D Corporations are funded principally by the Australian Government. State and Australian Governments contribute funds to the MDBC.

This report, a new addition to RIRDC’s diverse range of over 1600 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

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**Peter O’Brien**

Managing Director

Rural Industries Research and Development Corporation

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## Abbreviations

|        |                                                          |
|--------|----------------------------------------------------------|
| ALRTIG | Australian Low Rainfall Tree Improvement Group           |
| CP     | Controlled pollination                                   |
| CEF    | Commercial Environmental Forestry                        |
| CSIRO  | Commonwealth Scientific Industrial Research Organisation |
| CSO    | Clonal Seed Orchard                                      |
| DBH    | Diameter at breast height                                |
| DSE    | Department of Sustainability and Environment (Victoria)  |
| DPI    | Department of Primary Industry (Victoria)                |
| FNSW   | Forests New South Wales                                  |
| FPC    | Forest Products Commission (Western Australia)           |
| GCA    | General combining ability                                |
| IP     | Intellectual property                                    |
| IUFRO  | International Union of Forest research Organizations     |
| JVAP   | Joint Venture Agroforestry Program                       |
| PVI    | Pastoral and Veterinary Institute (of DPI)               |
| MAR    | Mean annual rainfall                                     |
| OP     | Open pollinated                                          |
| PT     | Progeny trial                                            |
| RIRDC  | Rural Industries Research and Development Corporation    |
| RWG1   | Research Working Group 1 (Genetics)                      |
| SO     | Seed orchard                                             |
| SPA    | Seed Production Area                                     |
| SSO    | Seedling Seed Orchard                                    |
| STBA   | Southern Tree Breeding Association                       |

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## Executive summary

### What the report is about

The Australian Low Rainfall Tree Improvement Group was established to select and breed trees to improve productivity of farm forestry in low rainfall regions of southern Australia. This report provides an overview of the group's achievements since its formation in 1999. A range of trials have been established, including provenance, progeny, genetic gain trials and seed orchards. Early results from field trials, as well as a description of extension, commercial opportunities and linkages to industry and other projects are provided. As a result of this project improved seed is available, with more seed orchards due to begin producing in 2007-08.

### Who is the report targeted at?

The report is for use by farm forestry extension and cooperatives, landholders, the plantation industry and policy interested in the availability of improved planting stock, and the status of tree breeding work for improving low to medium rainfall plantation productivity.

### Background

#### *Research need*

While tree genetic improvement research on species suited to Australia's low rainfall sheep-wheat belt had been ongoing for years in a number of State and Commonwealth organisations, the relative intensity had been low up until the late '90s, compared with high rainfall forestry research and development (R&D) where industry was already well-established. However, there was a growing awareness of wide-scale environmental problems such as dryland salinity, and the need to ameliorate this by planting of deep-rooted perennial vegetation. A workshop was organised by the Joint Venture Agroforestry Program (JVAP) and the South Australian State forestry research organisations in 1998 which involved low rainfall tree improvement stakeholders from relevant organisations. A cooperative model of research was proposed to achieve a 'critical mass' and thereby accelerate R&D in this important area. In 1999 following discussions with stakeholders, JVAP and the Department of Agriculture Fisheries and Forestry, a cooperative low rainfall tree improvement program was established. The mission of the newly formed Australian Low Rainfall Tree Improvement Group (ALRTIG) was defined as:

*to produce genetically improved planting material for farm forestry in the low rainfall areas of southern Australia, and inform tree growers of its availability.*

#### *Partnership*

ALRTIG is based on partnerships at a number of levels. Its 'core' partners are represented on the project steering Committee along with a JVAP representative. Other partners are representatives from collaborating scientific organisations, industry and the farming community. The high degree of cooperation between the various partners has been critical to ALRTIG's success.

#### *Organisation*

ALRTIG's scientific research is focused on three areas: Hardwoods, Softwoods and Short-Rotation Woody Crops. Each of the three areas is serviced by individual Technical Committees, with representation from experts from the partner organisations. The main task of the Technical Committees was initially to select a small number of 'key species' on which to concentrate, and then to devise strategic research plans, implement works and review and ensure that the plans were being executed.

The Technical and Steering Committees have been served by a full-time National Coordinator. The role of the Coordinator has been to carry out secretariat functions, plan and oversee aspects of trial establishment, edit scientific publications, represent ALRTIG in public and oversee extension activities, create and maintain the website and manage intellectual property and commercial aspects. The Coordinator has also been a central point of contact for the Partners, and responsible for budgets and delivery of milestone reporting to JVAP.

### **Aims/Objectives**

This project built on work done by the Australian Low Rainfall Tree Improvement Group (ALRTIG) between 1999 and 2001 on breeding tree species for commercial forestry in low rainfall areas of southern Australia. The aims were to:

- 1) update the breeding strategy for low rainfall hardwood species and establish new progeny trials, seed orchards and genetic gain trials for key species,
- 2) develop and begin to implement a breeding strategy for low rainfall radiata pine (*Pinus radiata*), and measure trials of *P. pinaster* established in phase 1 in south-eastern Australia
- 3) maintain short rotation species site x genotype trials established in phase 1 of ALRTIG
- 4) disseminate results from ALRTIG research, including to make recommendations on best-bet provenances and seed sources
- 5) provide improved seed sources to assist with profitability, investment in and uptake of dryland agroforestry.

### **Methods and Results**

#### *Hardwoods*

Five key hardwood species were selected for genetic improvement. These were *Eucalyptus camaldulensis* (river redgum), *E. cladocalyx* (sugar gum), *E. occidentalis* (swamp yate), *E. tricarpa* (red ironbark) and *Corymbia maculata* (spotted gum). The Hardwoods Technical Committee then set about securing both short-term supplies of genetically improved germplasm, and implementing a structured, long-term strategy to ensure continuous genetic gains. Some important elements of the strategy that have already been implemented are as follows:

- Analysis of Partner's existing pooled data to make recommendations on best-bet seed sources
- Conversion of existing planted stands and trials for seed production purposes to meet short-term demand for improved seed
- Establishment of a series of progeny trials, some of which will be managed for production of high quality seed while others will be retained for data collection and selection of genetic material for future generations
- Research into vegetative propagation
- Establishment of clonal seed orchards for production of substantially improved seed
- Establishment of genetic gain trials to test and demonstrate the superiority of genetically improved material

Genetic improvement strategies were published for each species, and a review was undertaken in 2002. *E. sideroxylon* and *C. citriodora* subsp. *variegata*, which are closely related to *E. tricarpa* and *C. maculata* respectively, were added to the list of key species. A review of the breeding strategies was published in 2004.

### Softwoods

The Softwoods Technical Committee initially chose two key species, *Pinus pinaster* (maritime pine) and *P. brutia* (Brutian pine). *P. pinaster* had already been significantly genetically improved by the Western Australian State over a number of years; however, the genetically improved material had not been extensively tested in the south-eastern Australia. It has broadly similar wood properties to *P. radiata*, and may therefore find ready industry acceptance. A series of ten yield trials were set up on sites representative of the target planting environment. The trials compare various genetically improved materials with unimproved *P. pinaster*. A comprehensive survey of soil physical properties was undertaken at each site.

A genetic improvement strategy similar to that of the hardwoods was prepared for *P. brutia*. This species, which has been introduced to Australia from the eastern Mediterranean and western Asia, was identified as having potential for very dry sites, including those with alkaline and/or shallow soils. It is amongst the most drought resistant *Pinus* species. ALRTIG has created a series of seed stands, by thinning existing stands, for short term seed production. A comprehensive survey of all known Australian stands was undertaken, and a list of candidate plus trees compiled. The top 39 of these trees have been grafted into a clonal seed orchard. Efforts were made to make new collections of seed from the species' natural range in 2000. An excellent collection was made, and it is hoped that this will be released from quarantine in the near future.

In 2002, it was decided by the Softwoods Technical Committee that the potential for creating a new, low rainfall breed of *P. radiata* would be examined. A strategy for creating a new breed, possibly based on the previously untapped Mexican island and Cambria provenances was devised. Preliminary work was undertaken to implement the strategy, including establishment of trials and controlled crossing.

### Short rotation woody crops

The Short Rotation Woody Crop Technical Committee chose two eucalypt mallee species *E. polybractea* (blue mallee) and *E. horistes* (oil mallee) for a series of genetic-by-environment trials to be established in each of the southern mainland States. Both of these species yield high volumes of cineole-rich leaf oils, and are grown on three-to-four-year coppice rotations. While in Western Australia it was already known that *E. horistes* was suited to relatively drier sites, and *E. polybractea* relatively wetter ones, the environmental niches on eastern site types were unknown. The study will provide information on the environmental plasticity of the two species, and will help to inform breeding programs. Initially, a clonal trial series was planned, and vegetative propagation studies were undertaken. However both species proved to be difficult to propagate, and so seedling-based trials were established in 2001.

### Extension

ALRTIG's mission is 'to produce genetically improved planting material for farm forestry in the low rainfall areas of southern Australia, and inform tree growers of its availability': communication has therefore been an important focus of the project. ALRTIG has communicated information and promoted the use of genetically improved germplasm through a variety of media including:

- Written publications for scientific and general audiences
- Representation at conferences and workshops
- Articles and interviews in rural press and radio
- Contribution to development of professionals in forestry and agroforestry practitioners
- Creation of a website containing information on the key species and best-bet seed sources

## **Implications for relevant stakeholders**

### *Commercial*

The market for low rainfall forestry germplasm is dependent on the development of broad-scale plantations in the sheep-wheat belt. It is envisaged that the 'commercial environmental forestry' concept may lead to broad-acre planting with deep-rooted perennial vegetation that will generate both harvest returns and attract environmental service payments such as salinity and/or carbon credits. There are technical and policy impediments to this being achieved. ALRTIG is addressing one of the technical impediments by breeding low rainfall tree species that will generate profits, and providing capacity to respond to demand for genetically improved germplasm when the need arises.

ALRTIG has created a resource that will have significant commercial value. The seed from the orchards may be sufficient in quantity to supply a sizeable plantation estate. It is envisaged that the Partners will market this to nurseries and growers. The sale of 'interim' improved seed (i.e. seed from pre-existing stands that have been treated to produce seed until the ALRTIG orchards start producing) has already commenced from some Partners' stands.

An important part of the commercial strategy has been to involve industry stakeholders directly in the genetic improvement programs. In 2003 a series of genetic gain trials were established on industrial partners' estates. The benefit of this approach is that industry stakeholders can assess the performance of genetically improved germplasm as compared with non-improved benchmarks on their own sites using their preferred silviculture regime.

### *Genetic improvement*

ALRTIG has created a valuable base of genetic improvement for a number of low rainfall key species. Early indications are that there will be significant improvement in the traits of interest. It is likely that through genetic improvement, commercially viable products can be obtained from low rainfall plantations. This will afford direct benefits to the grower, through the commercial revenue obtained, and indirect benefits to the grower and others, through positive environmental impacts.

## **Recommendations**

It is our assessment that overall, the program has achieved its objectives. Specific areas recommended for extra work include:

- continued measurement of ALRTIG trials to assist yield predictions and population genetic studies
- continued seed collections from trials and orchards using agreed promotion and sale procedure between by ALRTIG partners
- creation of extra short-term seed capacity in certain species
- maintenance of extension activities.

It is recommended that the ALRTIG cooperative model could be more widely applied to other areas of scientific research. The communication and leadership of geographically-spread partners from different organisations is a significant challenge. A recommendation arising from the ALRTIG experience is that a person with a component of time dedicated to communication and coordination, as well as a person or people to provide 'champion' scientific leadership in specific areas, are necessary for success.

# 1. Introduction

Since the 1900s, southern Australia's plantation estate has generally been established in higher rainfall areas (those receiving 800 mm mean annual rainfall or more). There has been a ready supply of land, often situated close to major population centres and/or ports, where highly productive species such as *Pinus radiata*, and more recently, *Eucalyptus globulus* have been successfully established. Forest research organisations carried out taxa evaluation trials on the higher rainfall sites, identified suitable species, and embarked on genetic improvement programs. Up until quite recently, due to a low level of impetus, relatively little research had been done to identify, domesticate and genetically improve plantation tree species suited to the low rainfall areas of Australia's wheat-sheep belt. There have been some important exceptions, for example in South Australia and Victoria there was interest in *E. cladocalyx* as a low rainfall farm tree species as early as the 1870s, while in Western Australia a program that identified and genetically improved *Pinus pinaster* commenced in the 1940s.

From the 1980s onwards, interest in lower rainfall plantation species has slowly grown, albeit from a low initial level. A number of factors have contributed, including:

- The gradual reduction in logging of native forests
- Government policy encouraging plantation forestry in general
- Recognition of the economic and environmental benefits of trees on farms which provide shelter, utility timber and erosion protection
- Recognition of the role of deep-rooted vegetation in the hydrology of dryland salinity

By the late 1990s, significant progress had been made by individual State and Commonwealth forestry research bodies towards identifying species with potential for low rainfall forestry. However, the research had generally been conducted at a low intensity, and peripheral to that on the main commercial species (AGO/MDBC 2001).

A workshop, organised during 1998 by the Joint Venture Agroforestry Program (JVAP) and the South Australian State forestry research organisations, involving tree improvement stakeholders from the southern States, examined the status of low rainfall tree improvement research (Bush and Bulman 1999). Participants recognised that while the discrete, small research programs being undertaken by southern Australia's various researchers had made significant achievements, a cooperative model of low rainfall tree improvement may be more effective. The concept of an Australian Low Rainfall Tree Improvement Group (ALRTIG) was put forward and agreed to in principle.

Following discussions between State and Commonwealth Government researchers, JVAP and representatives of the Department of Agriculture Fisheries and Forestry Natural Heritage Trust, a cooperative low rainfall tree improvement program was established in 1999. The mission of the newly formed Australian Low Rainfall Tree Improvement Group was defined as:

*to produce genetically improved planting material for farm forestry in the low rainfall areas of southern Australia, and inform tree growers of its availability.*

ALRTIG has benefited from two rounds of funding support through JVAP. The first phase from 1999 to 2001 saw the set-up of the project Steering Committee, three Technical Committees and the recruitment of a National Coordinator (see Section 2). This phase was characterised by the selection of key species (see sections 2.2, 2.3 and 2.4), formulation of tree improvement plans,

compilation and interpretation of jointly held data, and establishment of **breeding populations**<sup>1</sup>, interim seed production facilities and **seedling seed orchards** that will produce seed crops in the longer term. Genetic gain trials of *Pinus pinaster* and short **rotation** woody crops were established (sections 2.3.4 and 2.4 respectively).

The second round of JVAP support (2001-2005: “ALRTIG phase II”) has seen the consolidation of data on the key species, update of tree breeding strategies, establishment of hardwood gain trials and **clonal seed orchards** and development of a strategy to create a low rainfall breed of *P. radiata*. Some preliminary data has already been forthcoming from the first phase of ALRTIG: they are summarised here. Management of the growing IP portfolio has also been addressed.

A third round of JVAP supported ALRTIG activity commenced in 2005-2006. This phase will involve the assembly of metadata resulting from measurements of plantings established in the first and second phases. Existing indications are that the ALRTIG trials, all of which use sophisticated statistical designs and many of which are replicated across a range of sites in southern Australia, will yield data that will be of use to a wide range of disciplines. Scientists in the fields of yield modelling, population genetics and hydrology have already expressed interest in accessing the data. ALRTIG will therefore actively seek the involvement of postgraduate students to take full advantage of this valuable resource.

## 2. Overview of programs

### 2.1. How ALRTIG is organised

ALRTIG depends on partnerships at various levels to carry out its work. The ‘core’ Partners are from Commonwealth and State Government organisations (Table 1). These organisations are represented by voting members on ALRTIG’s Steering Committee. In addition, there are some associated research partners, as well as industrial forestry companies and landowners on whose land many of the trials and seed orchards are established. The high level of collaboration between the various stakeholders in ALRTIG has been a key factor in its success. A large number of collaborators have been involved (see Appendix 1).

ALRTIG’s work is divided into three main areas: hardwoods, softwoods and short rotation woody crops. Each area is serviced by a Technical Committee, comprised of scientists from each organisation with expertise in the relevant discipline. Each group focuses on a small range of ‘key species’, and is responsible for formulating and revising the tree improvement strategy, and implementing the tree improvement plan for each. The numerous scientific and technical tasks that go towards designing and implementing the three areas have involved a large number of staff from the Partner organisations. A few of the major contributors are named in Appendix I.

The Technical and Steering Committees have been served by a full-time National Coordinator. The role of the Coordinator has been to carry out secretariat functions, plan and oversee aspects of trial establishment, edit scientific publications, represent ALRTIG in public and oversee extension activities, create and maintain the website and manage intellectual property and commercial aspects. The Coordinator has also been a central point of contact for the Partners, and is responsible for budgets and delivery of milestone reporting to JVAP.

Sections 2.2, 2.3 and 2.4 describe the activities and achievements that have been made in each area since 1999.

---

<sup>1</sup> Note that words defined in the text by bold typeface can be found in the glossary.

Table 1. ALRTIG partners

| Organisation                                                                             | State             | Nature of Involvement                                    |
|------------------------------------------------------------------------------------------|-------------------|----------------------------------------------------------|
| <i>Core partners</i>                                                                     |                   |                                                          |
| CSIRO Ensis <sup>1</sup>                                                                 | Commonwealth      | Coordination and implementation of program               |
| Forests NSW <sup>2</sup>                                                                 | New South Wales   | Implementation of program                                |
| ForestrySA                                                                               | South Australia   | Implementation of program                                |
| Department of Primary Industries (DPI) and Sustainability & Environment DSE <sup>3</sup> | Victoria          | Implementation of program                                |
| Forest Products Commission (FPC) <sup>4</sup>                                            | Western Australia | Implementation of program                                |
| Joint Venture Agroforestry Program (JVAP)                                                | Commonwealth      | Funding body and program steering                        |
| <i>Other research partners</i>                                                           |                   |                                                          |
| Private Forests Tasmania                                                                 | Tasmania          | <i>P. pinaster</i> yield trial partner                   |
| Conservation and Land Management (CALM) <sup>4</sup>                                     | Western Australia | Led short-rotation project                               |
| The Australian National University                                                       | Commonwealth      | Involved in short-rotation project                       |
| Primary Industries and Resources (PIRSA)                                                 | South Australia   | Involved in hardwoods program and inauguration of ALRTIG |
| <i>Industrial partners</i>                                                               |                   |                                                          |
| G.R. Davis Pty Ltd                                                                       | NSW               | Short-rotation trial partner                             |
| Hancock Victorian Plantations Pty Ltd                                                    | Victoria          | Brutian pine collaborator                                |
| Integrated Tree Cropping Ltd                                                             | Western Australia | Yield trial partner                                      |
| Treecorp Ltd                                                                             | Victoria          | Yield trial partner                                      |
| Woollybutt Pty Ltd                                                                       | Victoria          | Yield trial partner                                      |

1. CSIRO ensis was formerly known as CSIRO Division of Forestry and Forest Products
2. Forests New South Wales was formerly known as State Forests of New South Wales
3. The Victorian Department of Natural Resources and Environment split into the department of Primary Industries and the Department of Sustainability and Environment in 2002. ALRTIG works with both.
4. The Forest Products Commission was split as a separate entity from Western Australia's Department of Conservation and Land Management. ALRTIG now works with both organisations

## 2.2. Hardwoods

### 2.2.1. Key hardwood species and background resources

Five key eucalypt species were selected in 1999 from a list of 60 candidates (Bush et al. 2001a). The species were selected because they were known to have good growth and survival, as well as the potential to produce sawn timber. Other important considerations were adequate knowledge of the species' biology and existing genetic resources, such as **provenance** trials, to make solid headway on breeding programs. Table 2 shows the species that were selected, and the pre-existing planted genetic resources for each. It can be seen that for each species there existed a range of trials, spread temporally and geographically, from which information had already been collected. These trials were used for three purposes:

- (1) to identify the provenances that performed well or poorly;
- (2) as a source of seed, pollen and cuttings material for breeding, and;
- (3) as sources for short-term production of somewhat improved seed for deployment.

Provenance trials of individual species are usually conducted only after species screening or species/provenance trials (i.e. trials containing a small number of provenances for each of a number of species) have identified them as being promising. This earlier round of trials was

carried out over an extended period from 1880-1998 for these species. For *E. cladocalyx*, large block plantings had also been tried near Wirrabara in South Australia and at various places such as Wail and Majorca in western Victoria. These plantings were also a valuable resource of biological material.

*Table 2. Key hardwood species and summary of trials prior to 2001*

| Common name   | Species                  | Trials                      | Established | Locations        |
|---------------|--------------------------|-----------------------------|-------------|------------------|
| Red ironbark  | <i>E. tricarpa</i>       | 6 provenance trials         | 1993-2000   | WA, VIC          |
| River red gum | <i>E. camaldulensis</i>  | 6 provenance trials         | 1978-1998   | WA, VIC, SA,     |
|               |                          | 3 clone trials              | 1988-1993   | NSW              |
|               |                          | 4 progeny trials            | 1995-1998   | VIC NSW          |
| Spotted gum   | <i>Corymbia maculata</i> | 9 species/provenance trials | 1983-1997   | WA, VIC, SA, NSW |
|               |                          | 3 progeny trials            | 1995-1996   | NSW, VIC         |
| Swamp yate    | <i>E. occidentalis</i>   | 7 provenance trials         | 1993-1998   | WA, VIC, SA,     |
|               |                          | 4 progeny trials            |             | NSW              |
|               |                          | 2 seed production areas     |             | SA               |
| Sugar gum     | <i>E. cladocalyx</i>     | 1 progeny trial             | 1998        | VIC              |
|               |                          | 4 provenance trials         | 1992-1996   | VIC, SA          |
|               |                          | 1 seed production area      | 1992        | SA               |

In 1999, when the strategy of key species selection was first developed, it was thought that new information might effect changes on the key species list in future. Information about the existing key species might cause them to be dropped, while new prospects might come to the fore as a result of novel findings. Thus far, the original key species selections have remained amongst the 'best bets' list in low rainfall forestry research, and there are no reasons to drop any of them to-date.

In 2001, it was decided that two new species would be added to the ALRTIG key species list. These are *Corymbia citriodora* subsp. *variegata* (spotted gum) and *Eucalyptus sideroxylon* (red ironbark). These species are very closely related to *Corymbia maculata* and *Eucalyptus tricarpa* respectively.

### 2.2.2. Collation of data from pre-existing provenance trials

ALRTIG's partners had established an extensive range of trials of the key species prior to the cooperative's formation. These had been established on a wide range of sites throughout the southern States, using a variety of different seed sources. By examining the available data, it was possible for the Hardwoods Technical Committee to make some very useful findings about provenances of certain key species that would be suitable for commercial environmental forestry. Very little information had hitherto been commonly available for *E. cladocalyx* and *E. occidentalis*. Box 1 shows a selection of the data that was used to make decisions about *E. cladocalyx*.

## Box 1. Provenance information about *E. cladocalyx*

*This information is sourced from Bulman et al. (2000) and Harris (2000)*

### *Provenance trials*

Sugar gum has been a popular farm forestry species in South Australia and western Victoria since the 1880s. It is often grown as a windbreak, several rows wide, on the edges of paddocks. It coppices well and farmers have traditionally cut the timber for use as poles and firewood, and let the windbreak regenerate from the cut stumps. The natural range of the species is entirely within South Australia, and there are three main populations: the southern Flinders Ranges, Eyre Peninsula and Kangaroo Island (see also Box 2). ALRTIG examined trial data from two of its partners, ForestrySA and DSE in 1999 and 2000 (Harris 2000 and Bulman et al. 2000). The data included height, diameter and form measurements from trials established across a range of sites.

### *Results*

The data revealed the following things:

1. Of the natural provenances tested, those from Kangaroo Island were slightly more vigorous than those from the southern Flinders ranges (e.g. Wirrabara). However these two populations were significantly more vigorous than those from the Eyre Peninsula (e.g. Wanilla).
  2. The form (stem straightness and branching) of the southern Flinders material is superior to that of the Kangaroo Island material.
  3. The Eyre Peninsula material does not have acceptable form for sawlog production.
- These generalisations held true across a wide range of sites of varying productivity
4. In two Victorian trials, a local **landrace** seed source was included. This was markedly more vigorous than any of the material taken from the natural populations.

Figure B1.1. compares the heights of several seed sources growing in Victorian and South Australian trials (not all provenances were tested at all the sites). The data are collected from a range of trials on sites of varying productivity, however, the trials' ages varied between 3 and 6 years, so this graph is not useful for comparing site productivity. With a few exceptions, the provenances are ranked from tallest to shortest (left to right) and this ranking applies across all of the sites. Wanilla, for example, is the shortest provenance everywhere that it has been tried. Flinders Chase is the tallest provenance at all sites, except at the only two Victorian sites (Shelford and Werneth) where the local landrace material, Lismore, was trialled. A similar trend was shown for DBH, with Flinders Chase consistently the largest, Wirrabara and Wilmington slightly smaller and Wanilla consistently the smallest of the natural provenances, with Lismore superior in the two Victorian trials.

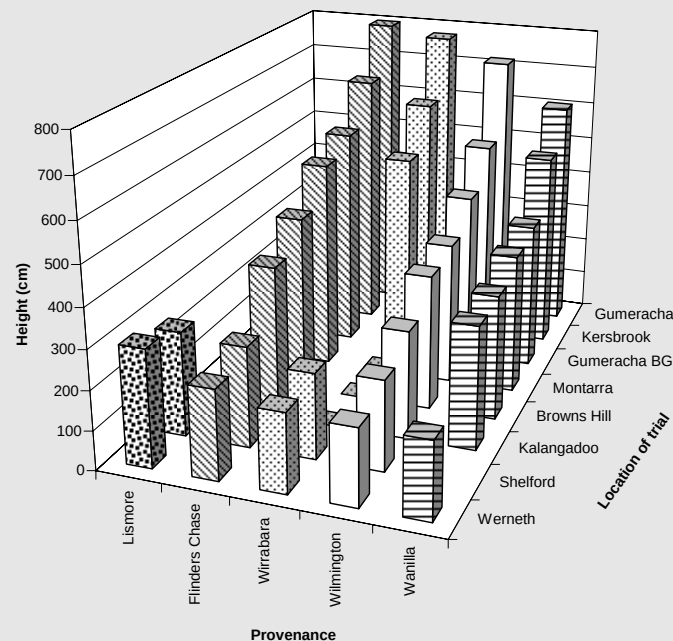


Figure B1.1. Height data for 5 seed sources of *E. cladocalyx* in 8 trials of varying ages in VIC and SA

#### How the information was used

The information from the partner's trials has proven to be extremely valuable. In early 2000, advice was posted on ALRTIG's website that growers and nurseries should try to source stock raised from southern Flinders Range provenances such as Wirrabara, as this was the best all-round provenance because of its good vigour and best form. The site also warned against the use of Eyre Peninsula provenances for timber production because of their low vigour and poor form.

The information was also used in the construction of the breeding population for the species. OP<sup>2</sup> family seedlots were selected only from the Kangaroo Island and southern Flinders Range provenances, since we knew that the Eyre Peninsula material would likely make a deleterious contribution.

The findings in Victoria that the landrace material had been the top performer caused us to make several selections for the breeding population from landrace stands. We also decided to develop seed stands at Wail (a planted stand near Horsham, Victoria). A molecular genetic study was initiated to check the provenance origins of the western Victorian landrace material, which were believed to have been derived from the southern Flinders Ranges (see section 3.6).

### 2.2.3. Overview and update of hardwood breeding strategies

The Hardwoods Technical Committee held an inaugural meeting at Manjimup, Western Australia in October 1999. Objectives were to devise a general approach for each key species, compare and assemble existing data and genetic resources, and to make plans to ensure sufficient seed supply to meet both short and long-term demand. The ALRTIG Compendium of Hardwood Breeding Strategies which includes four discrete breeding strategies for each of the key species was published in 2001 (Harwood et al. 2001).

The main, common elements of the individual tree improvement strategies include the following:

- Conversion of existing planted stands (of suitable, proven seed source) to seed stands by selective thinning for short-term production of somewhat-improved seed.
- Conversion of existing provenance trials to **seed production areas** (SPAs) by selective thinning for short-term production of improved seed.

<sup>2</sup> Note list of abbreviations on page vi

- Establishment of a series of progeny trials (PTs), some of which will be progressively thinned to **seedling seed orchards** (SSOs), for production of high quality seed. Other progeny trials will be retained longer for collection of progeny data and accurate selection of superior trees.
- Establishment of clonal seed orchards (CSOs). Selections will be made from elite trees in existing trials and supplemented by selections from the progeny trials.
- Controlled pollination (CP) between selected trees to develop outstanding families
- Testing of clones for the development of **clonal forestry**

The hardwood key species share a common approach to genetic improvement termed ‘recurrent selection for general combining ability’. ‘Recurrent’ refers to the fact that the strategy will operate over a number of generations, with selection from earlier generations and **infusion** of new genetic material occurring cyclically. The selections that pass from one generation to the next will be those with the highest general combining ability (GCA). When mated with a range of individuals, trees with high GCA produce progeny that perform well, making them suitable for inclusion in open pollinated seed orchards.

The following breeding objective is also common to the hardwood key species:

*To develop breeds that will maximise the net present value (stumpage value – growing costs) of logs produced on rotations of 20-40 years, on a per-hectare basis. Focus will be on production of a low cost, high value final crop, which can be used for solid wood applications including sawlogs, veneer and engineered wood products.*

Taking into account the above breeding objective and the likely wood products, the core selection **traits** for the key hardwood species are:

|                  |                                                                              |
|------------------|------------------------------------------------------------------------------|
| <b>Survival</b>  |                                                                              |
| <b>Growth</b>    | (height and DBH, which can be combined into an index related to stem volume) |
| <b>Stem form</b> | (apical dominance and stem straightness)                                     |
| <b>Branching</b> | (light branching and tendency for self-pruning)                              |

### **The breeding populations**

The breeding populations for each species were drawn from the species’ *base populations* which consist of two main sources: wild open-pollinated (OP) individuals (from best-bet provenances where data existed) and; phenotypically selected OP candidate **plus trees** from planted stands including provenance trials and seed production areas. The breeding populations have been established in a series of *progeny trials* established from seedlings, some of which will be thinned later to create *seedling seed orchards* (termed PT-SSOs). The performance of the progeny trials will be monitored over time. The best-performing trees will be selected and seed collected to contribute to the next generation of the breeding population. These seedlots will be supplemented by infusion of new material from the base population that are not closely related to those that are selected. The infusion is done to provide additional promising selections and to guard against inbreeding that would eventually occur if recurrent selection was from the original breeding population alone.

### **Update of hardwood breeding strategies**

An update of the original hardwood breeding strategies was undertaken in 2003 (Harwood et al. 2005). The update incorporated new biological information that had become available during the first few years of ALRTIG (see for example Box 3 on hardwood vegetative propagation). A further example is the change in the taxonomy of spotted gums. Isozyme studies and

morphological evidence led to the relegation of *Corymbia variegata* to sub-specific status as *C. citriodora* subsp. *variegata*. This evidence vindicated the ALRTIG strategy of maintaining *C. maculata* and *C. citriodora* subsp. *variegata* in separate breeding populations. While none of the strategies changed radically, it was possible to make significant refinements.

#### 2.2.4. Seed production

One of ALRTIG's main activities has been to ensure that there will be sufficient seed production capacity to meet demand for low rainfall farm forestry in future. At the project's inception in 1999, there was only limited demand for the ALRTIG hardwood species. A survey in 2001 of some of southern Australia's larger nurseries revealed that demand for two species, spotted gum and sugar gum had started to rise (see section 4.1).

The program has aimed to meet both immediate and short-medium term demand for improved seed as well as provide substantial genetic gain in the longer term. To achieve this ALRTIG has:

- 1) Developed existing and new **seed production areas** and seed stands to provide somewhat-improved seed in the short-medium term (from 1999 until such time as better facilities can meet the demand)
- 2) Developed facilities that will provide more substantial genetic improvement such as seedling seed and clonal seed orchards linked to structured breeding programs.

The main approach to hardwood breeding was to establish dual-purpose progeny trial/seedling seed orchards (PT-SSOs). A number of these were established for each species. Table 3 summarises the trials that were established. Those that are destined to be PT-SSOs share a common design, based on four replicates of five-tree row plots. It is envisaged that the progeny trials will be converted for seed production purpose by two thinnings, each of which will remove the two lowest ranked trees thereby leaving a single tree. Also, families ranked in the lowest 20% will be completely removed.

The Western Australian trials will be retained as PTs for collection of data, and won't be thinned to SSOs unless demand requires this. These trials were established as five replicates of four-tree row plots. It is also possible that some eastern State trials will also be retained unthinned for data collection if they are not required for seed production.

*Table 3. PTs and PT-SSOs by location and year of establishment*

| Species                 | No. orchards/State location | Total area (ha) | PT-SSO area (ha - net of PTs) | Establishment year |
|-------------------------|-----------------------------|-----------------|-------------------------------|--------------------|
| <i>C. maculata</i>      | 4 VIC                       | 7.5             | 7.5                           | 2001               |
| <i>E. cladocalyx</i>    | 2 NSW, 2 SA, 3 VIC, 2 WA    | 10.9            | 7.5                           | 2001               |
| <i>E. camaldulensis</i> | 1 WA                        | 4               | -                             | 2001               |
| <i>E. sideroxylon</i>   | 2 NSW, 1 VIC                | 3               | 3                             | 2002               |
| <i>E. occidentalis</i>  | 1 SA, 4 VIC, 2 WA, 1 NSW    | 12.6            | 9                             | 2001               |
| <i>E. tricarpa</i>      | 2 VIC, 1 NSW, 1WA           | 4               | 3                             | 2000               |

The first measurements from the progeny trials established in 2000 and 2001 are now available. Already the data is contributing valuable knowledge. Box 2 shows a summary of a measurement of a ForestrySA progeny trial/seedling seed orchard carried out in December 2003. A new project, approved by JVAP in 2004, will extend the ALRTIG work. Early (three or four-year) measurement data will be collected from the trials, and a report on the metadata will be compiled. These data will be highly valuable to those interested in yield, growth modelling and genetics of

low rainfall species. It is envisaged that some of the more detailed analyses will be undertaken by one or more postgraduate research projects.

## Box 2. Early results from *E. cladocalyx* progeny trial-seedling seed orchard

The PT-SSO is situated approximately 10 km west of Bordertown, South Australia. It was established in July 2001 by ForestrySA, and a first assessment was carried out 28 months later. At this time, height diameter and form assessments (forking score 1-6) were made. Forking was scored as 1 (a fork at ground level); 2, a fork in the first quarter of the stem; 3 a fork in the second quarter through to 6; no forks. Provenance means from the height and forking measures are shown in Figures B2.1 and B2.2. Height and diameter were closely related, so diameter data are not given.

Figure B2.1. 28-month form data from Bordertown *E. cladocalyx* progeny trial

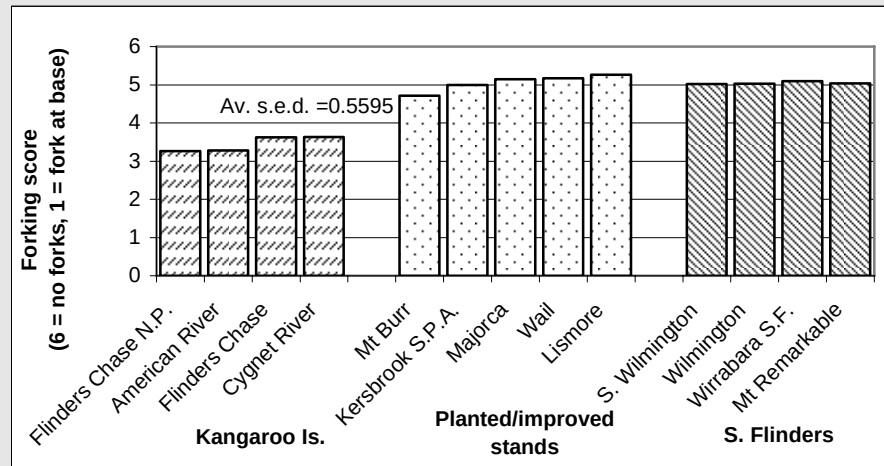
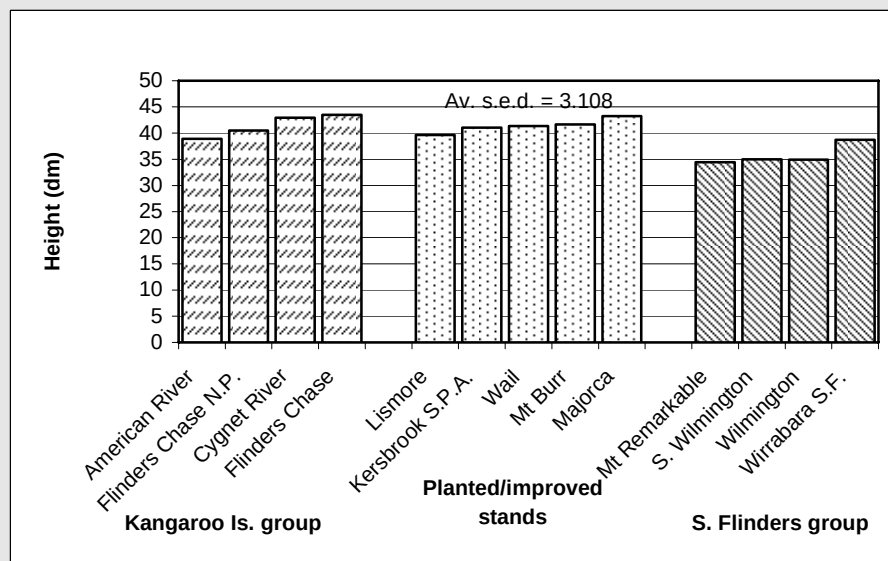


Figure B2.2. 28-month height data from Bordertown *E. cladocalyx* progeny trial



The results indicate significant genetic differences at a number of levels. The data have been grouped into provenances and regions of provenance (see 2.2.7) in the Figures B2.1 and B2.2. The southern Flinders provenances have significantly better form (less forking) than those from Kangaroo Island. Conversely, the Kangaroo Island provenances tend to be somewhat more vigorous than those from the southern Flinders. The seed sources (actually landraces originally derived from southern Flinders provenance, except for Kersbrook SPA, which is a mixture of S. Flinders and Kangaroo Island provenances) in the planted/improved group have equalled the Kangaroo Island group for growth and the Flinders group for forking.

This result is very encouraging. It corroborates information derived from Partner's earlier trials (see Box 1) and suggests that ALRTIG's recommendation to use material derived from the identified seed stands and seed production areas remains valid.

### 2.2.5. Clonal seed orchards

A clonal seed orchard (CSO) of *E. occidentalis* was established at Corowa, New South Wales. The CSO was based on the best available candidate plus trees identified in planted stands from which seed was collected for the seedling seed orchards. The CSO is likely to produce seed of higher genetic quality than seedling seed orchards based on OP material, because the selection intensity is higher. It can be managed either to produce open-pollinated or control-pollinated seed.

### 2.2.6. Vegetative propagation

Vegetative propagation of forest trees offers some considerable advantages over normal seedling-based propagation. Species that can be vegetatively propagated may be deployed either as clones or as control-pollinated families, which may be multiplied by cuttings ('family forestry'). In eucalypt clonal forestry, outstanding individuals are felled and basal coppice is used to establish hedges from which rooted cuttings can be mass-propagated. These deployment strategies allow advantage to be taken of non-additive genetic gain. Cutting propagation can also be a useful property in the process of tree breeding: for example the creation of clonal seed orchards from rooted cuttings would obviate the need for **grafting** which is a relatively complex and expensive method.

A plantation that is genetically identical to the parent (or small group of parents) has the advantage of being very uniform in terms of the growth, stem form, branching, and wood properties. Worldwide, adoption of clonal forestry (sometimes called 'varietal' forestry) with eucalypts has increased greatly in recent decades, especially for tropical and subtropical eucalypt species including *E. grandis* and interspecific hybrids involving *E. grandis*, which are easy to propagate from cuttings. However, temperate species such as *E. globulus* and *E. nitens* have generally proved to be more difficult to propagate vegetatively: cuttings of these species do not readily strike roots. The most successful temperate eucalypt species has been *E. camaldulensis* which roots very readily. Hybrid combinations of *E. camaldulensis*, *E. grandis* and *E. globulus* have been tried with some success on moderately dry, saline and waterlogged sites in the southern Murray-Darling Basin and Western Australia (Dale 2002).

ALRTIG undertook studies on propagation of cuttings taken from seedling hedge plants of several eucalypt species during 2000. The results of this work are summarised in Box 3.

This work has subsequently been built on by CSIRO (unpublished data) with investigations centring on the relatively new mini-cutting technique pioneered in South America. In the studies described in Box 3, comparatively large two-node cuttings were taken from quite woody parts of the hedge plants. The new mini-cutting technique uses smaller, less lignified cuttings, and requires careful nutritional management of the seedling hedge plants. Results from these mini-cutting experiments were that *E. occidentalis*, *E. cladocalyx* and *E. tricarpa* rooted very readily. *C. maculata* rooting did not improve greatly relative to that in the macro-cuttings experiment described. There is scope for more work to refine the rooting protocols for these species, but we can already say that clonal forestry based on hedge plants derived from elite seedlings genotypes would be feasible for *E. cladocalyx*, *E. occidentalis* and *E. tricarpa* using mini-cuttings technology.

### Box 3. ALRTIG hardwood propagation study

(This information is drawn from Brammall and Harwood 2001).

**Aim:** To determine the rooting ability of ALRTIG key hardwood species

**Method and materials:** Five seedlings from each of five open-pollinated families per provenance (as detailed in table B1.1) were raised. Plants were pruned to a multi-leader habit. Complete liquid fertilizer was applied weekly. Rooting of two-node stem cuttings was evaluated in two trials when hedge plants were aged 5 and 8 months. An average of 4 cuttings (Trial 1) and 4.7 cuttings (Trial 2) per hedge plant were used.

| Code | Species                 | Provenance     |
|------|-------------------------|----------------|
| cl1  | <i>E. cladocalyx</i>    | Wirrabara      |
| cl2  | <i>E. cladocalyx</i>    | Flinders Chase |
| oc1  | <i>E. occidentalis</i>  | Jerramungup    |
| oc2  | <i>E. occidentalis</i>  | Red Lake       |
| tri  | <i>E. tricarpa</i>      | Tarnagulla     |
| sid  | <i>E. sideroxylon</i>   | Chiltern       |
| mac  | <i>C. maculata</i>      | Mottle Range   |
| gra  | <i>E. grandis</i>       | Coffs Harbour  |
| cam  | <i>E. camaldulensis</i> | Lake Albacutya |

TableB3.1. Plant material used

Cuttings were set in a 2:1 perlite: coco-peat potting mix in BCC 65 cm<sup>3</sup> root trainers. Clonex Red gel (8 gL<sup>-1</sup> IAA) was used to promote rooting. Bed heat was 25°C, air temperature 20°C and light intensity reduced by 50% shade cloth. Misting, to prevent moisture stress, was controlled by timer to minimise leaf wetting.

After 6-8 weeks, cuttings were assessed for presence/absence of roots (Trials 1 and 2), and for presence of new shoots and number of roots produced (Trial 2 only).

#### Results:

Means from analysis of variance are summarised in Figure B3.1.

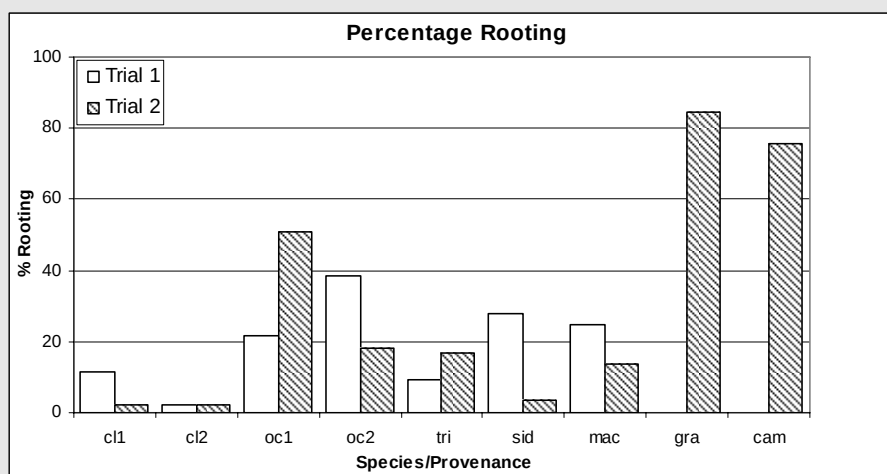


Figure B3.1. Mean percentage rooting by species for experiments 1 and 2.

#### Conclusion

The techniques used gave high (>75%) rooting of the easy-to-root control species *E. grandis* and *E. camaldulensis* in Trial 2, and surprisingly high rooting of the difficult-to-root species *C. maculata* (19% across Trials 1 and 2). *E. occidentalis* was the best of the other species tested, with an overall percentage rooting of 31%, and percentage new shoots of 65%, achieved across Trials 1 and 2. The root systems of this species were judged healthy and vigorous with an average of 3.1 roots per cutting.

In contrast, the low percentage of *E. cladocalyx* cuttings that rooted averaged only 1.1 roots per cutting. However, most of the cuttings of *E. cladocalyx*, *E. tricarpa* and *E. sideroxylon* which failed to root did produce basal stem callus, suggesting adjustment of techniques might improve rooting of these species.

### 2.2.7. Molecular genetics studies on hardwood species

Molecular genetic techniques have proven extremely useful for informing ALRTIG's hardwood tree improvement programs. Taxonomic studies using molecular techniques have provided updated information on sugar gum and spotted gum, and similar techniques have been employed to test some assumptions about the design strategies of ALRTIG's seed production facilities.

#### *Taxonomic information*

An isozyme survey of natural and cultivated populations of *E. cladocalyx* (McDonald *et al.* 2003) confirmed that there is clear genetic divergence between the three main regions of natural occurrence (southern Flinders Ranges, Kangaroo Island and Eyre Peninsula – see also Box 2). Cultivated populations from western Victoria were genetically similar to the superior Wirrabara natural provenance from the southern Flinders Ranges, supporting historical records that indicate Wirrabara is the origin of the western Victorian populations. The two Kangaroo Island populations sampled contained less than half the allelic diversity of the Wirrabara provenance. Multi-locus estimates of outcrossing rates in four natural populations averaged 0.57, and single-locus estimates averaged 0.52, indicating that in natural provenances about 40% of viable seeds produced are the result of self-fertilization, with additional neighbourhood inbreeding. This must be taken into account when estimating genetic parameters from open-pollinated progeny trials. Assuming that inbreeding depression of growth has a significant impact in *E. cladocalyx*, as it does in other eucalypts (Eldridge *et al.* 1993), achieving higher rates of outcrossing in seed orchards should improve the vigour of orchard-derived planting stock seed (see Box 4).

There has been a change in the taxonomy of spotted gums. Based on isozyme studies (McDonald *et al.* 2000) and morphological evidence, *Corymbia variegata* was relegated to sub-specific status as *C. citriodora* subsp. *variegata* by McDonald and Bean (2000). The isozyme evidence showed that *C. maculata* and *C. citriodora* subsp. *variegata* are separate species and should therefore be maintained in separate breeding populations, as has been done by ALRTIG.

#### *Seed quality*

ALRTIG has placed a major emphasis on producing genetically improved hardwood seed by methods that rely on open pollinated mating: the seedling seed orchards, seed stands and seed production areas all fall into this category. One serious limitation to relying on open pollination in eucalypts is that there can be a significant proportion of inbreeding. The two forms of inbreeding that commonly occur in natural populations are 'selfed' or self-pollinated (an individual mates with itself, since individual trees have both male and female reproductive structures) and neighbourhood inbreeding. Neighbourhood inbreeding occurs when closely related individuals mate. Insects, which are believed to be the primary pollen vectors for the ALRTIG key species, do not tend to travel large distances between trees, and adjacent trees in natural stands are usually closely related through common descent. In seed orchards, tree breeders aim to minimise neighbourhood inbreeding through careful spatial design that ensures that the few closely related individuals are never clustered together.

However, despite the use of carefully executed designs in seedling seed orchards, problems can still occur. One potentially serious problem is that levels of selfing can be high. This can occur when seed is collected following patchy flowering, when only a low percentage of trees in the orchard flower. Patchy flowering is common in the early life of a seed orchard when not all trees have reached reproductive maturity, or it may be the result of an unfavourable season during flower crop development. Some eucalypt species have alternating years of light and heavy flowering on a biennial or some other time scale, regardless of stand age (Eldridge *et al.* 1993). Another cause of selfing may be that some genotypes included in the orchard flower out of synchrony with the other trees, making them reproductively isolated from the rest of the orchard.

High levels of inbreeding can also occur in seed production areas that have been created by selectively thinning provenance trials. Inadequate pollen movement between trees, because suitable pollen vectors such as bees are absent in sufficient numbers, would also contribute to high levels of selfing.

ALRTIG decided to investigate the outcrossing levels in two of its interim seed facilities (a **seed production area** and a **seed stand**) using molecular genetic techniques. The results of the studies are described in Box 4.

#### **Box 4. Outcrossing rates in two low rainfall species seed facilities**

*Results presented here are from McDonald (2004) and Byrne (2004)*

**Aim:** To investigate the outcrossing rates in two facilities designated for interim production of genetically improved seed of ALRTIG key species.

##### **Sites**

###### *Swamp yate*

Bundaleer *E. occidentalis* Seed Production Areas (SPAs). This planting was purpose-created as a seed production area by the South Australian State Government in 1992, and designated by ALRTIG as an interim best-bet seed source. It is based on single tree plots of open pollinated bulk provenance seedlots from ten *E. occidentalis* provenances. Following measurement, the SPAs were selectively thinned in 1997 and at that time stand **stocking** was reduced from 1600 to 360 sph.

###### *Spotted gums*

Deniliquin spotted gum seed orchard. This seed orchard was established in 1995 by CSIRO and included four replicates of five-tree plots of 100 families of three spotted gum species, *Corymbia maculata*, *C. citriodora* subsp. *variegata* and *C. henryi*. By 2003, the orchard had been thinned to 400 sph, and the majority of five tree plots were thinned to single tree plots. Thus, most *C. maculata* trees sampled had unrelated neighbours: either unrelated *C. maculata* individuals, or individuals of the other two species.

##### **Molecular genetic methods**

The swamp yate multi-locus outcrossing estimate (Byrne 2004) was carried out using microsatellite markers (SSRs). The spotted gum multi and single-locus outcrossing estimate (McDonald 2004) was done using allozyme marker techniques. The techniques, while different, are both commonly used to determine levels of outcrossing in population genetic studies. Both studies provided statistical estimates of the  $t_m$  parameter (an estimate of multi-locus outcrossing rate). In the *E. occidentalis* study, a direct measure from the raw data was also derived. It is possible that the SSRs, which have greater variation than do allozymes and are therefore more powerful for detecting outcross events, may have given a slightly higher estimate of  $t_m$  than the allozymes. However, the  $t_m$  estimates from the studies can be considered to be broadly comparable for the purposes of determining whether the seed being produced from the facilities is acceptably outcrossed.

**Table B4.1. Estimates of outcrossing rate in 10 families of *Eucalyptus occidentalis***

| Seedlot No.                   | Provenance    | Progeny (N) | Stat $t_m$ <sup>1</sup> | Direct $t_m$ <sup>2</sup> |
|-------------------------------|---------------|-------------|-------------------------|---------------------------|
| 15406                         | Pallerup Rock | 18          | 0.69                    | 0.72                      |
| 13647                         | Grass Patch   | 18          | 0.8                     | 0.78                      |
| 15406                         | Pallerup Rock | 18          | 1                       | 0.89                      |
| 15406                         | Pallerup Rock | 18          | 0.86                    | 0.72                      |
| 13642                         | Ravensthorpe  | 18          | 1                       | 1                         |
| 13633                         | Katanning     | 18          | 1                       | 1                         |
| 13635                         | Rocky Gully   | 18          | 0.95                    | 0.94                      |
| 13640                         | Bremer Bay    | 18          | 0.9                     | 0.89                      |
| 13642                         | Grass Patch   | 18          | 0.96                    | 0.94                      |
| 13642                         | Grass Patch   | 18          | 1                       | 1                         |
| <b>Mean <math>t_m</math></b>  |               | <b>180</b>  | <b>0.92</b>             | <b>0.89</b>               |
| <b>Range <math>t_m</math></b> |               | <b>180</b>  | <b>0.69-1.00</b>        | <b>0.72-1.00</b>          |

1. Stat  $t_m$  = statistical estimate of multi-locus outcrossing rate using MLTR
2. direct  $t_m$  = direct estimate of multi-locus outcrossing rate

**Table B4.2. Estimates of outcrossing rate in 10 families of *Corymbia maculata***

| Seedlot No.                   | Provenance | Progeny (N) | $t_m$ (s.e.)       |
|-------------------------------|------------|-------------|--------------------|
| 19308                         | Kioloa     | 40          | 0.99 (0.03)        |
| 13568                         | Wyong      | 40          | 0.50 (0.10)        |
| 19308                         | Kioloa     | 40          | 0.79 (0.13)        |
| 19102                         | Bodalla    | 40          | 0.70 (0.14)        |
| 19102                         | Bodalla    | 40          | 0.99 (0.03)        |
| 19422                         | Bodalla    | 40          | 0.89 (0.12)        |
| 19102                         | Bodalla    | 40          | 1.00 (0.01)        |
| 19422                         | Bodalla    | 40          | 0.53 (0.11)        |
| 19421                         | Mumbula    | 40          | 0.83 (0.11)        |
| 19422                         | Bodalla    | 40          | 1.00 (0.00)        |
| <b>Mean <math>t_m</math></b>  |            | <b>400</b>  | <b>0.76 (0.10)</b> |
| <b>Mean <math>t_s</math></b>  |            | <b>400</b>  | <b>0.70 (0.09)</b> |
| <b><math>t_m - t_s</math></b> |            | <b>400</b>  | <b>0.05 (0.02)</b> |
| <b>Range <math>t_m</math></b> |            | <b>400</b>  | <b>0.50-1.00</b>   |

### Implications

The higher outcrossing in the yate study ( $t_m = 0.89$ ) showed that gene flow within the SPA was higher than usual for eucalypts from natural stands. Moreover, only three trees had outcrossing rates lower than 0.9. An analysis of the distribution of a rare allele in the orchard also indicated that geneflow was widespread throughout, and not only localised to neighbouring trees. The result might partly reflect good SPA design: despite heavy thinning the single tree plots resulted in good spatial dispersal of unrelated trees with good tree-to-tree pathways for insect pollinators. It may also reflect that *E. occidentalis* in provenance trials has been observed to flower heavily and synchronously.

The spotted gum study indicated a mean multi-locus outcrossing rate of 0.76, which is typical for eucalypts, and acceptable for a seed orchard. However, there was significant variation within the stand: five trees had  $t \geq 0.9$ , while two had  $t$  values of 0.5 and 0.53 and there was evidence that inbreeding was due mainly to selfing rather than neighbourhood inbreeding based on the single versus multi-locus estimates. Observations of flowering times at the orchard indicate that flowering of *C. maculata* occurs over several months in the autumn, with some overlap to *C. henryi* but very little overlap to *C. citriodora* subsp. *variegata*. It is possible that outcrossing rates may be increased in mono-specific spotted gum orchards, such as those newly established by ALRTIG, through an increase in the proportion of neighbouring trees that are compatible and flowering synchronously, relative to the multi-species seed orchard studied here.

## 2.2.8. Future

The ALRTIG hardwoods program has made excellent progress towards securing future availability of genetically improved germplasm of the key eucalypt species. Future activities will include the following:

- Data collection and data analysis to provide further genetic information from the PTs and PT-SSOs
- Development of some of the PT-SSOs into seedling seed orchards by selective thinning
- Development of clonal seed orchards using selections from the PT-SSOs
- Investigation and development of interspecific hybrids involving *E. camaldulensis* and *E. occidentalis*
- Development of clonal trials and pilot clonal forestry programs
- Investigation of genetic variation in wood property traits such as colour, density, durability and traits relating to sawing recovery
- Periodic review of genetic improvement strategies

## 2.3. Softwoods

### 2.3.1. Key softwood species

The ALRTIG Softwoods Technical Committee initially chose, from a short list of 37 conifers, two key species: *P. brutia* (Brutian pine, also known as red pine, Calabrian pine, black pine) and *P. pinaster* (maritime pine also known as cluster pine). *P. pinaster* has been extensively planted and genetically improved in Western Australia for over 50 years (Butcher 2002), while Brutian pine had been tested to a much lesser extent in Western Australia, South Australia, New South Wales and Victoria (Spencer and Boardman 2002). There are currently two improved breeds of *radiata* in Australia, one developed here and one developed in New Zealand, both optimised for higher rainfall (700 mm MAR-plus) sites. In 2001, it was decided that a strategy would also be developed to create a low rainfall breed of *P. radiata* (Matheson et al. 2007).

These three species are each intended to occupy different environmental niches in the low rainfall zone and to provide resource for production of softwood sawntimber. Table 4 compares and contrasts some of the species' basic characteristics.

*Table 4. Characteristics of the three key softwood species*

| Species                                     | Growth rate | Soils                                        | Wood                                                            | Drought resistance                        |
|---------------------------------------------|-------------|----------------------------------------------|-----------------------------------------------------------------|-------------------------------------------|
| <i>P. brutia</i>                            | Low-medium  | Wide range, including alkaline and shallow   | Denser than others; relatively resinous                         | Most resistant pine                       |
| <i>P. pinaster</i><br>(FPC improved breed)  | Medium      | Well-drained, probably prefers light texture | Slightly denser than <i>P. radiata</i> , otherwise very similar | Higher than <i>P. radiata</i>             |
| <i>P. radiata</i><br>(AU/NZ improved breed) | High        | Wide range where depth sufficient            | Industry standard softwood                                      | Moderate. May be possible to improve this |

#### *Brutian pine*

*Pinus brutia* is amongst the most drought resistant of pines, originating from the eastern Mediterranean. It is closely related to *P. eldarica* and *P. halepensis* (Aleppo pine), and the group are often referred to as the *P. brutia-halepensis* complex. The species was selected for genetic improvement because of its extreme hardiness and good form in select provenances. Australian Aleppo pine introductions typically have very poor form, and for this reason they have not been

included in the ALRTIG program. *Pinus brutia* is suited to sites receiving as little as 350 mm MAR. While it grows more slowly than *P. pinaster*, it can tolerate shallow, heavy clay and highly alkaline soils. It complements *P. pinaster*, being suitable for planting at the lower end of the rainfall spectrum, and on shallow soils. Pests and diseases have not been a problem for *P. brutia* in Australia.

### *Maritime pine*

Maritime pine is a hardy conifer of Mediterranean origin. FPC has managed a long-term tree breeding program for this species in Western Australia, where around 40,000 ha have been planted since 1959. They aim to deploy this species extensively in the 400-600 mm rainfall zone, to help control salinity problems on agricultural land (though not on land already salt-affected), and to diversify farm income. It produces a useful sawn timber, which can be processed in sawmills designed for *P. radiata*, and its wood can also be used for pulp. While it has been planted to a limited extent in the eastern States (especially South Australia on low nutrition sites, otherwise suited to *P. radiata*), detailed information on the performance of FPC's improved breeds throughout much of the low rainfall zone is lacking.

### *Radiata pine*

Radiata pine wood forms the raw material for several commercially valuable products and it is the most widely accepted species in the timber trade in southern Australia. It is mainly grown in the high rainfall (i.e. greater than 650 mm MAR) zone, though expansion of the resource in this land base is becoming increasingly restricted due to competing land uses.

Although there are five provenances of *P. radiata*, the Australian and New Zealand breeds are based nearly entirely on Monterey and Año Nuevo provenances respectively. This material has proven to be extremely adaptable to a very wide range of climate types. In Australia, both breeds have been planted on a significant scale for commercial purposes from high rainfall, viz. greater than 1500 mm MAR in Tasmania and Victoria, down to less than 600 mm MAR in parts of Victoria, South Australia and the Australian Capital Territory. Most successful plantations of the species are in the higher rainfall areas.

The natural distribution of *P. radiata* spans a significant range of MAR and climatic variation. The Guadalupe and Cedros Island sites have the lowest MAR of the five provenances and Cambria the next lowest (Table 5) and so these three drier climate provenances may have traits that are expected to contribute towards a breed with greater drought resistance. All provenances are situated within a few kilometres of the coast, and receive supplementary moisture from sea fogs.

**Table 5. Climate data for *P. radiata* provenances**

| Provenance                                                        | MAR<br>(mm) | Pan evaporation<br>(mm per annum) | Temperature (mean max.<br>hottest/coldest month) °C |
|-------------------------------------------------------------------|-------------|-----------------------------------|-----------------------------------------------------|
| Año Nuevo (Santa Cruz)                                            | 756         | 1270                              | 25.1/14.7                                           |
| Monterey (Del Monte)                                              | 450         | 1270                              | 22.2/14.7                                           |
| Cambria (San Luis Obispo, Poly)                                   | 540         | 1400                              | 25.3/16.8                                           |
| Cedros Island (San Fernando, Ensenada<br>200 km N. of Cedros Is.) | 96          | 1888                              | 35.2/20.9                                           |
| Guadalupe Island (marine garrison, S. tip<br>of island.)          | 124         | No data                           | 24/19                                               |

### 2.3.2. Overview of softwood improvement strategies

Separate strategies have been produced for each key species. The *P. brutia* and *P. pinaster* strategies were published together with an ALRTIG program overview (Boardman et al. 2002). The *P. radiata* strategy is outlined in Matheson et al. (2007). A short description of each is given below.

### 2.3.3. *P. brutia* genetic improvement strategy

The improvement objective for *P. brutia* is the same as that of the key hardwood species (see Section 2.2.3): to maximise the value of logs (per hectare per year) produced by plantations in the target planting zone (the southern Australian sheep-wheat belt). It is envisaged that these plantations would produce small logs suited to sawn timber, post and pole manufacture on a rotation length of 20-40 years. In the first generation of breeding, traits to be selected for include superior stem-form, light, flat-angled branching and apparent resistance to disease. In later generations, wood properties, particularly resin content, may be added to the selection criteria.

The *P. brutia* breeding strategy includes the following elements:

- Conversion of selected stands to SPAs by phenotypic selection and thinning as an interim seed source
- Selecting and ranking superior phenotypes from all existing resources in Australia to form a breeding population
- Establishing replicated clonal seed orchards of the phenotypically selected best 39 individuals to form a first stage nucleus breeding population
- Establishing open pollinated progeny tests based on the nucleus selections and the rest of the breeding population
- Augmenting the Australian *ex situ* breeding population with new germplasm from range-wide provenance seed collections in the natural stands.

### Survey of Australian *P. brutia* plantings and plus tree register

One of the first tasks the Softwood Technical Committee tackled in 1999 was an Australia-wide survey of *P. brutia* trials and plantations. The survey's purpose was twofold: firstly, information on the species' genetic diversity (from introductions) was gathered, and secondly, trees for inclusion in the breeding population were identified. A consistent method for scoring candidate plus trees was developed. Each stand was assessed and candidate plus trees were selected (to be evaluated as plus trees by the results of progeny trials). The candidate plus trees and their progeny form the base population. Each tree was assessed for a number of traits, including stem-straightness, branch characters and dominance and catalogued using a specially developed plus tree register sheet (see Appendix 2). A total of 161 candidate plus trees are now placed on the register. The genetic make-up of the trees is summarised in Table 6.

*Table 6. Summary of P. brutia candidate plus tree selections made from the base population including nucleus population (grafted) selections*

| Stand                        | State | Stand type(s)         | Year      | Selections made |                                                                                                                                                       |               |           |
|------------------------------|-------|-----------------------|-----------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|-----------|
|                              |       |                       |           | No. trees       | Provenances                                                                                                                                           | Progeny trial | Nucleus   |
| Back Yamma S.F.              | NSW   | Provenance block      | 1931-32   | 5               | 1 (Cyprus)                                                                                                                                            | 5             | 1         |
| Jerilderie                   | NSW   | Provenance trial      | 1968      | 36              | 9 (1 <i>P. pithyusa</i> , USSR; 3 Greece; 1 Turkey; 1 Cyprus; 1 <i>P. eldarica</i> , Iran; 1 <i>P. pithyusa</i> var. <i>stankewiczii</i> ; 1 Lebanon) | 22            | 10        |
| Wagga                        | NSW   | Provenance trial      | 1969      | 5               | 2 (Cyprus, two seedlots)                                                                                                                              | 4             |           |
| Rennick Forest (HVP)         | VIC   | 2 provenance blocks   | 1971      | 6               | Cyprus                                                                                                                                                | 0*            | 0*        |
| Wail S.F.                    | VIC   | 1 provenance planting | 1969      | 4               | Unknown                                                                                                                                               | 4             | -         |
| Bundaleer F.R.               | SA    | 5 provenance blocks   | 1958-1965 | 28              | 2 (Cyprus, two seedlots)                                                                                                                              | 2             | -         |
| Bundaleer F.R., Bundaleer N. | SA    | Provenance trial      | 1972      | 11              | 9 (Cyprus; 5 Turkey; 2, Greece; 1 Lebanon)                                                                                                            | 5             | -         |
| Wirrabara F.R.               | SA    | 7 provenance blocks   | 1957-1969 | 28              | Cyprus                                                                                                                                                | 7             | 7         |
| Rottneest Island             | WA    | CSO                   | 1969      | 5               | Cyprus                                                                                                                                                | 5             | 3         |
| Yanchep                      | WA    | Provenance blocks     | 1952      | 9 (25)          | Cyprus                                                                                                                                                | 9             | 3         |
| Bussells, Asplins            | WA    | Provenance blocks     | 1969      | 14 (28)         | Cyprus, Turkey, Mediterranean                                                                                                                         | 6             | 8         |
| Mundaring                    | WA    | Family blocks         | 1969      | 10              | Cyprus                                                                                                                                                | 4             | 6         |
| <b>Totals</b>                |       |                       |           | <b>161</b>      |                                                                                                                                                       | <b>70</b>     | <b>43</b> |

\* Selections were not made from Rennick because the stands were only located after the progeny trial and grafting programs had commenced

### Breeding populations

ALRTIG embarked on a nucleus breeding strategy, with seed production capacity based on grafted clonal seed orchards. This strategy entails concentrating on a small clonal nucleus of circa 40 ‘elite’ trees, while the larger main breeding population is maintained as a series of seedling based progeny trials. Selections can be exchanged between the nucleus and main populations as breeding values are obtained. Both open pollinated and control pollinated progeny can be produced from these populations. In the first generation, the ‘elite’ trees are the top selections from the plus tree register. Details of the main and nucleus breeding population plantings are given in Table 7.

*Table 7. Details of the P. brutia main and nucleus breeding populations*

| Location                   | Population type | No. families (main) or clones (nucleus) | Area ha | Year established |
|----------------------------|-----------------|-----------------------------------------|---------|------------------|
| Back Yamma, NSW            | Main, PT        | 70                                      | 1.9     | 2002             |
| Brookton, WA (2 plantings) | Main, PT        | 70                                      | 1.9     | 2002             |
| Bundaleer, SA              | Main, PT        | 70                                      | 2.0     | 2002             |
| Bundaleer, SA              | Nucleus, CSO    | 39                                      | 1.0     | 2002, 2004       |
| Weston, ACT                | Nucleus, CSO    | 39                                      | 1.0     | 2002, 2004       |
| Manjimup, WA               | Nucleus, CSO    | 39                                      | 1.0     | 2002, 2004       |

The progeny trials were established from seedlings raised from cones collected from the candidate plus trees in 2000 and 2001. Only 70 of the 123 trees had cones. The clonal nucleus was grafted from the top 39 trees. The majority of grafting was carried out by FPC, with ForestrySA also doing some. The first grafting attempt in 2001 was partially successful, with most of the elites being captured and established in 2002, though not all clones were present at all orchards. More grafting was done in 2003 to fill up the orchards in all three locations.

The Weston orchard which is located on the western fringe of Canberra miraculously survived the devastating 2003 bushfires, while the forest immediately surrounding it and for a 10 km radius was completely burnt. However it is likely that it will have to be relocated in future, as the surrounding land will almost certainly be re-zoned for residential use.

In future generations, it is likely that infusion of new trees, unrelated to those in the breeding population will be necessary. This will be particularly important if the Cyprus inclusions are in fact closely related. However, this will necessitate importation of new materials into Australia. Box 5 focuses on a collection carried out in 2000 to achieve this end.

### Box 5. Brutian pine range-wide collection

The Softwoods Technical Committee identified a need to widen the genetic base of *P. brutia* in Australia when the strategy was initially published. The majority of *P. brutia* growing in Australia originates from Cyprus (see Table 6), though there are a few others represented in provenance trials. One reason for this may be that trees from Cyprus have performed well in Australia relative to other provenances. It was therefore logical to draw from the various Cyprus provenance and block plantings for the *P. brutia* first generation breeding population. In many cases the exact origin of the Cyprus seed sources is not known: if the seed came from only a few places it is therefore possible that many of the trees growing in Australia may be closely related.

David Spencer, a CSIRO scientist with a long standing interest in the species, arranged to make range-wide collections of *P. halepensis-brutia* complex from the western Mediterranean and eastern Asia. He embarked on this arduous collection trip in August-December 2000. The trip involved visiting stands of the species throughout its natural range and the cooperation of a number of different agencies. He saw the species being used commercially for a wide range of purposes including sawntimber, pole construction, resin production and firewood. Figure B5.1. shows the locations from which David arranged seed collections, and Table B5.1. gives details of the seed collected.

Figure B5.1. Locations of *P. halepensis-brutia* complex seed collections

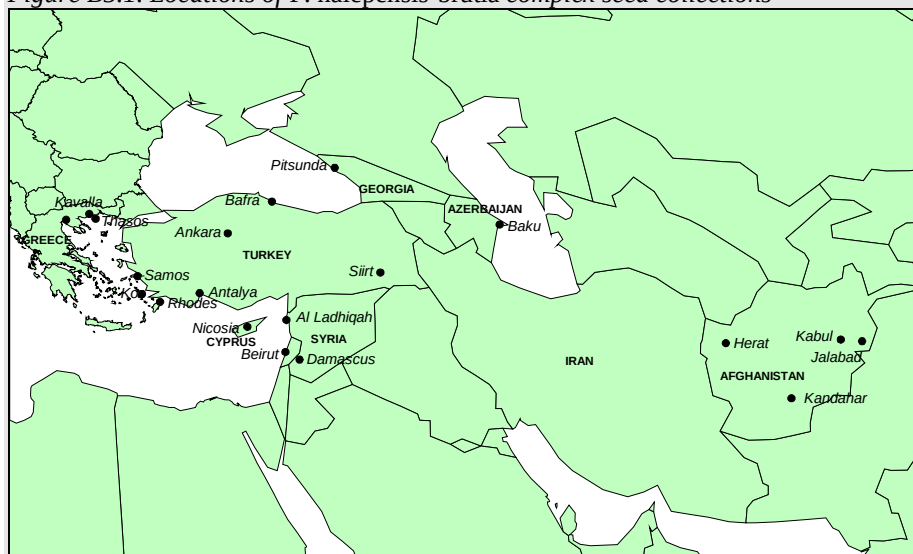


**Table B5.1. Details of seed: *P. halepensis-brutia* complex seed collections**

| Country                   | Provenance                                 | Elevation | Material collected                                                                              | Weight (kg) |
|---------------------------|--------------------------------------------|-----------|-------------------------------------------------------------------------------------------------|-------------|
| <b><i>P. eldarica</i></b> |                                            |           |                                                                                                 |             |
| Afghanistan               | Jalalabad                                  | 569       | 200 cones from trees within 150 km radius of Jalalabad                                          | 2           |
|                           | Kabul                                      | 1797      | 200 cones from trees within 10 km radius of Kabul                                               | 2           |
|                           | Kandahar                                   | 1009      | 200 Cones from within city of Kandahar                                                          | 2           |
|                           | Herat                                      | 920       | 200 cones from region; 3 kg bulk from further afield                                            | 6           |
| Azerbaijan                | Baku                                       |           | 200 cones from trees scattered in city                                                          | 1           |
|                           | Eller Oughi                                | 600       | 200 cones from 10 trees in natural stand                                                        | 3           |
| <b><i>P. pithyusa</i></b> |                                            |           |                                                                                                 |             |
| Abkhazia                  | Pitsunda                                   | 0         | Bulk collection from 3 areas: each 20+ trees                                                    | 3           |
| <b><i>P. brutia</i></b>   |                                            |           |                                                                                                 |             |
| Cyprus                    | Nicosia                                    | 0-900     | 20 cones from 10 trees across 2 altitudes within 4 natural stands. 10 seed orchard lots         | 7           |
| Lebanon                   | Beirut                                     | 300-900   | 20 cones from 10 trees from 5 natural stand. 4 in north near Syrian border, 1 south near Israel | 10          |
| Syria                     | Damascus                                   | 0-800     | 200 cones from 10 trees ex. Five natural stands, including by water's edge                      | 10          |
|                           | Al Ladhiqah                                | 0         |                                                                                                 |             |
| Greece                    | Thessaloniki                               | 0-1100    | 20 cones/tree by 10 trees from each of 7 islands and 1 mainland stand                           | 16          |
|                           | Samos, Thasos, Kavalla, Kos, Crete, Rhodes |           |                                                                                                 |             |
| Turkey                    | Ankara                                     | 0-1000    | 48 seed stands x 2 kg each; 7 seed orchards x 2 kg each; 2 special provenances x 2 kg each      | 112         |
|                           | Bafra                                      |           |                                                                                                 |             |
|                           | Siirt                                      |           |                                                                                                 |             |
|                           | Antalya                                    |           |                                                                                                 |             |
| <b>Total</b>              |                                            |           |                                                                                                 | <b>174</b>  |

#### Outcome

The collection is outstandingly valuable and probably unique in the world. Moreover, it is unlikely that such a collection could be undertaken in the near future, especially from areas such as Afghanistan, where destruction of forests as a result of human conflict and access issues are obvious impediments.

However, the seed has not as yet become available for use and testing. The collections did not arrive in Australia with certification against pitch canker (*Fusarium circinatum*) a species with the potential to devastate *P. radiata*, but as yet unknown in species of the *P. brutia-halepensis* complex. The seed was impounded by the Australian Quarantine Inspection Service and was held in their storage facilities until early 2005. It has now been moved to CSIRO's Australian Tree Seed Centre Quarantine Store, where it remains sealed in drums. This environment should slow viability loss. It is hoped that a solution can be found to clear the seed for trial work in the near future.

#### Interim seed production capacity

Short-term seed production capacity was created by selectively thinning good quality existing plantings to create seed production areas at Bundaleer and Wirrabara. These, together with an existing clonal seed orchard at Rottneest Island and seed stands at Yanchep and Bussells Arboretum in Western Australia will meet immediate requirements for genetically improved seed.

### 2.3.4. *P. pinaster* evaluation strategy

Interest in *P. pinaster* as a tree crop with potential for drier sites that are marginal for *P. radiata* in Western Australia started over 50 years ago. Early introductions led to the development of provenance trials and a breeding program that is now producing the third generation of genetically improved material. A viable softwood industry centred on a resource of *P. pinaster* planted in the Perth region has been established. By the late 1990s the potential of the species for combating land degradation and providing a commercial return in the low to medium rainfall zone of Western Australia was well recognised and the ALRTIG Softwood Technical Committee considered that it may well have potential in other areas of southern Australia.

ALRTIG's strategy for *P. pinaster* was to establish a series of genetic gain trials (also known as yield trials) across a range of ten sites representative of the potential target planting zone in southern Australia. The trials included FPC improved breeds as well as control materials. The trial series will be used to determine important information on genetic-by-environment interaction (often referred to as GxE – see also section 2.4).

Ten genetic gain trials of *P. pinaster* improved seed sources developed by Forest Products Commission WA were trialled in five southern states in 2000 (Butcher 2002). Table 8 shows the details of where each trial was established.

*Table 8. ALRTIG P. pinaster genetic gain trials site information*

| State | Location      | MAR (mm) | Soil type                   | Survival %<br>Oct. 2001 |
|-------|---------------|----------|-----------------------------|-------------------------|
| WA    | Esperance     | 619      | Dunal sand                  | 92                      |
| WA    | Marchagee     | 418      | Deep yellow sand            | 97                      |
| NSW   | Wagga - south | 560      | Acidic loam over brown clay | 53                      |
| NSW   | Wagga - north | 560      | Acidic loam over red clays  | 64                      |
| VIC   | Kamarooka     | 500      | Heavy clay                  | 15                      |
| VIC   | Shelford      | 612      | Silty loam over clay        | 91                      |
| SA    | Telopea Downs | 460      | Dunal sand                  | 72                      |
| SA    | Tintinara     | 460      | Dunal sand                  | 76                      |
| TAS   | Carrick       | 706      | Lateritic podzol            | 95+                     |
| TAS   | Campbell Town | 561      | Siliceous sand              | 15                      |

The types of material included are summarised in Table 9. There are four groups of genetically improved seedlings. An unimproved seed source was also used as a control, resulting in a total of five main 'yield treatment' groups.

*Table 9. ALRTIG P. pinaster genetic gain trials, description of treatments*

| Treatment              | Treatment description                                                                           |
|------------------------|-------------------------------------------------------------------------------------------------|
| 1. Vigour              | Selected for high vigour, average stem and crown form                                           |
| 2. Stem and Crown Form | Selected for high stem and branching traits; average vigour.                                    |
| 3. Wood density        | Progeny of clones with above average wood density; average vigour and form.                     |
| 4. 1.5 generation      | Backward selection, best first generation clones.                                               |
| 5. Unimproved          | Unimproved seed collected in Leiria and from unimproved, unthinned stands in Western Australia. |

A first round of assessments of the trials was carried out in 2004. Some results of the assessment are given in Box 6.

### **Box 6. First results from ALRTIG's ForestrySA and FPC-WA *P. pinaster* yield trials at age 4 years**

On certain sites in Western Australia, poor tree form in *P. pinaster* is associated with changes in leader dominance or physical damage to the leader. This reduces future timber harvest and the value of the species as a commercial tree crop. Apical dominance is being investigated in 28 WA progeny trials on medium rainfall sites covering an area of 51 hectares. These show that there is a level of genetic control of this malformation trait. New CSOs have been recently developed to include malformation control and drought tolerance as well as increased vigour, reduced size of branching and stem straightness.

ALRTIG trials include a range of families from the WA *P. pinaster* breeding population to test on potential planting sites across southern Australia. Trials in WA and SA were assessed in April – May 2004 at age 4 years for tree height and malformation. Due to the complexity of the malformation assessment and the need for a standard assessment across sites, the same Technical Officer (FPC) assisted with the assessment at each trial. Data at this early age has been grouped for 'improved' (treatments 1, 2, 3 and 4) and 'unimproved' (treatment 5) trees for general comparison at each site (Table B6.1). Improved and unimproved groups are similar in control of apical dominance as evidenced by numbers of trees with slight or minor malformations (malform). However, within the improved group consisting of 64 families, there is a large and consistent range in control of apical dominance. Trees in South Australia have shown good control of apical dominance and are similar to the good form of *P. pinaster* grown at Esperance in WA. Gain in height averaged 12% across these 4 trials which will equate to volume gains of about 40% (Butcher and Hopkins, 1993). Although not assessed, branching on the improved trees was noticeably reduced in size in comparison with the unimproved trees. This will be quantified at the 8 year measurement.

**Table B6.1. Results from *P. pinaster* growth and malformation assessment**

|                  | Survival | Trees | Malform | Height<br>(m) | Gain |
|------------------|----------|-------|---------|---------------|------|
| WA Esperance     |          |       |         |               |      |
| Improved         | 93%      | 1433  | 66%     | 4.34          | 15%  |
| Unimproved       | 83%      | 320   | 67%     | 3.76          |      |
| WA Marchagee     |          |       |         |               |      |
| Improved         | 90%      | 1375  | 45%     | 3.38          | 12%  |
| Unimproved       | 72%      | 276   | 45%     | 3.02          |      |
| SA Telopea Downs |          |       |         |               |      |
| Improved         | 73%      | 1119  | 66%     | 3.49          | 10%  |
| Unimproved       | 83%      | 318   | 65%     | 3.18          |      |
| SA Tintinara     |          |       |         |               |      |
| Improved         | 72%      | 353*  | 77%     | 2.74m         | 11%  |
| Unimproved       | 70%      | 90*   | 77%     | 2.47          |      |

\*10 plots only were assessed for malformation at Tintinara.

### **2.3.5. *P. radiata* strategy**

The Softwoods Technical Committee started developing a strategy for creating a breed of low rainfall (LR) radiata pine in 2002. This followed a review of the key species and recognition of the fact that many radiata growers are already pushing into the warm-dry fringe of the current genetically improved breeds' environmental limits. In such areas, seasonal dry spells and occasional protracted droughts are likely to be experienced. The new breed would have broadly similar wood properties and end-uses to the existing breeds, and will be suitable for processing by existing infrastructure.

The strategy (Matheson et al. 2007) comprises a number of components:

- preliminary screening of a selection of material for genetic variation in drought resistance;
- establishment of longer-term field trials on target site types;
- formation of a breeding population using stored seed and controlled-crosses using existing stands and later;
- possible integration of new drought resistance genes through interspecific hybridisation.

An important initial assumption is that material from *radiata*'s drier Mexican provenances (Cedros and Guadalupe) and Cambria, in California, might be a good source of drought resistant material for integrating into the low rainfall breed. The strategy is intended as a starting point for a program that will take significant time and effort to implement.

### ***P. radiata* provenance trials**

Field trials to test different provenances of *P. radiata* were established at three low rainfall sites; one each at Kendenup, Western Australia, Bordertown, South Australia and Wagga Wagga, New South Wales during 2004. The trials will provide the links to provenance performance on dry sites with the older plantings established in higher rainfall sites in the 1980s, and secondly, they can be used to assess drought resistance throughout a rotation on dry site types. The trials were raised from stored seed of native populations which are further segregated into sub-populations (Eldridge 1978, Eldridge 1998). As well, Tallaganda SO (a commonly used benchmark seedlot) and STBA routine material were included. Details of the population /sub-population seedlots included are given in Table 10.

*Table 10. Details of materials collected for the P. radiata progeny trials and controlled pollinations*

| Populations             | Sub-populations included | Pollens collected<br>(controlled pollinations) |
|-------------------------|--------------------------|------------------------------------------------|
| Ano Nuevo               | 3                        | 7                                              |
| Cambria                 | 4                        | 9                                              |
| Cedros                  | -                        | 10                                             |
| Guadalupe               | 1                        | 12                                             |
| Monterey                | 6                        | 7                                              |
| Tallaganda seed Orchard | 1                        | -                                              |
| STBA                    | 1                        | -                                              |
| <b>Total</b>            | <b>16</b>                | <b>45</b>                                      |

The base population for the LR breed of *radiata* will be augmented later with field trials of CP material. Controlled pollinations were carried out in 2003 in South Australia, Western Australia and New South Wales. 45 pollens were collected from trials growing in NSW (Table 10). These trials were raised from the same collection of seed used to raise the field trials (Eldridge 1978). The pollens were applied to mothers at Scrimshaws Seed Orchard and Chokaloo Clone Bank in South Australia as well as to mothers in Western Australia and NSW. Cones from these pollinations were available for collection in 2005.

### 2.3.6. Future

Future activities for the softwoods component of ALRTIG will include the following:

- Further development of the low rainfall radiata strategy, including establishment of the progeny resulting from the CP crossing already carried out;
- Taking steps to maximise the possibility that the *P. brutia* material collected from the natural range will be released from quarantine storage for testing and integration into the Australian breeding population
- Review of the *P. brutia* breeding strategy
- Analysis of the *P. pinaster* GxE trials
- A review of the key species list with attention to new species that might have potential. *P. canariensis* is one species that has been shown to have favourable wood properties, and may be worth considering.

## 2.4. Short rotation woody crops

A possible impediment to the broad-scale establishment of deep-rooted, woody vegetation in the Australian sheep-wheat belt is the long timeframe associated with returns from traditional forestry: forestry that is focussed on the production of large-stemmed trees for solid wood production. An alternative approach is to plant deep-rooted perennials that can be harvested after a much shorter time (less than about five years). Existing essential oil industries based on tea tree and eucalypts are managed on circa three-year coppicing rotations and prove that the concept is viable. It has also been argued (Bartle 2001) that short rotation crops will be the only practical way to achieve the widespread cover of deep rooted vegetation required to control salinity, particularly in the Western Australian wheatbelt.

An extension to the short rotation concept is the integrated processing of short rotation crops to produce fibre, energy, chemicals and possibly other products within a short time-frame. In Western Australia a demonstration integrated pilot plant is in late stage commissioning at Narrogin. This plant will process leaf oils, produce activated carbon and produce energy. The plantation mallee crops that produce the feedstock are also being used to earn carbon credits. The Narrogin plant, which has largely been developed within the timeframe of the ALRTIG project reported on here, will serve as an important model for the industry.

The short rotation woody crop concept is dependent on research being carried out concurrently in a variety of areas including harvesting and processing technology, silvo-agriculture, and product and market development. Matching the right taxa to the available site types is an important component, and this work fitted well with the ALRTIG philosophy in 1999. The trials described in the following sections will provide valuable data that will be complementary to those being produced by projects such as Search and Florasearch (see section 3.6).

### 2.4.1. Short-rotation key species and background resources

The first task of the ALRTIG Short Rotation Woody Crop Technical Committee was to choose a subset of key species on which to focus. Given the relatively low level of background knowledge on prospective short rotation species available at that time, the short list of potential key species was almost immediately narrowed to the mallee eucalypts.

There is a large amount of genetic diversity in the mallees. By 1999, around six mallee taxa had been identified in Western Australia as having strong prospects for short rotation cropping, and around 20 more had been identified as having potential. Indications linked taxon performance

strongly to site, a phenomenon known as genotype-by-environment interaction (GxE). This phenomenon has ramifications for breeding strategies: if GxE is strong, specific taxa are required to achieve best productivity in specific regions. If this is indeed the case, site-species matching may take precedence over genetic improvement.

The six, short-listed eucalypts included *E. angustissima*, *E. kochii* ssp. *kochii*, *E. kochii* ssp. *plenissima* and *E. loxophleba* ssp. *lissophloia*. However it was decided that the two prime candidates for ALRTIG should be *E. horistes*, which had been shown to perform well on drier sites in Western Australia, and *E. polybractea*, which is well-suited to higher rainfall sites in Western Australia and is grown in plantations in New South Wales. The demonstrated environmental plasticity of the latter species was a particularly influential consideration for its inclusion.

## 2.4.2. Overview of short-rotation tree improvement strategy

### Sites

The strategy for the short rotation woody crops was to test the site by genotype interaction of the two key species across a range of sites in southern Australia (Bartle and Brennan 2002). Both species had indicated strong segregation of performance across sites in WA. A ‘wetter’ site, with more ground water availability was chosen there for *E. polybractea* and a ‘drier’ one for *E. horistes*. In South Australia, Victoria and New South Wales, both species were trialled on individual sites to gauge their relative performance. Brief location and site details are given in Table 11. The sites selected are representative of the southern Australian winter rainfall dryland/cereal cropping zone where large areas of land that could feasibly be targeted for oil mallee plantations exist.

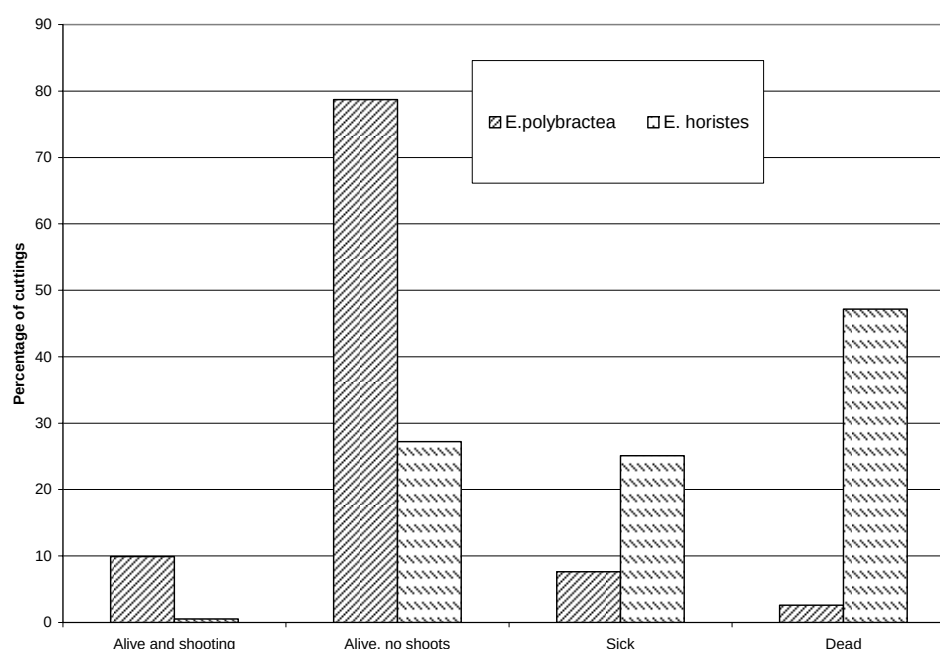
Table 11. Location and site details of short –rotation trial sites

| Site     | Species               | Coordinates<br>(Approximate) | Regional town | Soil type                 | Mean<br>rainfall<br>(mm) | Elevation<br>(m a.s.l.) |
|----------|-----------------------|------------------------------|---------------|---------------------------|--------------------------|-------------------------|
| WA (1)   | <i>E. horistes</i>    | 31°11'S 117°02'E             | Dowerin       | Gravelly sand over clay   | 325                      | 239                     |
| WA (2)   | <i>E. polybractea</i> | 32°43'S 117°31'E             | Wickepin      | Dark loamy clay           | 325                      | 505                     |
| SA       | Both                  | 35°07'S 139°16'E             | Murray Bridge | Sandy clay loam           | 342                      | 55                      |
| Victoria | Both                  | 36°46'S 144°21'E             | Bendigo       | Brown loam                | 551                      | 210                     |
| NSW      | Both                  | 33°55'S 147°12'E             | West Wyalong  | Loamy sand over<br>gravel | 486                      | 300                     |

### Genetic material

The trials originally proposed were to determine the relative performance of a set of clones of the two species. Clonal propagation proved to be more difficult than anticipated. Despite the use of techniques proven for *E. globulus* and *E. camaldulensis*, and various treatments being tried, rooting percentages for both species were unsatisfactory (Barbour 1999). Figure 1 summarises the overall performance of the two species three weeks after the cuttings had been set. The graph shows combined data for one- and two-node cuttings with and without cut leaves.

Figure 1. Performance of mallee cuttings three weeks after setting



It was therefore decided to proceed with the experiments using seedling stock. A combination of open-pollinated wild and genetically improved seedlots were selected (Table 12).

Table 12. Seedlots included in the short rotation GxE trials

| Species/seed source   | Families  | Material type |
|-----------------------|-----------|---------------|
| <i>E. horistes</i>    |           |               |
| Canna                 | 12        | OP wild       |
| Collie orchard        | 12        | OP-SO         |
| <b>Total</b>          | <b>24</b> |               |
| <i>E. polybractea</i> |           |               |
| West Wyalong          | 6         | OP wild       |
| Bendigo               | 6         | OP wild       |
| Collie Orchard        | 12        | OP-SO         |
| GR Davis Pty Ltd      | 1         | OP plus tree  |
| <b>Total</b>          | <b>25</b> |               |

### Trial assessment

The trials were successfully established at all sites in the winter of 2001 and have reached rotation age, when the first harvest of leaves and branches may occur. Preliminary results from a 2004 assessment of vegetative growth at the G.R. Davis/CSIRO West Wyalong site has shown that *E. polybractea* (which is a regional endemic) has clearly outgrown *E. horistes*. However there were no statistically significant differences within families or other groupings (such as orchard versus wild) seedlots for either *E. polybractea* or *E. horistes*. An assessment of the oil yields and analysis (i.e. composition of certain valuable compounds such as cineole) from the trial series was undertaken by CALM during 2005. This assessment analysed the variation between families, as much of the selection in orchard lots is for oil yield and quality traits. Results of these analyses will be published later.

### 3. Extension

ALRTIG's mission is 'to produce genetically improved planting material for farm forestry in the low rainfall areas of southern Australia, and inform tree growers of its availability': communication has therefore been an important focus of the project. ALRTIG has communicated information and promoted the use of genetically improved germplasm through a variety of media. The following sections summarise the major achievements by the relevant mode of extension.

#### 3.1. Publications, conferences and presentations

ALRTIG has been well represented at national conferences and has received extensive publicity in professional farm forestry forums. Additionally, a number of publications have been produced and published through RIRDC. Table 13 lists RIRDC publications, and Table 14, conference papers and presentations. The Hon. Wilson Tuckey, Minister for Conservation and Forests was personally presented with an overview of ALRTIG activities in April 2001.

*Table 13. ALRTIG publications*

| Title                                                                                                                 | Authors                                                                                                     | Date |
|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|------|
| 1. Australian Low Rainfall Tree Improvement Group: Compendium of Hardwood Breeding Strategies                         | Harwood, C., Bulman, P., Bush, D., Stackpole, D and Mazanec, R.                                             | 2001 |
| Overview of Species Selection Process and Tree Improvement Strategies <sup>1,2</sup>                                  | Bush, D., Harwood, C. and Stackpole, D.                                                                     | 2001 |
| <i>Eucalyptus occidentalis</i> : genetic improvement strategy in southern Australia <sup>1</sup>                      | Harwood, C.                                                                                                 | 2001 |
| <i>Eucalyptus camaldulensis</i> : genetic improvement strategy in southern Australia <sup>1</sup>                     | Harwood, C. and Mazanec, R.                                                                                 | 2002 |
| <i>Eucalyptus cladocalyx</i> : genetic improvement strategy in southern Australia                                     | Harwood, C. and Bulman, P.                                                                                  | 2001 |
| Spotted gum: genetic improvement strategy in southern Australia <sup>1</sup>                                          | Mazanec, R. and Harwood, C.                                                                                 | 2001 |
| <i>Eucalyptus tricarpa</i> : genetic improvement strategy in southern Australia <sup>1</sup>                          | Stackpole, D. and Harwood, C.                                                                               | 2001 |
| 2. Australian Low Rainfall Tree Improvement Group: Update of Hardwood Breeding Strategies                             | Harwood, C.E., Bird, R., Butcher, T., Bush, D.J., Jackson, T., Johnson, I., Stackpole, D. and Underdown, M. | 2005 |
| 3. Australian Low Rainfall Tree Improvement Group Compendium of Softwood Breeding Strategies.                         | Boardman, R., Bush, D., Butcher, T., Harwood, C. Spencer, D. and Stackpole, D.                              | 2002 |
| Genetic gain trial strategy for <i>Pinus pinaster</i> in southern Australia <sup>2</sup>                              | Butcher, T.                                                                                                 | 2002 |
| Genetic improvement strategy for <i>Pinus brutia</i> in southern Australia <sup>2</sup>                               | Spencer, D. and Boardman, R.                                                                                | 2002 |
| 4. Australian Low Rainfall Tree Improvement Group: A strategy to develop a low rainfall breed of <i>Pinus radiata</i> | Matheson, A.C., Bush, D.J., Spencer, D.J. and Porada, H.                                                    | 2007 |
| 5. Australian Low Rainfall Tree Improvement: Mallee genotype/environment interaction                                  | Bartle, J. and Brennan, G.                                                                                  | 2002 |
| 6. Breeding trees for the low rainfall regions of southern Australia.                                                 | Harwood, C.E. and Bush, D. Eds.                                                                             | 2002 |

<sup>1</sup> in Australian Low Rainfall Tree Improvement Group: Compendium of Hardwood Breeding Strategies.

<sup>2</sup> in Australian Low Rainfall Tree Improvement Group compendium of softwood breeding strategies.

RIRDC Publication No. 02/028, Rural Industries Research and Development Corporation, Canberra.

*Table 14. ALRTIG conference papers and presentations*

| Title                                                                                                            | Material presented                                                                        | Authors                                                                                                                                                             | Location                | Organiser                       | Date                        |
|------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|---------------------------------|-----------------------------|
| Tree improvement for low rainfall farm forestry                                                                  | Paper to IUFRO World Congress<br>Forests in the Balance: Linking Tradition and Technology | Harwood, C., Bush, D.,<br>Butcher, T., Bird, R.,<br>Henson, M., Lott R.,<br>Shaw, S.                                                                                | Brisbane,<br>Australia. | IUFRO                           | 8-13<br>August<br>2005      |
| Australian low Rainfall Tree Improvement Group                                                                   | Paper to Research Working Group 1 (Genetics)                                              | Harwood, C., Bush, D.,<br>Bird, R., Butcher, T.,<br>Henson, M., Jackson, T.,<br>Johnson, I., Lott R.,<br>McCrea, T., Porada, H.,<br>Stackpole, D.,<br>Underdown, M. | Grafton,<br>NSW         | RWG1                            | 10-11<br>February<br>2005   |
| Tree Breeding for Southern Australia's Low Rainfall Zone                                                         | Paper in "Proceedings of the National Low Rainfall Farm Forestry Conference"              | Bush, D., Butcher, T.,<br>Harwood, C., Porada, H.,<br>O'Connell, D., Stackpole, D.,<br>Underdown, M.                                                                | Horsham,<br>Victoria    | DSE                             | September<br>(2002)         |
| Plantations in the low rainfall zone: the contribution of tree breeding                                          | Paper in "Proceedings of the AFG National Conference"                                     | Bush, D., Butcher, T.,<br>Harwood, C., Porada, H.,<br>O'Connell, D., Stackpole, D.,<br>Underdown, M.                                                                | Albany                  | AFG                             | September<br>(2002)         |
| Vegetative propagation by rooted cuttings of <i>Eucalyptus</i> species from temperate low-rainfall environments. | Conference poster at: "Developing the Eucalypt of the Future"                             | Brammall, B. and<br>Harwood, C.E.                                                                                                                                   | Valdivia,<br>Chile      | IUFRO                           | September<br>10-14,<br>2001 |
| Cooperative Low Rainfall Tree Improvement in Australia                                                           | Conference poster at: "Developing the Eucalypt of the Future"                             | Bush, D., Butcher, T.,<br>Davis, S., Harwood, C.,<br>Porada, H., Stackpole, D.,<br>Underdown, M.                                                                    | Valdivia,<br>Chile      | IUFRO                           | September<br>10-14,<br>2001 |
| ALRTIG Overview to 'Plantation expansion into low rainfall areas' meeting                                        | Abstract and handouts                                                                     | Bush, D., Butcher, T.,<br>Davis, S., Harwood, C.,<br>Porada, H., Stackpole, D.,<br>Underdown, M.                                                                    | Mt<br>Gambier           | RWG12                           | May 2001                    |
| National salinity/forestry forum "Forestry with a Pinch of Salt"                                                 | Presentation                                                                              | Bush, D.                                                                                                                                                            | Dubbo                   | Macquarie Farm Forestry Project | September<br>2001           |
| AFFA 'New Horizons for Revegetation industries' seminar                                                          | Resource policy makers                                                                    | Bush, D.                                                                                                                                                            | Canberra                |                                 | June 2001                   |
| QFRI National Farm Forestry Silviculture Project meeting                                                         | Overhead slides in proceedings                                                            | Bush, D., Butcher, T.,<br>Davis, S., Harwood, C.,<br>Porada, H., Stackpole, D.,<br>Underdown, M.                                                                    | Brisbane                |                                 | May 2001                    |

### 3.2. Website

A website was launched in December 1999: [www.ffp.csiro.au/alrtig/](http://www.ffp.csiro.au/alrtig/). The website contains over 30 pages of information on the key species, including attributes of the species, best seed sources

and unsuitable seed sources for specific applications and a contact list so that users can obtain further information. Statistics collected in 2005 indicate that pages from the site are typically well-visited: usually at least one ALRTIG page ranks amongst the 20 most visited in each month since statistics have been collected in August 2004. The average hits per month number around 1200 in total for the ALRTIG site. The most popular pages are the ones relating to redgum, spotted gum and sugar gum.

### 3.3. National meeting

A national meeting of ALRTIG stakeholders was held in Canberra, 15-16 October 2001. The first day included a public session to which low rainfall tree improvement stakeholders were invited. This session provided a valuable opportunity to showcase the ALRTIG project. Speakers are given in Table 15. Fifty-five invited participants attended this forum. The participants included public policy makers, scientists, natural resource stakeholders, forest industry representatives and farmers. The second day was used for Technical and Steering Committee meetings.

*Table 15. Presenters at the 2001 ALRTIG National Meeting*

| Speaker           | Organisation       | Topic                                                                          |
|-------------------|--------------------|--------------------------------------------------------------------------------|
| Deborah O'Connell | RIRDC              | JVAP Perspective on ALRTIG                                                     |
| Peter Bulman      | AFG                | Australian low rainfall tree improvement – how we got to where we are now      |
| Chris Harwood     | CSIRO Ensis        | ALRTIG research update and future directions                                   |
| Hugh Stewart      | Treecorp           | The potential for low rainfall forest industry in Australia                    |
| Rod Bird          | DPI                | Integrating genetically improved trees on farms                                |
| David Carr        | Greening Australia | Low rainfall farm forestry – genetics, the environment and people <sup>1</sup> |
| David Spencer     | CSIRO Ensis        | Brutian pine collection trip report <sup>1</sup>                               |

<sup>1</sup> See Box 5.

### 3.4. Professional development

The ALRTIG National Coordinator and Partner extension officers have made presentations to a number of groups of farm forestry professionals as detailed in Table 16. Presenting to farm forestry professionals has been an effective way of communicating the importance and availability of genetically improved germplasm for low rainfall species.

*Table 16. ALRTIG contribution to professional development of farm forestry practitioners*

| Place and audience                                                        | Type of audience                                          | Time           |
|---------------------------------------------------------------------------|-----------------------------------------------------------|----------------|
| Yass, Master Tree Growers course                                          | Forest farmers                                            | July 2000      |
| Canberra, Greening Australia Farm Forestry Support Workshop               | Resource management professionals                         | August 2000    |
| Coolamon, Farm Forestry in the Riverina Field Day                         | Farmers, farm forestry extension workers                  | August 2001    |
| Culcairn, Murray Riverina Farm Forestry Field Day                         | Farmers, farm forestry extension workers                  | September 2001 |
| Dubbo, Macquarie Farm Forestry 'Forestry with a pinch of salt' conference | Farm forestry professionals, farmers - strategic          | September 2001 |
| Yanco, Riverina Farm Forestry Research Committee briefing                 | Farm forestry professionals - strategic                   | September 2001 |
| Bordertown, Australian Forest Growers Field Day                           | Forestry professionals and farmers – on-farm presentation | January 2005   |

### 3.5. Media

A number of articles have been published in the rural press as detailed in Table 17.

*Table 17. Articles published in the media about ALRTIG*

| Publication and date of publishing                                              | Title of article                                                             | Publisher                                         |
|---------------------------------------------------------------------------------|------------------------------------------------------------------------------|---------------------------------------------------|
| Shaping the Future with Farm Forestry, Issue, 4 May 1999                        | Prospects for low rainfall tree improvement                                  | JVAP                                              |
| Queensland Country Life, 29 July 1999                                           | Genetics hold key to farm forestry profits                                   | Rural Press Ltd.                                  |
| Australian Forest Grower, Winter 1999 Vol 22 No 2                               | Tree Improvement Pursued in Low-rainfall Zone (Alastaire Sarre)              | Australian Forest Growers                         |
| Australian Tree Resources News Number 5, July 1999                              | Australian Low Rainfall Tree Improvement Group (ALRTIG)                      | CSIRO                                             |
| Shaping the Future with Farm Forestry Issue 5, September 1999                   | Low-rainfall project starts                                                  | JVAP                                              |
| Trees and Natural Resources, December 1999                                      | Tree genetics - key to profitable dry land farm forestry                     | Natural Resources Conservation League of Victoria |
| Australian Landcare, March 2000                                                 | Conifers in the Dry Country                                                  | Landcare Australia                                |
| ONWOOD, Autumn 2000, No 28                                                      | Better Trees for Low Rainfall Farm Forestry                                  | CSIRO                                             |
| Farming Ahead with the Kondinin Group, November 2000 No. 107                    | Better Trees for Farm Forestry                                               | Kondinin Group                                    |
| ONWOOD, Autumn 2001, No 32                                                      | Better Pines for Low Rainfall Country Conifers...                            | CSIRO                                             |
| The Land 15 June 2001                                                           | National Tree Push                                                           | Rural Press Ltd.                                  |
| Weekly Times, 26 September 2001                                                 | Correct Seed Idea Begins to Take Root (Kim Woods)                            | News Ltd.                                         |
| ABC Country (Western Victoria) – radio interview, September 2001                | ALRTIG National Coordinator on relative merits of cypress pine and sugar gum | Australian Broadcasting Corp.                     |
| Australian Farm Forestry (supplement to the Australian Farm Journal) April 2002 | The search is on for key low-rainfall trees (David Bush)                     | Rural Press Ltd.                                  |
| ONWOOD, Spring 2002, No 38                                                      | Low Rainfall Tree Breeding Program Extended                                  | CSIRO                                             |
| Environment Business, October 2002 (also run in LAWN, October 2002)             | Low rainfall forest research program continued                               | Hallmark Editions (Both publications)             |
| Agroforestry News, November 2002                                                | Tree breeding for southern Australia's low rainfall zone (Brioni Brammall)   | SE Australia Agroforestry Networks                |

### 3.6. Links to other projects

ALRTIG has strong links with a number of other projects. Perhaps one of the most important outputs from the ALRTIG project has been the publication of the key species lists. The key species have served as a focal point for a number of other projects, and they been widely included as benchmark species, and/or as preferred species on which other (non-tree breeding) work has been focussed.

Projects which have links to ALRTIG are listed in Table 18.

**Table 18. Links between ALRTIG and other projects**

| Project name                                                  | Project managers                       | Nature of link                                                                                                                                                    |
|---------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| The Heartlands Initiative                                     | CSIRO, Murray-Darling Basin Commission | ALRTIG provided advice on suitable material to benchmark to key species                                                                                           |
| Greening Australia Low Rainfall Species trialling             | Greening Australia                     | ALRTIG provided advice on suitable material to benchmark to key species                                                                                           |
| Forests NSW salinity trials                                   | FNSW                                   | ALRTIG recommended species and provenances included as benchmark species                                                                                          |
| Wood and fibre properties of dryland conifers                 | FNSW; RIRDC (for JVAP)                 | Sawn wood properties determined for ALRTIG key softwood species                                                                                                   |
| Wood products from low rainfall (450-650 mm/yr) farm forestry | CSIRO; RIRDC (for JVAP)                | Solid wood processing studies for <i>E. cladocalyx</i> and <i>E. occidentalis</i> logs grown in low rainfall plantations to determine recovery and product grades |

## 4. Commercial opportunities

The preceding sections have emphasised the considerable capacity for production of high quality, genetically improved seed established by the ALRTIG project. Some of the interim seed production capacity such as seed production areas and seed stands are already producing seed, which has been advertised and sold through the ALRTIG website and via the partners' considerable extension networks. While the quantities have only been modest thus far, the capacity should be substantial by around 2008. The following sections discuss the likelihood of a market for this seed, and the capacity of ALRTIG to meet demand. Also addressed is marketing, industry linkage and product-proving.

### 4.1. Low rainfall forestry market drivers and impediments

Since the inception of the ALRTIG program, the concept of Commercial Environmental Forestry (CEF) has been developed. The concept is based on the following principles:

- (1) Deep-rooted perennial vegetation, planted at a very broad scale in the sheep-wheat belt, is an important part of the solution to remediating environmental problems such as Australia's dryland salinity problem (Stirzaker et al. 2002);
- (2) the vegetation planted must yield commercial products, such as wood, fibre, biochemicals etc. that will generate income;
- (3) the vegetation planted must also attract environmental payments, such as salinity and/or carbon credits; and
- (4) the income streams from (2) and (3) will together make the plantings commercially viable.

There are impediments associated with both (2) and (3). ALRTIG addresses one fundamental problem at point (2): the tree species that are suited to the harsh climate of the sheep-wheat belt generally have a woodland habit, characterised by heavy branching, crooked stems and low-moderate growth rates. This makes harvesting, transport and processing of whole logs less viable. However this report shows that the prospects for genetically improving some suitable low rainfall tree species are very promising. Advances in farming systems, silviculture as well as wood processing technologies will further address the impediments at point (2).

The impediments associated with point (3) present a significant challenge for policy makers and scientists alike. The challenge is to develop a system of environmental payments that society can afford and that will provide sufficient incentive to realise the environmental benefits where they are most needed. Significant policy advances, development of market based instruments (e.g. tradeable environmental credits) and detailed understanding and measurement of the impacts of vegetation based environmental management solutions will be required.

If the impediments discussed above can be overcome, it is likely that the demand for genetically improved germplasm of suitable CEF species will be significant. ALRTIG's challenge is to provide a basis for long term genetic improvement programs as well as sufficient capacity to meet demand in the shorter term.

## 4.2. Planting rate

The planting rate in low rainfall areas has probably fluctuated during the time that ALRTIG has been in operation, though this is not borne out by the statistics presented for 2004 (Table 19). The estimate of planting rates is made from nursery production statistics (17 large nurseries in WA, SA, VIC and NSW) for the 2001 and 2004 planting years. The rising popularity of sugar gum as a low rainfall plantation species is clearly shown. Although mallee production dropped off in 2004, there were 4.8 million seedlings produced in 2003. The Oil Mallee Company established 2.5 million of these on behalf of Japan's second largest power company for carbon sequestration in the Kalannie region of the WA wheatbelt. A good 2004 cropping season combined with non-availability of a number of grants that had been available to farmers to establish mallees may also have impacted (Ben Roberts, Oil Mallee Company pers. com.).

*Table 19. Plantation rates for ALRTIG key species*

| Species                             | Number of seedlings raised<br>in major nurseries |           | Assumed<br>planting<br>density (trees<br>per hectare) | Estimate of area planted<br>(ha) |      |
|-------------------------------------|--------------------------------------------------|-----------|-------------------------------------------------------|----------------------------------|------|
|                                     | 2001                                             | 2004      |                                                       | 2001                             | 2004 |
| <i>E. cladocalyx</i>                | 402,000                                          | 989,000   | 1000                                                  | 400                              | 1000 |
| <i>E. occidentalis</i>              | 107,500                                          | 109,200   | 1000                                                  | 100                              | 100  |
| <i>E. Tricarpa/<br/>sideroxylon</i> | 101,500                                          | 83,700    | 1000                                                  | 100                              | 100  |
| <i>E. camaldulensis</i>             | 325,000                                          | 140,800   | 1000                                                  | 300                              | 100  |
| Mallees                             | 3,695,000                                        | 1,596,000 | 2600                                                  | 1400                             | 600  |
| <i>Corymbia</i> spp.<br>(southern)  | 523,000                                          | 253,200   | 1000                                                  | 500                              | 300  |
| <i>P. pinaster</i>                  | 9,200,000                                        | 2,367,000 | 1500                                                  | 6200                             | 1600 |
| <i>P. brutia</i>                    | 4000                                             | 9000      | 1000                                                  | 4                                | 9    |

Spotted gum seed sales from the Australian Tree Seed Centre have also fluctuated in recent years. In 2001, 2.5 kg were sold, in 2002 between 6.6 kg, and 1.8 kg in 2003 (B. Brammall pers. com.).

## 4.3. ALRTIG orchard seed yields and capacity

ALRTIG's Technical Committees believe that enough orchards of certain key species have been established to meet the anticipated demand for improved seed, which might reasonably be expected to double within the next five years. If during this time it becomes apparent during this timeframe that plantation establishment of certain species will continue to rise significantly, more orchards could be established. Until the existing orchards actually start producing, seed yields will be impossible to verify, however it is possible to estimate for some species for which seed orchards and/or seed production areas already exists. Some quantitative information has been obtained on seed yields from interim SPAs, as shown in Table 20.

Table 20. Seed yields obtained from ALRTIG interim seed production areas managed by ForestrySA (from Harwood et al. 2005)

| Species                | SPA       | Area (ha) | Crop year | Age of SPA (years) | Seed yield           |
|------------------------|-----------|-----------|-----------|--------------------|----------------------|
| <i>E. cladocalyx</i>   | Kersbrook | 0.5       | 2000      | 8                  | 2000 g               |
| <i>E. occidentalis</i> | Bundaleer | 0.64      | 2000      | 8                  | 440 g from 14 trees  |
|                        |           |           | 2001      | 9                  | 1790 g from 11 trees |
| <i>E. occidentalis</i> | Redhill   | 0.67      | 2000      | 9                  | 500 g from 10 trees  |

It should be noted that the Table 20 yields are from collections of a small proportion of superior trees within the SPA, not from all seed-bearing trees. Comparable yields have been obtained from CSIRO's irrigated SPAs of spotted gum in the Deniliquin area. However, it has been noted that yields are not consistent from year to year, with poor seed crops in the year following a heavy collection.

Based on experience from the interim SPAs, it is anticipated that seed yields of 5 kg per hectare will be obtained from well-sited and well-managed seed orchards every second year or so for *E. cladocalyx*, *E. occidentalis* and *C. maculata*, from age 7-8 years after planting (earlier in some cases). A seed yield of 2 kg per hectare per year, averaged across several years, would appear to be achievable on suitable sites. These yields can be translated into the capacity to provide planting stock and areas of plantations, as shown in Table 21.

Table 21. Capacity of seed orchards to meet plantation establishment targets

| Species                                                             | <i>E. cladocalyx</i> | <i>E. occidentalis</i> | <i>C. maculata</i> |
|---------------------------------------------------------------------|----------------------|------------------------|--------------------|
| Seed yield from orchards (kg/ha) <sup>1</sup>                       | 2                    | 2                      | 2                  |
| Viable seeds/kg                                                     | 150,000              | 200,000                | 100,000            |
| Assumed recovery from nursery (% plantable seedlings) <sup>2</sup>  | 70                   | 70                     | 70                 |
| Plantation stocking (trees/ha)                                      | 1,000                | 1,000                  | 1,000              |
| Area of plantations per hectare of seed orchard                     | 210                  | 280                    | 140                |
| Area of ALRTIG orchards (ha)                                        | 9.4                  | 7.6                    | 7.5                |
| Max. ann. plant rate supported by ALRTIG orchards (ha) <sup>3</sup> | 2000                 | 2000                   | 1000               |

<sup>1</sup> Seed weight after cleaning by sieving

<sup>2</sup> Assuming sowing by machine in an efficient nursery, allows for losses during final cleaning of seed for machine sowing

<sup>3</sup> Assuming that all of the ALRTIG PT-SSOs are managed for seed production, and bear adequate seed crops.

Less information on seed yields is available for the other key ALRTIG species. It appears from observations made in provenance and progeny trials of *C. citriodora* subsp. *variegata* and red ironbark (*E. sideroxylon* and *E. tricarpa*) in dryland Victoria and southern New South Wales that these species are slower to attain general flowering than are the three species shown in Tables 20 and 21. Experience with *P. brutia* has shown that cone set and germination rates from Australian trees tend to be low compared with those overseas. This is an area that requires further research.

The extent to which hardwood seed crops might be enhanced by application of paclobutrazol (a chemical that promotes heavy flowering in most angiosperm tree species including eucalypts) is

also unknown at present. It is unlikely to significantly increase the seed yields of *C. maculata*, which normally tends to have heavy flower bud crops but variable retention of flowers, though it may have a useful effect on *E. cladocalyx*. Seed crops of *P. brutia* could possibly be increased by application of gibberellic acid, though this is not a straightforward procedure compared with paclobutrazol application, and may not be cost-effective.

#### **4.4. Marketing**

Seed produced by ALRTIG seed production facilities will be sold commercially to nurseries and forest growers. There is already a significant demand for spotted gum, sugar gum and to a lesser extent, swamp yate seed. Seed sourced from 'interim' seed production facilities (seed production areas and seedling seed orchards) belonging to the partners is selling quite readily, and in the case of sugar gum, demand cannot be met.

The model for commercial deployment has been discussed by ALRTIG's partners. It has been agreed that commercial quantities of seed will most probably be marketed jointly, that is, seed of similar quality from each partner's orchard will be sold with a common identity or brand, to avoid confusion. Because IP from each orchard is jointly owned by the partners, royalties will also be payable and shared amongst the partners for commercial sales of significant volumes.

#### **4.5. Industry links and genetic gain trials**

An important part of ALRTIG's commercialisation strategy has been to involve potential industry stakeholders in tree improvement activities early in the implementation of the breeding strategy work plans. ALRTIG first sought involvement from industry stakeholders in 2001 when excess stock of *E. cladocalyx* material grown for deployment into the ALRTIG PT-SSOs was made available for testing in provenance trials. In the second phase of ALRTIG, ITC, Woollybutt and Treecorp agreed to participate in the genetic gain trial program which is featured in Box 7. In this program, companies were given the opportunity to test genetically improved material against controls on land available to them, using their own silvicultural practices.

## Box 7. Hardwood genetic gain trials

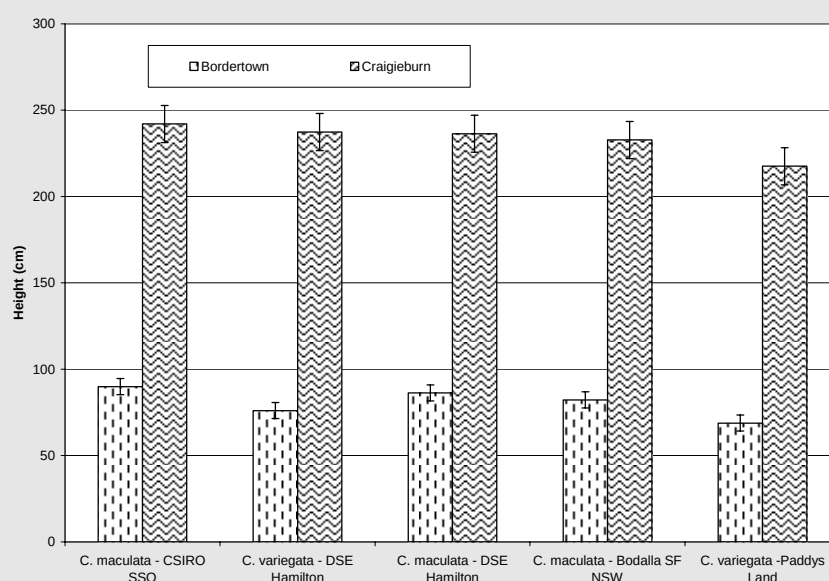
As for maritime pine yield trials and the mallee genotype-by-environment trials, it was decided that gain trials would be established for the hardwood species, comparing the recommended best-bet seed sources with other material. ALRTIG took the opportunity to seek collaboration from industry partners in 2003 to undertake gain trials on sites managed by companies with an interest in low rainfall plantation development. Table B7.1 shows the details of gain trials.

**Table B7.1. Hardwood gain trial information summary**

| Species                 | State | Location        | Partner/Collaborator | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-------------------------|-------|-----------------|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>E. camaldulensis</i> | WA    | Kojonup         | ITC                  | Figure B7.1 shows provenance means from early measures of the spotted gum gain trials established by Woollybutt Pty Ltd at Craigieburn (north of Melbourne) and by ForestrySA near Bordertown, SA. At the relatively warmer and drier Bordertown site, there is already a significant superiority of <i>C. maculata</i> over <i>variegata</i> . However at Craigieburn, the treatments are nearly even, with the exception of the Paddys Land <i>C. variegata</i> . This was the poorest performer at both sites. It was selected because of its superior frost tolerance (Larmour et al. 2000), but growth performance was previously unknown. |
| <i>E. cladocalyx</i>    | NSW   | Wagga Area      | SFNSW                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | VIC   | Lismore         | DSE                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | VIC   | Craigieburn     | Woollybutt           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Tenterden       | FPC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Rocky Gully     | ITC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | SA    | Bundaleer       | ForestrySA           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | SA    | Kangaroo Island | ForestrySA           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <i>E. occidentalis</i>  | NSW   | Wagga Area      | SFNSW                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | SA    | Marcollat       | ForestrySA           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | SA    | Mundulla        | ForestrySA           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | VIC   | McKerrals       | Treecorp             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Tenterden       | FPC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Rocky Gully     | ITC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <i>Corymbia</i> spp.    | NSW   | Quirindi        | SFNSW                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | SA    | Bordertown      | ForestrySA           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | VIC   | Melville Forest | DPI                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | VIC   | Craigieburn     | Woollybutt           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Tenterden       | FPC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|                         | WA    | Rocky Gully     | ITC                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |

It is encouraging that the seed orchard material is the tallest in both trials at this early stage. A recent inspection of the FPC WA trial also indicated that the SSO material is the tallest there.

**Figure B7.1. ANOVA means from two *C. maculata* gain trials planted in 2003 and measured approximately 15 months later**



## 5. Implications

Since 1999, ALRTIG has made significant progress in advancing the state of tree breeding for low rainfall environments in Australia. During this time, the need identified by participants of the 1998 Low Rainfall Tree Improvement Workshop (Bush and Bulman 1999) to make available significant quantities of genetically improved seed for low rainfall plantation establishment generally appears to be vindicated. Interest in low rainfall farm forestry has grown. It now seems to be widely accepted that plantation of deep rooted woody germplasm in the sheep-wheat belt will play a significant part in ameliorating Australia's dryland salinity problem.

A major advantage of ALRTIG has been the cooperative model and approach to breeding trees for low rainfall environments. The following points stand out as being significant advances on the situation that prevailed prior to ALRTIG's formation, where each State ran relatively discrete programs:

- The resources have been available to produce comprehensive, well documented and thoroughly reviewed genetic improvement strategies which have been placed in the public domain
- The opportunity to draw leading experts and stakeholders together
- Sharing and pooling of biological resources
- Consistent trial designs replicated over a wide range of sites, that will yield rich data for a variety of uses
- The size of the program has allowed good media exposure and other extension opportunities
- Creation of a significant germplasm production capacity to underpin low rainfall planting programs

Perhaps the most significant achievement of the ALRTRIG program has been the progress towards remedying a serious impediment to broad-scale adoption of plantation forestry in the sheep-wheat belt: making available planting material that will yield a commercial product in addition to an environmental benefit.

There is a critical difference in the likely impacts of the tree improvement programs that have been undertaken for high rainfall species and those of the ALRTIG key species. In *E. globulus* for example, certain natural provenances produce very acceptable plantation pulp crops with good growth rates and fibre yields, provided the site receives enough rainfall. A commercially viable industry has been built on planting material predominantly derived from wild seed resources. The role of tree breeding for *E. globulus* has therefore been to further increase gain in growth and fibre traits, resulting in a higher rate of return for growers.

In *E. occidentalis* and *E. tricarpa*, on the other hand, the form and growth rates of natural provenance material would produce plantations that yield marginal commercial returns from sawn timber production, even on higher rainfall sites. In this case, farmers do not establish plantations, and the environmental benefits that accrue both to the farmer and the wider community are never realised. ALRTIG's genetic improvement programs are therefore helping shift the commercial return threshold at which people decide to plant in the low rainfall zone. In practice, genetic improvement *together* with improved **silviculture**, environmental service

payments, harvesting, transport and processing advances, will jointly contribute to providing the productivity lift required to encourage investment (Harwood et al. 2005).

## 6. Recommendations

### *Overall achievement*

Overall, the program has been very successful in achieving its objectives. It has set up short and long term strategies to ensure that Australian low rainfall forestry initiatives will not be constrained by lack of germplasm in the medium-long term. There have also been steps taken to ensure short-term supply of seed for hardwood and softwood species.

### *Short term demand for seed*

However, there is some evidence that demand for certain species might already be outstripping supply. *E. cladocalyx* is the main species falling into this category. It may be advisable to create extra short term seed production capacity by thinning additional stands. Interest in spotted gum is also high, though there is reasonable capacity to meet demand. It is also the case that short term capacity to produce red ironbarks and Brutian pine is relatively limited. In the case of Brutian pine extra capacity could be created at any time with a two year lead time to seed production.

### *Extension*

It will be important to maintain public awareness of the importance of using improved germplasm for low rainfall plantings as the ALRTIG seed orchards start to come on line. With the cessation of the national coordination position in 2005, each Partner will be responsible for promoting genetically improved resources via their own extension networks. It may be advisable to seek funding and commitment for specific extension activities. These might include a web site upgrade, promoting seed production and sales and maintenance of contact between the partners.

### *Cooperative R&D*

The ALRTIG project has proven that cooperative research between a number State and Commonwealth Government Partners, other researchers, farmers and industry stakeholders can be highly successful and productive. This model could be applied more widely to other areas of scientific research. However, experience from ALRTIG suggests that success is probably contingent on two things: firstly, the availability of a person who is available to spend a considerable proportion of time on inter-partner coordination and communication (in the case of ALRTIG a National Coordinator was appointed to do this) and secondly; one or more people willing to ‘champion’ major areas of scientific endeavour. In the case of ALRTIG there was a high degree of motivation and willingness of individuals to take overall responsibility in each of the major scientific areas.

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## Appendix 1. Some contributors from Partner organisations

This lists just some of the people involved from the various partner organisations at various times since 1999 (affiliations given are those at the time of participation in ALRTIG). In addition, around 50 farming families have made sites available and been involved in the establishment of the trials and plantings.

### *Hardwoods program*

Adrian Agars (ForestrySA)  
Rod Bird (DPI)  
Brioni Brammall (CSIRO)  
Peter Bulman (PIRSA)  
Trevor Butcher (FPC)  
Margaret Byrne (CALM)  
Sally Collins (ITC)  
Keith Cumming (Arborline)  
Jeff Fairlamb (PIRSA)  
Liz Hamilton (DSE)  
Sue Harris (DSE)  
Chris Harwood (CSIRO)  
Michael Henson (FNSW)  
Tim Jackson (DPI)  
Ian Johnson (FNSW)  
Adrian Lynch (Treecorp)  
Richard Mazanec (CALM)  
Tracee McCrea (ForestrySA)  
Maurice McDonald (CSIRO)  
John Reed (DPI)  
Puspa Rowell (FPC)  
Dean Severino (Woollybutt)  
Des Stackpole (Forest Science Centre)  
Hugh Stewart (Treecorp)  
Clinton Tepper (Woollybutt)  
Chris Vellios (FPC)

### *Short rotation program*

Liz Barbour (FPC)  
John Bartle (CALM)  
Gary Brennan (CALM)  
Jeff Fairlamb (PIRSA)  
Rob Murphy (PIRSA)  
Doug Rowell (FNSW)  
Doug Rowell (FNSW)  
Des Stackpole (DSE)  
Mike Slee (ANU)  
Mick Underdown (ForestrySA)

### *Softwood program*

Adrian Agars (ForestrySA)  
Yumiko Bonnardeaux (FPC)  
David Bower (Private Forests Tasmania)  
Bob Boardman (ForestrySA)  
Bev Boyer (FPC)  
Trevor Butcher (FPC)  
Sally Carpenter (FPC)  
Mike Cully (FPC)  
Charles Hajek (DSE)  
Arthur Lyons (Private Forests Tasmania)  
Tracee McCrea (ForestrySA)  
Colin Matheson (CSIRO)  
Hans Porada (FNSW)  
Doug Rowell (FNSW)  
David Spencer (CSIRO)  
Mick Underdown (ForestrySA)  
Bob Wood (ForestrySA)

### *Steering Committee*

Tom Baker (DSE)  
Brioni Brammall (CSIRO)  
Peter Bulman (PIRSA)  
Trevor Butcher (FPC)  
Sharon Davis (RIRDC)  
Chris Harwood (CSIRO)  
Michael Henson (FNSW)  
Rosemary Lott (RIRDC)  
Deborah O'Connell (RIRDC)  
Hans Porada (FNSW)  
Sue Shaw (ForestrySA)  
Des Stackpole (DSE)  
Mick Underdown (ForestrySA)

## Appendix 2. Example of *P. brutia* plus tree register sheet

### ALRTIG Pinus brutia Candidate Tree Assessment Score Sheet

|                                                                                                                                    |                                                                             |                                                                                                                                                                                                     |                                     |                                             |     |      |   |     |       |   |     |    |  |    |     |  |    |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|---------------------------------------------|-----|------|---|-----|-------|---|-----|----|--|----|-----|--|----|
| <b>Register Code</b> <b>5 B 0 0 1</b><br>(number before B is state postcode, numbers after B are tree number)                      |                                                                             | <b>Provisional ID Code:</b> 1                                                                                                                                                                       |                                     | <b>Grade:</b> C<br>(A,B,C ±, or X [reject]) |     |      |   |     |       |   |     |    |  |    |     |  |    |
| <b>Seed Origin</b> (if known)<br>CYPRUS FD, n/s SA S.I. 915                                                                        |                                                                             | <b>Local ID</b> (local plantation or trial code)<br>CPT 156                                                                                                                                         |                                     |                                             |     |      |   |     |       |   |     |    |  |    |     |  |    |
| <b>State</b><br>S.A.                                                                                                               | <b>Locality</b> eg. Forest name and locality name<br>BUND F.R. SPALDING RD. |                                                                                                                                                                                                     | <b>Plantation Est. Date</b><br>1965 |                                             |     |      |   |     |       |   |     |    |  |    |     |  |    |
| <b>Date of Measure</b><br>29/11/1999                                                                                               |                                                                             | <table border="1"> <tr> <td>Lat.</td> <td>°</td> <td>' S</td> <td>Long.</td> <td>°</td> <td>' E</td> </tr> <tr> <td>33</td> <td></td> <td>19</td> <td>138</td> <td></td> <td>35</td> </tr> </table> |                                     |                                             |     | Lat. | ° | ' S | Long. | ° | ' E | 33 |  | 19 | 138 |  | 35 |
| Lat.                                                                                                                               | °                                                                           | ' S                                                                                                                                                                                                 | Long.                               | °                                           | ' E |      |   |     |       |   |     |    |  |    |     |  |    |
| 33                                                                                                                                 |                                                                             | 19                                                                                                                                                                                                  | 138                                 |                                             | 35  |      |   |     |       |   |     |    |  |    |     |  |    |
| <b>Site</b> (describe aspect, slope etc)<br>Precambrian, Torrensian, Skillogalee dolomite<br>East aspect: lower-mid slope 420m asl |                                                                             | <b>Soil</b> (type & depth)<br>Belalie loam<br>red-br clay loam with limestone, <120cm                                                                                                               |                                     | <b>Annual Rainfall</b> (mm)<br>580          |     |      |   |     |       |   |     |    |  |    |     |  |    |
| <b>Tending History</b> (eg thinned, pruned to height )<br>Unthinned, poor survival                                                 |                                                                             |                                                                                                                                                                                                     |                                     |                                             |     |      |   |     |       |   |     |    |  |    |     |  |    |

|                                                 |      |                                                    |           |           |           |
|-------------------------------------------------|------|----------------------------------------------------|-----------|-----------|-----------|
| <b>DBHOB</b> (centimetres & 10ths)<br>Edge tree | 50.7 | <b>DBHOB of 3 largest neighbours*, 10 m radius</b> | 1<br>44.8 | 2<br>44.3 | 3<br>30.1 |
| <b>Height</b> (metres & 10ths)                  | 17.5 | *(Large blocks only, not small plots)              |           |           |           |

|                                                       |   |                                                                                 |
|-------------------------------------------------------|---|---------------------------------------------------------------------------------|
| <b>Stem Straightness</b><br>Score 1worst -6 best      | 5 | <b>Stem Straightness</b> near straight<br>Subjective description lean 3° to SW. |
| <b>Branch weight</b><br>Score 1worst -6 best          | 4 | <b>Branch weight</b> Edge tree 4 on internal face<br>Subjective description     |
| <b>Branch Angle</b><br>Score 1worst -6 best           | 5 | <b>Branch Angle</b> internal branches are 75 -85°<br>Subjective description     |
| <b>Whorl Count</b><br># whorls between 1 and 6 metres | 9 | <b>Whorl Count</b> fairly regular and even weight<br>Subjective description     |
| <b>Forks</b><br>Count No. Forks                       | 0 | <b>Forks</b><br>Subjective description                                          |
| <b>Ramicorns</b><br>Count No. ramicorns               | 0 | <b>Ramicorns</b><br>Subjective description                                      |
| <b>Other Defect</b><br>Baskets, top out, lean, etc    |   | <b>Other Defect</b><br>Subjective description wolfish                           |

|                                                                                                                                                                                                                                                                                                                                                                                         |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| <b>Describe Tree</b> (crown, bark, cones, abnormalities, lean, branch retention, lean, dominance, gaps etc )<br><br>vig.crown / carries vol well / good coner, persistant / orange bark app. Edge tree - exposed to S and W<br>not bad for an Edge tree<br><br><div style="text-align: center;">RPT RATING X</div><br><b>NOTE:</b> This seedlot typified by fine, fairly-flat branching |  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|

# Glossary

(After Harwood and Bush 2002).

## Breeding population

A population of selected trees, which is managed to achieve genetic improvement through successive cycles of selection and breeding.

## Clonal forestry

Plantation forests comprising genetically uniform planting stock derived from mass propagation of selected superior trees. The planting stock is produced by vegetative propagation techniques such as rooted stem cuttings. An individual clone is comprised of the original selected tree (the ortet) and all of the plants (the ramets) propagated from the ortet. All the plants of a clone are genetically identical. Typically, clonal plantations incorporate a number of different clones rather than just one clone.

## Clonal seed orchard

A seed orchard that incorporates ramets of a number (usually more than 20) of superior clones

## Grafting

The cut surface of a shoot (the scion) from a selected tree is matched with the cut surface of a seedling (the stock) and the tissues grow together forming a graft union. The grafted plant is then grown on so that the scion can be represented in a clone bank or a seed orchard.

## Infusion

The addition of new trees (sometimes called the infusion population) to a breeding population. The infused trees are unrelated to the ones that have been brought forward from previous generations. Infusion is important to introduce desirable new genes and maintain the breadth of the genetic base.

## Landrace

A population of individuals that have become adapted to a specific environment in which they have been planted due to natural or human-induced influence.

## Plus tree

A plus tree is a tree that contributes superior progeny to a breeding population. A candidate plus tree is a selected, phenotypically superior individual tree whose progeny are expected to perform well: it would be classified as a true plus tree when the progeny are statistically proven to have above average performance.

## Provenance

The place of origin of a population of trees (usually referring to a location of natural occurrence). Can also be used to refer to the seed collected from the provenance location, or the trees raised from the seed. Example: a *Eucalyptus camaldulensis* plantation of Lake Albacutya provenance.

## Rotation

The rotation length refers to the amount of time elapsing between a stand being planted and the final harvest of the stand.

## Seed production area

A seed production area is a planted stand of trees of suitable provenance that has been thinned to leave only the best trees, from which seed is harvested. The parents of the individual trees in the seed production area are not known.

## Seedling seed orchard

A seedling seed orchard is developed from a progeny trial testing a large number of seedling families raised from known, superior mother trees. After data on the traits of interest to the tree breeder have been collected, the trial is selectively thinned to remove inferior trees. The superior trees remaining in the seed orchard flower and produce seed, which is harvested.

**Selection**

In natural populations, natural selection favours gene variants (alleles) that confer fitness in the natural environment and enable trees with these alleles to survive and reproduce, hence these gene variants become more prevalent over time. Tree breeders select for traits that are desired in plantations, such as straight stems and high growth rates under cultivation, so the gene variants associated with these traits become more prevalent in the breeding population.

**Silviculture**

The science and management of growing trees. Tree improvement is one aspect of silviculture.

**Stocking**

The number of trees in a given area, typically expressed as stems (or trees) per hectare.

**Trait**

The character selected by the tree breeder: growth rate, stem straightness, wood density, salinity tolerance, etc.