Cooperative Research Centre for Temperate Hardwood Forestry

ANNUAL REPORT 1995/96

CRC AUSTRALIA

Established and supported
under the Australian Government's
Cooperative Research Centres Program

Objectives

General:

The general objectives of the Centre are:

- to undertake high-quality scientific and technological research which contributes to national forestry objectives, including economic and social development and the development of an internationally competitive industry sector;
- to ensure that industry captures the benefits of research and to strengthen the links between research and its commercial and other applications by the active involvement of the industrial participants in the work of the Centre;
- to develop a centre of forestry research by promoting cooperative research and through it a more efficient use of resources;
- to provide relevant education and training, particularly in graduate programs, through the involvement of researchers from outside the higher education system in educational activities and by involving graduate students in major research programs;
- to operate effectively and efficiently according to international standards and under sound financial control;
- to ensure staff are well motivated, appropriately skilled and work safely.

Specific:

The Centre aims to become a national centre for developing and promoting innovation in hardwood forestry by:

- developing forest management systems to increase wood productivity in temperate hardwood forests in an environmentally sustainable and responsible way;
- improving the quality of wood from hardwood forests to ensure its market suitability for efficient, value added processing;
- gaining a competitive advantage for Australia's forestry sector over other hardwood producing countries;
- developing a national centre of excellence for postgraduate training with emphasis on training graduates relevant to the industry sector.

COOPERATIVE RESEARCH CENTRE
FOR TEMPERATE HARDWOOD FORESTRY

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UNIVERSITY OF TASMANIA

Participating Organisations

The CRC for Temperate Hardwood Forestry has chosen Australian-made paper for the body of this report.

Contents

Chairman's Letter

CRC Secretariat
GPO Box 9839
Canberra City
ACT 2601

Dear Sir

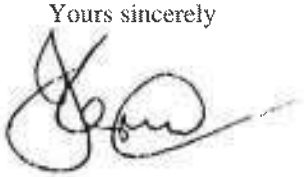
I am pleased to present to you the 1995/96 Annual Report of the Cooperative Research Centre for Temperate Hardwood Forestry.

This document summarises the major research and education activities of the Centre, during what has been an extremely productive and busy year for us.

Significant advances in research continue to be made in all program areas, and our post-graduate training program has attracted over 40 students. We have also been preparing for the Centre's Fifth Year Review (Stage One has now been completed, with Stage Two scheduled for September 1996) and developing an application for a new CRC in the 1996 round. I am delighted to report that all partners in the CRC for Temperate Hardwood Forestry have readily agreed to continue their association in a new CRC, and a number of new partners from throughout Australia have also joined in our application.

I believe that more than any other measure, the desire by our partners to continue and build on the relationship that has developed over the past five years between academia, research organisations and industry is testimony to the success of our Cooperative Research Centre.

Yours sincerely



John Kerin
Chairman

22 July 1996

Director's Report

This year has again been one involving substantial challenges and significant achievements.

We undertook the first stage of the crucial Fifth Year Review which will determine the future of the Centre after the completion of its initial seven year contract. This review examined, for the CRC Committee, the complete scientific and technical functions of the Centre over the first five years and the prospects for the last two years of our contract. The review panel consisted of Dr Mike Carson (Manager, Biotechnology Division of the New Zealand Forest Research Institute), Professor Roger Sands (Head of the New Zealand School of Forestry, University of Canterbury), and Mr Ian Whyte (Chief Executive of the Forest Industries Association of Tasmania).

The review was strongly supportive of the scientific and technical aspects of all programs in the Centre and stated that the CRC "must be rated as a very successful example of co-operative research involving traditional research providers and industry. The quality of the Genetic Improvement and Education and Technology Transfer programs in particular, has been outstanding". This report provides a major input to the second stage of the Fifth Year Review which will focus on technology transfer. The second stage will occur in early September 1996 and will also examine our application for renewed funding.

After extensive discussion with forestry organisations throughout Australia, it was decided that our application for a new CRC would have a broader focus than the current CRC for Temperate Hardwood Forestry. There was enthusiasm from our current partners and from a number of potential new members for the proposal to be broadened to include work on softwoods and tropical and sub-tropical environments. Hence, the proposed new CRC will be titled the Cooperative Research Centre for Sustainable Production Forestry.

The research of the current Centre has continued to expand during 1995/96 in all three program areas - Genetic Improvement, Soil and Stand Management and Resource Protection. This is best seen by the increase in technology transferred to our industry partners, either directly via seminars, workshops or technical publications, or via the Southern Tree Breeding Association, and by our enhanced publication rate. This latter point is emphasised by the increase in publications from 23 in 1992 to 97 in 1995. The level in 1992 reflects research output by the partners prior to the development of the CRC, while the 1995 level shows the synergy created by fully integrated cooperative research.

The Education and Technology Transfer program has also continued to grow with 41 research students currently in the Centre. A further satisfying aspect has been the ability of our graduates to find employment in the industry on, or prior to, the completion of their degrees. The Centre is also reaching an ever widening audience with its message of the benefits of technological developments in the forestry industry. For example, a Royal Society of Tasmania Symposium 'The Search for New Technology in Australian Forestry' is organised for mid July with an audience comprising industry personnel, representatives of conservation organisations, the general public and Society members.

There have been numerous staffing changes during the year, with two highlights being the appointment of Dr David de Little from North Forest Products research unit, North Eucalypt Technologies as the Deputy Director and Mrs Jan Lynch as our Business Manager. The latter appointment has resulted in the development of a detailed Business Plan and major changes to our Strategic Plan and intellectual property documentation.

Prof James B Reid
Director

Management

The Board

The Board of Management of the CRC is comprised of an independent Chairman, the Director and Deputy Director of the CRC and the Chief Executive (or representative) from each participating organisation. The Board determines policy and sets guidelines for the efficient running of the Centre.

Dr David de Little has been appointed Deputy Director of the Centre replacing Dr Philip West.

Structure

The Management Structure of the CRC is headed by the Board and links are depicted in Fig. 1. Operation of the four programs is directed through three committees: the Management Committee, the Industry Research Committee and the Scientific Review Committee.

Management Committee

The Management Committee coordinates the day-to-day running of the CRC and is comprised of the Executive Officer (Administrative Officer and Business Manager), Program Managers, the Director and the Deputy Director.

Mr Geoff McArthur
Manager
Bunnings Treefarms

Mrs Shelley Caswell
Administrative Officer

Mrs Jan Lynch
Business Manager

Prof Jim Reid
Director

Dr David de Little
Deputy Director

Dr Nuno Borralho
Genetic Improvement Program

Mr Robin Cromer
Soil and Stand Management Program

Dr John Madden
Resource Protection Program

Dr Neil Davidson
Education and Technology Transfer Program

CRC Board members

Mr John Kerin
Chairman

Prof Jim Reid
Director

Dr David de Little
CRC Deputy Director
Manager Eucalypt Research
North Eucalypt Technologies

Prof Pip Hamilton
Pro-Vice Chancellor
(Research)
University of Tasmania

Mr John Cameron
Manager
Group Development
Amcor

Mr Allan Jamieson
Manager
North Eucalypt
Technologies

Dr Glen Kile
Chief
CSIRO Forestry & Forest
Products

Mr Ken Felton
General Manager
Forest Management
Forestry Tasmania

Mr Neil Humphreys
General Manager
ANM Forest Management

Mr Ross Waining
Manager
Boral Timber Tasmania

The Scientific Review Committee

The Scientific Research Committee reviews projects in each research program. It performs the role of monitoring the quality of the research conducted at the Centre for the Board and is composed of outside experts in each of the research program areas. Its members are:

Dr Russell Haines

Director, Queensland Forest Research Institute

(Genetic Improvement)

Dr Sadanandan Nambiar

Chief Research Scientist,

CSIRO Forestry and Forest Products, Canberra

(Soil and Stand Management)

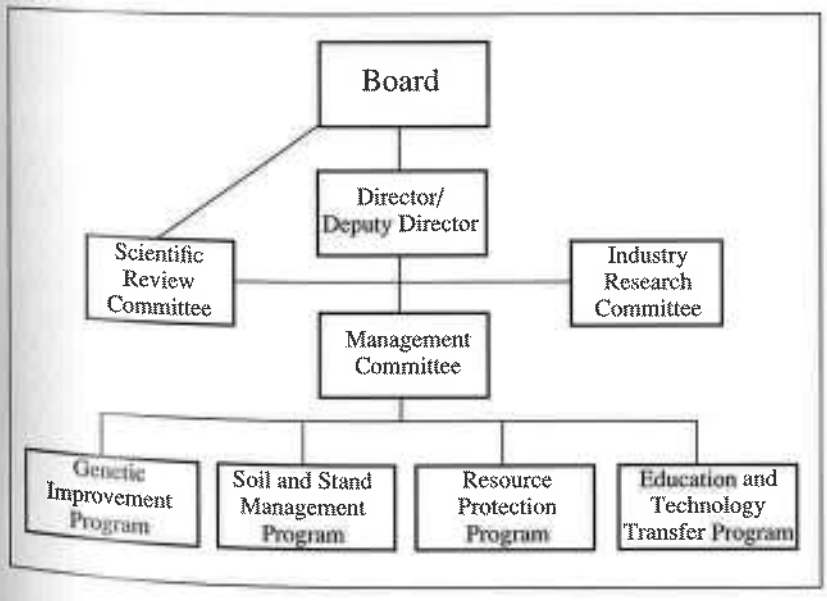
Dr Lindsay Barton Browne

Honorary Fellow,

CSIRO Division of Entomology, Indooroopilly

(Resource Protection)

Figure 1 Management Structure



Industry Research Committee

The Industry Research Committee is comprised of senior research scientists from all participating organisations and the Management Committee and advises the Board on the research priorities for the Centre. This committee is chaired by a leading industry researcher, Dr David de Little from North Forest Products and its members are:

Mr Peter Volker
Silviculture Superintendent, ANM Forest Management

Dr Humphrey Elliott
Chief, Division of Silvicultural Research and Development, Forestry Tasmania

Dr David de Little
Manager, Eucalypt Research, North Eucalypt Technologies

Mr Peter Naughton
Research and Planning Forester, Boral Timber

Mr Philip Whiteman
Technical Manager, Amcor Plantations

Mr Richard Breidahl
Chief Forester, Bunnings Treefarms

Prof Jim Reid
Director, CRC-THF

Dr Nuno Borralho
Program Manager, CRC Genetic Improvement

Mr Robin Cromer
Program Manager, CRC Soil and Stand Management

Dr John Madden
Program Manager, CRC Resource Protection

Dr Neil Davidson
Program Manager, CRC Education and Technology Transfer

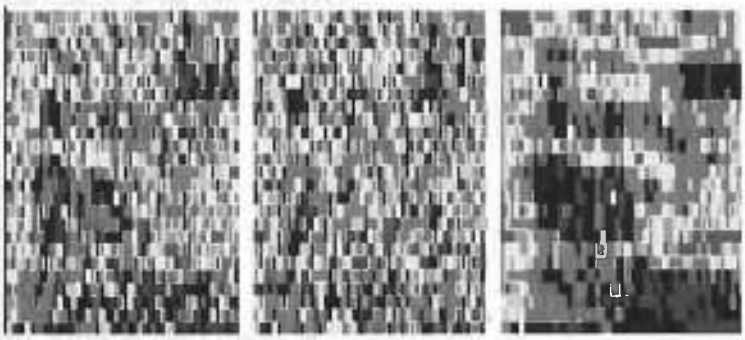
Prof Robert Hill
Head, Department of Plant Science, University of Tasmania

Dr Geoffrey Gartside
Co-Director, CRC for Hardwood Fibre and Paper Science

MAJOR DEVELOPMENTS

A new approach for selecting elite trees

The analysis of breeding trials for plantation forestry has become a complex task. There is now a wider range of biological traits considered economically important (e.g. height, diameter, stem straightness, branching pattern, wood density, pulping characteristics, proportion of cellulose in the fibre), and more is known about the genetic control of these biological traits and this changes with environment. For example, trees grown from seed collected at one geographic location (population) may grow more rapidly than trees from other populations in a plantation in a region of high rainfall but be the slowest in growth in a plantation in a region receiving low rainfall. Biological traits also need to be analysed from trials of different ages and generations. These analyses require very sophisticated statistical techniques.



Map showing growth of trees in a breeding trial - warmer colours relate to higher growth rates.
***LHS**: represents growth of trees where no account is taken of environmental gradients (appears patchy).*
***RHS**: the environmental gradient (patchy).*
***Centre**: variation in growth when account is taken of environmental gradients (uniform). This modelling approach allows direct comparisons of the growth rates of trees without the complication of environmental influences.*

A major contribution of the CRC for Temperate Hardwood Forestry to the forestry industry has been to adapt, from animal breeding theory, the so-called 'Mixed Model' methods for the prediction of the breeding value of a tree (i.e. its worth as a parent for the next generation of plantations). 'Mixed Model' methods can assess concurrently a large number of biological traits and take account of the differences in pedigree and genetic controls that might apply (additive and dominance genetic effects, inbreeding depression) as well as changes in these traits with environment.

Estimates of genetic parameters (i.e. the degree of inheritance) have been conducted for a number of key traits, such as growth and wood density, across a number of sites in Australia. There has also been considerable work on the genetic control of other traits of importance such as bark thickness, flowering, resistance to pests, diseases and frost, rooting ability, and early survival to frost and drought. Some of the heritabilities determined were the first published for eucalypts on these traits.

The 'Mixed Model' methods and the resulting genetic parameters have also been used in a national analysis of base population trials for the two key temperate hardwood species in plantation forestry, *Eucalyptus globulus* and *E. nitens*, in collaboration with the Southern Tree Breeding Association (STBA). This analysis has led to the determination of breeding values for over 100,000 trees established in plantations across the country. These breeding values are now being used by the STBA and the industry in their breeding programs.

Breeding for wood quality

Traditionally, in forestry operations, tree breeders have selected trees on the basis of growth rate (height and diameter) and form (straightness and branching characteristics). However, the Cooperative Research Centre for Temperate Hardwood Forestry has recently shown that wood density (the amount of fibre per unit volume of a log) is one of the key factors affecting total pulp costs (i.e. there is generally more pulpable fibre in a log of high density), consequently, breeding programs from temperate eucalypts should include some measure of wood density in their genetic evaluations.

Weighing discs for wood density

Unfortunately, wood density and pulp yield are difficult and expensive traits to measure directly. As a cost-effective indirect measure of wood density, the CRC for Temperate Hardwood Forestry has been investigating the Pilodyn, a hand-held instrument which drives a steel pin into a tree. The conclusions from this study were that Pilodyn penetration is under strong genetic control, highly correlated with wood density, and robust across sites and ages. Investigations are proceeding to determine the potential of the Pilodyn as a breeding tool.

Research is now being conducted on indirect procedures to estimate pulp yield, such as Near Infrared Reflectance Analysis (NIRA). This work is part of a collaborative project with the CRC for Hardwood Fibre and Paper Science.

The greater emphasis on wood properties, and the use of Pilodyn and NIRA measurements as an indirect source of information on wood density and pulping properties, is expected to save the industry an extra $7.00 per tonne of pulp produced (current values), over selection strategies relying solely on growth rate and form. These savings are possible from a reduction in harvesting, transport and pulping costs per tonne of pulp produced from wood of improved quality.

The CRC for Temperate Hardwood Forestry has also identified important differences between *E. globulus* ssp. *globulus* and other subspecies of *E. globulus* in wood density. Similar studies are under way for *E. nitens*.

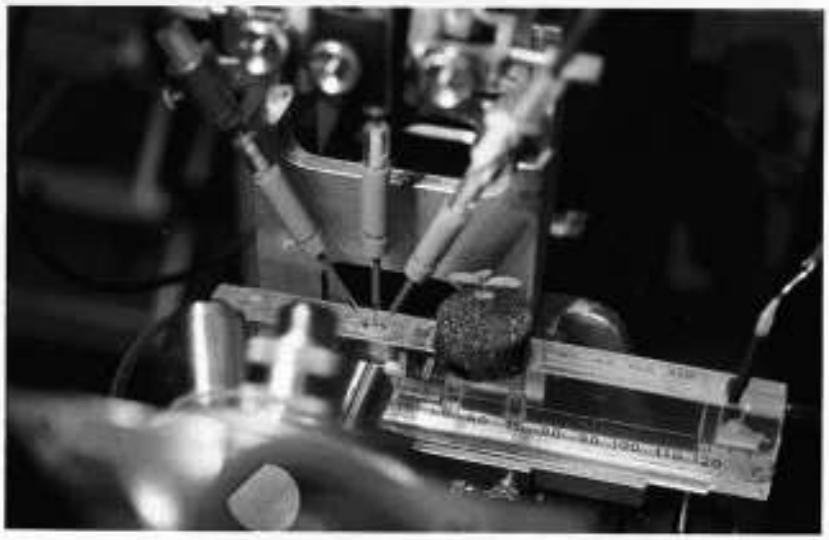
Wood density or Pilodyn assessments are now incorporated in the selection criteria in the national eucalypt breeding program coordinated by the Southern Tree Breeding Association (STBA) as well as in a number of other eucalypt, pine and acacia breeding programs in Australia and overseas.

MAJOR DEVELOPMENTS

Advances in fertiliser practice

Nitrogen is naturally present in low concentrations in the Australian environment. However, nitrogen is an essential element and required in large amounts to achieve maximum growth of trees and other agricultural crops. Application of nitrogen fertiliser to a eucalypt plantation at the time of establishment or at a later age, is a major cost to forestry companies, so the amount of fertiliser applied and the way this fertiliser is used by the trees is of great importance.

Research at the CRC for Temperate Hardwood Forestry has shown that on most recently cleared forest sites, mineralisation (release from soil organic matter) is sufficient to maintain concentrations of nitrogen that can sustain high growth rates of plantations during the first two years. Application of nitrogen fertiliser is generally only needed at a plantaion age of three years or older.



Microelectrodes for measuring nitrate and ammonia concentrations near the root tip for an E. nitens seedling

In addition, pioneering work is being undertaken on the uptake of nitrogen by eucalypt roots. A new technique is being employed which uses microelectrodes sensitive to individual ions. The microelectrodes are oscillated between two radial positions very close to the root surface in a nutrient solution. Differences in the concentrations of each of the two important nitrogen containing ions (nitrate and ammonium) at these two positions indicates the rate of uptake by the root.

Measurements on roots bathed in ammonium nitrate solutions of different concentrations revealed a complex relationship between the external concentration of ammonium and nitrate and uptake of these ions by young *E. nitens* roots. The results indicate that there are at least two distinct phases of ammonium and nitrate uptake by young *E. nitens* roots, and suggest that N supplied as ammonium will be taken up more rapidly than if it were supplied as nitrate. Further, in some combinations of concentrations, nitrate uptake may be suppressed in the presence of ammonium.

These results point to ammonium as the preferred source of nitrogen for *E. nitens*. Therefore the most appropriate fertiliser to apply is urea which, soon after application, is converted to ammonium. Urea is also cheaper, and has less of an acidifying effect on the soil, than alternative ammonium fertilisers.

Controlling insect pests

The *Eucalyptus* leaf beetle, *Chrysophtharta bimaculata*, can consume up to 50% of the new leaf growth produced by a eucalypt plantation in a single year, and by reducing stand productivity, may increase by 2 to 5 years the time taken for a plantation to reach a harvestable size. The resulting delays in return on investments in plantations reduces the profits forest companies make. Therefore, finding a mechanism for controlling the *Eucalyptus* leaf beetle is important to industry.

Field experiments conducted by the CRC for Temperate Hardwood Forestry have shown that *E. regnans* is more susceptible than *E. nitens* to feeding damage by the *Eucalyptus* leaf beetle when the two species are planted side by side. Genetic differences also exist between families (trees with the same mother i.e. grown using seed from the same tree) of both these species in the degree of insect damage incurred.

The variation in susceptibility of eucalypts to leaf beetle attack was not due to plant factors influencing larval growth and survival (antibiotic factors) for two reasons. Firstly, larval growth and survival in laboratory experiments was greater on *E. nitens* foliage than *E. regnans* although this was not reflected in field damage. Secondly, in the field larval growth and survival did not differ on *E. regnans* trees of known differences in susceptibility.

In contrast, plant factors affecting the choice of a site to lay eggs (antixenotic factors) were shown to be strongly linked with variation in susceptibility to *Eucalyptus* leaf beetle attack. *E. regnans* shoots were preferred over *E. nitens* shoots as sites for egg laying. This response appeared to be linked to the preferential laying of eggs by female beetles on young, expanding leaves, and this trend could be reversed by manipulating the age class of leaves. *E. regnans* carries a greater proportion of young leaves, and leaves mature much more slowly than in *E. nitens*, so *E. regnans* is preferred for egg laying. Further, when a range of *E. regnans* families was assessed the final damage score was strongly correlated with the size of the initial egg lay and large differences existed between families. This indicates that susceptibility to damage was under strong genetic control, and strongly associated with the suitability of leaves for egg laying.

The Eucalyptus *leaf beatle,* Chrysophtharta Bimaculata

There are two important outcomes from these studies. Firstly, there is a possibility of breeding trees with greater insect resistance. Secondly, *E. regnans* (which is not a preferred species for eucalypt plantations) can be planted within an *E. nitens* plantation (a preferred plantation species) to deflect insect damage away from the commercial species. The higher concentrations of insects on the 'trap trees' will also make it easier to control insect pest outbreaks.

Cooperative Linkages

Strategy for developing cooperative linkages

1. Sharing of research trials

Most CRC research is conducted using company trials, or trials established on company land. Existing base population trials of *E. globulus* and *E. nitens*, established on company land before the advent of the CRC, have been fundamental to the quantitative genetic analyses of these species and have led to determination of breeding values (value as a parent) and genetic parameters (heritability of advantageous characteristics). Subsequently, genetics trials on inbreeding and hybrid breeding have been established on company land and are maintained by company partners. Similarly, fertiliser and cultivation trials which were established on company land at the outset of the CRC with assistance from the partners are now a major resource in the research conducted in Soil and Stand Management projects. These have led to recommendations on the use of excavators, cultivation, and the rates and timing of fertiliser applications (see Utilisation and Application of Research). The Resource Protection program has also relied on provenance and family trials established by the CRC partners for its research into genetic differences in susceptibility to insect predation.

2. Sharing of equipment and facilities

To assess genetic trials for wood properties, the Genetic Improvement program has relied on its close relationships with companies and the CRC for Hardwood Fibre and Paper Science (CRC-HFPS) to provide pulping facilities and Near Infrared Reflectance Analysis (NIRA, an indirect measure of kraft pulp yield) technology. The companies have also gained greatly from access to the sophisticated 'Mixed Model' technology developed by the CRC for quantitative analyses of genetics trials.

The gas chromatograph mass spectrometer at the Central Science Laboratory of the University of Tasmania has been of key importance in research on hormonal control of flowering in eucalypts.

CSIRO/CRC facilities for analysis of nutrients (particularly N and P), water relations and photosynthesis, have been of fundamental importance to the progress made by the CRC in the Soil and Stand Management program. The Integrated Pest Management Program, developed by Forestry Tasmania, was an important piece of technology contributed to the Centre which has been advanced greatly by the Resource Protection program during the life of the Centre.

3. Newsletter and news sheet

Linkages are maintained by several means in addition to the shared scientific experiments and equipment. A quarterly newsletter 'Overstorey' which describes CRC activities and provides updates on personnel changes is distributed throughout the CRC. A news sheet, 'Hot off the seedbed' informs partners of new scientific developments in the Genetic Improvement program. Phone, fax, E-mail and informal visits to company operations are also important in maintaining CRC linkages. The CRC organises seminars, field days, workshops and short courses which keep the contributing organisations in regular contact with scientific developments (for details see Utilisation and Application of Research).

The linkages each project has with partners and other projects, as well as links that exist with other organisations both nationally and internationally, are presented in Table 1 (below).

Table 1	CRC staff	Collaborator(s)	Research
Genetic Improvement **Project 1** **Strategies for breeding and deployment**	**Within Centre links**		
	Nuno Borralho	North Forest Products	Gains of different clonal options for deployment of improved *E. nitens*
	National links		
	Nuno Borralho	STBA	Cooperative Breeding Program
	Nuno Borralho	NSW Agriculture	Analysis of genetic trials using auto correlation spatial models
	Nuno Borralho	QFRI, ANU, and Hyne and Son	FWPRN & D Project coordinated by QFRI - Breeding objectives for sawn timber in pines
	International links		
	Nuno Borralho, consultant	Cooperativa de Mejoramiento Genetico (Chile)	Prediction of breeding values and development of breeding strategies in *Pinus radiata*
	Nuno Borralho, consultant in a PEDIP (major EC research grant)	Sociedade Portuguesa de Celulose (SOPORCEL)	Development of breeding strategies in eucalypts
	Nuno Borralho, consultant	Jaakko Pöyry/Indah Kiat Pulp and Paper	Selection strategies for Indah Kiat breeding program
	Nuno Borralho, consultant	Fletcher Challenge Forests	Selection of second generation clones
Project 2 **Wood properties**	**Within Centre links**		
	Carolyn Raymond, Bruce Greaves Allie Muneri	ANM Corporate Research Division (Bob Cox, Paul Banham)	Pulping technology
	Carolyn Raymond Bruce Greaves	Amcor Research and Technology Centre (Allan Farrington)	Develop a pulp mill model for definition of breeding objectives
	National links		
	Carolyn Raymond	CRC for Hardwood Fibre and Paper Science (CRC-HFPS)	Investigation of wood properties in breeding programs
	Carolyn Raymond	CSIRO Forest Products Laboratory, Clayton	Organisation of collaborative research programs with CRC-HFPS and CR-CTHF
Project 3 **Molecular genetics**	**Within Centre links**		
	René Vaillancourt, Brad Potts, Heidi Dungey Caroline Mohammed	CSIRO and Dept. of Ag. Sci., Univ. Tas and North Eucalypt Technologies	Develop a bioassay and begin the genetic study of *Mycosphaerella* resistance in *E. globulus*
	Peter Bundock, René Vaillancourt, Jean-Noël Ruaud,	North Eucalypt Technologies	Find molecular markers for rooting ability in *E. globulus*
	National links		
	René Vaillancourt	S. Read, CRC-HFPS	Map cambial-expressed genes
Project 4 **Genetic parameters**	Brad Potts	Projects 1, 3 and 6	Quantitative genetics, molecular genetics and inbreeding

	CRC staff	Collaborator(s)	Research
	Brad Potts Paul Tilyard Craig Hardner	North Eucalypt Technologies, Forestry Tasmania and Boral Timber	Establishment of trials on inbreeding
	Brad Potts	North Eucalypt Technologies, ANM Forest Management	Review of reproductive biology of *Eucalyptus* and application to breeding
	Brad Potts	Resource Protection Program	(i) Control of sawfly damage on *E. globulus*, (ii) the inheritance of susceptibility to possum browsing, and (iii) phytochemcial studies on eucalypt pest interactions
	National links		
	Brad Potts Greg Dutkowski Nuno Borralho	STBA	Estimation of genetic parameters in base population trials of *E. globulus* and *E. nitens* and the genetic control of self sterility
	Brad Potts	Peter Ades and Angus Carnegie, University of Melbourne	Study of the genetics of *Mycosphaerella* spp resistance
	Brad Potts, Greg Dutkowski, Nuno Borralho	A.E. O'Connor Pty Ltd and STBA	Estimation of genetic parameters and breeding values for flowering time in *E. globulus*
	International links		
	Brad Potts Peter Gore	Cooperativa de Mejoramiento Genetico (Universidad Austral de Chile, Valdivia, Chile)	Production of a manual on controlled crossing of *E. globulus* and *E. nitens* (in Spanish)
Project 5 **Vegetative propagtion**	**Within Centre links**		
	Jean-Noël Ruaud	North Eucalypt Technologies, sole industry partner with tissue culture facilities	Micropropagation and somatic embryogenesis
	Jean-Noël Ruaud	Project 3 and North Eucalypt Technologies	Finding molecular markers for rooting ability in *E. globulus*
Project 6 **Breeding systems and development**	**Within Centre links**		
	Jim Reid Craig Hardner	Projects 1, 3 and 4	Quantitative genetics, molecular studies and genetic parameters
	National links		
	Jim Reid	Mike Moncur, CSIRO Forestry and Forest Products, Canberra	Hormonal control of flowering
	Craig Hardner Nuno Borralho	Animal genetics and breeding unit, Univ. of New England	Accounting for inbreeding in 'Mixed Models'
	Craig Hardner	North Eucalypt Technologies	Inbreeding depression in *E. nitens*
Soil and Stand Management **Project 1** **Plant production and water use**	**Within Centre links** Chris Beadle Neil Davidson	Project 3, Univ. of Tas., Forestry Tasmania, North Eucalypt Technologies, Amcor, Boral Timber and ANM Forest Management	Management of vegetation competition in commercial tree plantations

	CRC staff	Collaborator(s)	Research
	Chris Beadle	ANM Forest Management	Scheduling irrigation in eucalypt plantations
	Chris Beadle Libby Pinkard Jane Medhurst	Forestry Tasmania, Boral Timber	Development of thinning regimes for *E. nitens* plantations for sawn timber
	Charlie Turnbull	Project 4 and all partners	Development of empirical relationships for closed canopy leaf area index (LAI) in response to environmental and site factors.
	National links		
	Chris Beadle	CRC-HFPS and CSIRO Forestry and Forest Products	Impact of available water on wood quality, cambial development and diameter growth of *E. globulus* and *E. nitens*
	Chris Beadle Neil Davidson	Marilyn Ball, Dept of Environmental Mechanics RSBS, ANU	Effects of photoinhibition and chilling on growth of plantation eucualypts
Project 2 Dynamics of carbon and nutrients	**Within Centre links**		
	Robin Cromer	Project 3	Nitrogen and phosphorus concentrations in soils and plant tissue
	National links		
	Robin Cromer Ann LaSala Charlie Turnbull	ANM Forest Management, North Eucalypt Technologies and Boral Timber	Establishment, measurement and maintenance of experimental sites
	Robin Cromer	Shell Australia, Forest Research Institute, Qld	Data analysis and modelling of past collaborative trials with CSIRO
Project 3 Nutrient supply and acquisition	**Within Centre links**		
	Philip Smethurst Trevor Garnett	Ian Newman and his group in the Physics Dept., Univ. Tas	Nitrogen uptake studies using microelectrodes
	National links Philip Smethurst	Phil Moody, Dept Primary Industry, Qld	Use of a nutrient uptake model which incorprates soil solution P, P buffer power and root characteristics to evaluate P availability in several crops
Project 4 Modelling plantations systems	**Within Centre links**	all industrial partners and Univ. NSW	
	Mike Battaglia Peter Sands		Preparation of model to predict site productivity
	Mike Battaglia	Projects 1 & 3	Preparation of models on stomatal function and water use, and uptake of nutrients
	International links		
	Peter Sands	Annikki Mäkelä, Helsinki University, Finlan	Forest growth modelling

	CRC staff	Collaborator(s)	Research
	Peter Sands	Alex Shashkin, Institute of Forest and Wood, USSR Academy of Science, Krasnoyarsk, Russia	Forest growth modelling and cambial activity
	Peter Sands	Harold Fritts, Laboratory of Tree-Ring Research, Tuscon, Arizona, USA	Forest growth modelling and cambial activity
	Peter Sands	Eberhard Voit, Medical University of South Carolina	Forest growth modelling
	Peter Sands	Richard Waring, Dept of Forest Science, Oregon State University	Forest growth modelling, remote sensing of roductivity and soil and forest properties
Resource Protection **Project 1** **Leaf and tree factors influencing host location and attack by insects**	**Within Centre links** John Madden	Projects 2 and 4	Control of insect defoliators and other insect pests
	John Madden	Forestry Tasmania & North Eucalypt Technologies	Attraction of insects by coloured traps and use of trap trees
	National links John Madden	Browsing Animal Research Council	Chairman
	John Madden	Private Forestry Tasmania	Board member
	John Madden	Forest Practices Tasmania	Board member
Project 2 **Control of insect defoliators**	**Within Centre links** All staff	All partners	Integrated Pest Management Program
Project 3 **Vertebrate browsing in eucalypt plantations**	**Within Centre links** Clare McArthur	North Forest Products, ANM Forest Managment	Studies of animal browsing in company plantations
	National links Clare McArthur	Mick Statham, DPI Launceston	Use of animal tracking equipment
	Clare McArthur	Boral Timber	Studies of animal browsing
Project 4 **Biology of other insects pests of eucalypts**	**Within Centre links** Zoltan Lukacs, Tony Clarke	North Forest Products	Autumn gum moth field research
	Tara Simmul, Tony Clarke	North Eucalypt Technologies	Biology of the fire blight beetle
	National links Zoltan Lukacs	Robert Floyd, CSIRO Div of Entomology Canberra	Parasitoids of autumn gum moth
	Martin Steinbauer	Robert Floyd, CSIRO Div of Entomology Canberra	Modelling the distribution of coreid bugs

Genetic Improvement Program

Introduction

The program aims to increase the productivity of plantations by improving the genetic quality of planting stock. This requires two major thrusts. Firstly, it is necessary to identify the characteristics required in plantation trees (breeding objectives) and the existing variation in these characteristics (available genetic resources). Reliable estimates must be made of the inheritance of these characteristics. This information should then be integrated using advanced statistical models so that breeding programs can be effectively managed. Once genetically superior material has been identified, it must be transferred to plantations as quickly as possible either by seed or by vegetative propagation.

Research carried out in the program has made important contributions to our understanding of; (i) economic aspects of breeding and breeding decisions, (ii) relations between wood properties and the end use for the wood, (iii) genetic structure of native and domesticated populations, (iv) inheritance of traits of economic or adaptive importance at the molecular and quantitative level, and (v) the ability to manipulate flowering and vegetative propagation of eucalypts.

Project 1

Strategies for breeding and deployment

Leader

Dr Nuno Borralho

Staff

Mr Xianming Wei

Mr Paul Chambers

Mr Andrew MacDonald

Mr Bruce Greaves

Background

This project aims to more accurately select the elite trees which will be mated to produce the next generation of eucalypt plantations. This involves: (i) clearly defining breeding objectives for the pulp and paper, and sawn timber production systems; (ii) applying improved statistical models to predict the breeding value of a tree (its value as a parent), using all available information across sites, ages and generations; (iii) optimising selection and crossing programs to take into account the economic importance of different traits; and (iv) recognising the genetic and reproductive constraints characteristic of the species.

The project also provides direct support to industry partners in the implementation of results to their breeding and deployment programs.

Outcomes

- A cooperative national breeding program for *E. globulus* and *E. nitens*, has been developed in collaboration with the Southern Tree Breeding Association (STBA). The program, which has been running since 1994 and involves most of the major forest companies in southern Australia, is being managed by STBA staff located in the CRC-THF in Hobart.
- Advanced statistical techniques (mixed models) have been adapted from animal breeding programs and used in the genetic evaluation of trees. These techniques have the capacity to cope with unbalanced data collected from a range of sites, across years and generations, and greatly improve the accuracy of selection for any particular trait or set of traits. The models have also been improved to take better account of thinning, native population structure and non-additive genetic effects, and are now being applied in a number of breeding or deployment programs in Australia (e.g. STBA, NFP, Amcor) and overseas (as a result of collaboration and consultancy work).
- The project coordinated and compiled the databases for the two large *E. globulus* and *E. nitens* breeding populations tested in Australia. This includes pedigree (parentage) and race (a natural population that has evolved distinct characteristics) information, links between over 80 trials and data on survival, growth, wood density and bark thickness for over 150,000 trees. Data include trials from our industry partners, and

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organisations around the world (New Zealand, Chile, Portugal and Spain). The database is now being used by the STBA and industry partners in their genetic evaluations.

- A general forest and pulp mill production model was developed, based on inputs of wood volume, wood density, pulp yield and stem straightness. The model is being applied to define breeding objectives for chemical pulpwood production in a number of breeding programs (e.g. STBA). The main outcome has been the identification of wood density as an important trait in current selection programs.

Nuno Borralho amongst seedlings in a genetics trial at the University of Tasmania

Goals

- Refine breeding and deployment strategies for pulp and paper and sawn timber by comparing (i) 'Mixed Models' (BLUP) analyses of overlapping generations, which include inbreeding, with (ii) traditional index selection using discrete generations.
- Improve software for selection and crossing programs.
- Transfer to industrial partners the new 'Mixed Models' procedure for selecting elite *E. globulus* trees from base populations. This procedure will account for age, site and race effects, differential inbreeding across families and co-ancestry between native stands.
- Determine the optimum age for selection of pulp and paper properties in *E. nitens*.
- Determine the improvement in the accuracy of predicted breeding values from using 'Mixed Models' which account for spacing and competition.
- Review strategies for deployment of *E. nitens* and *E. globulus* including clonal options, seedling and clonal seed orchards.
- Determine the reliability of breeding values obtained for *E. globulus* using data from international plantations, and its implications for international exchange of genetic material.

Project 2

Leader

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Staff

Dr Allie Muneri

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Mr Jason Lawson

Wood properties

Background

This project provides a direct linkage between the CRC for Temperate Hardwood Forestry (CRC-THF) and the CRC for Hardwood Fibre and Paper Science (CRC-HFPS) allowing for ideas and new technology to pass between the Centres and the establishment of joint projects. The work in CRC-THF has concentrated on:

- defining the relationship between wood, pulping and paper properties;
- developing non-destructive sampling strategies for wood and fibre properties;
- determining the feasibility of altering wood properties by breeding or silviculture.

Implementation of technology developed at the CRC-HFPS, such as SilviScan and Near Infrared Reflectance Analysis (NIRA, an indirect measure of kraft pulp yield), is a feature of this project and research has been conducted in collaboration with the pulping laboratories of the industry partners.

Carolyn Raymond (left) and Jason Lawson preparing wood samples for Near Infrared Reflectance Analysis (NIRA)

Outcomes

- The economic relationship between the cost of producing unbleached kraft pulp and the biological traits of tree growth, stem straightness, wood density and pulp yield has been modelled and used to develop a breeding objective and economic weights for a new kraft pulp mill.
- Strategies for non-destructive sampling for basic density have been developed for *E. globulus* and *E. nitens* based on studies of longitudinal (lengthwise) variation within trees. Sampling recommendations have been provided to industry and implemented immediately. Identical work on sampling for fibre length, fibre coarseness and NIRA for *E. globulus* and *E. nitens* is nearing completion.
- The relationship between basic density, fibre length, fibre coarseness and paper strength has been established for cold soda pulping.
- Age-age correlations and heritabilities for wood density (from SilviScan) and NIRA have been determined for *E. nitens*. NIRA was found to be both repeatable and heritable, indicating that the screening of genotypes is feasible.

Goals

- Complete sampling recommendations for fibre length, fibre coarseness and NIRA in *E. globulus* and *E. nitens*.
- Core sample *E. globulus* breeding trials across southern Australia to determine genotype by environment interactions for basic density and NIRA.
- Determine the effect of fertiliser treatments on basic density and NIRA.

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Project 3

Leader

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Staff

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Dr Brad Potts

Dr Dorothy Steane

Mr Peter Bundock

Ms Alexandra Mitchell

Ms Katherine Nesbitt

Mr Timothy Eldridge

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Ms Eleanor Loughhead

Mr Matthew Hayden

Mr Martin Tyson

Molecular genetics

Background

The objectives of this project are to:

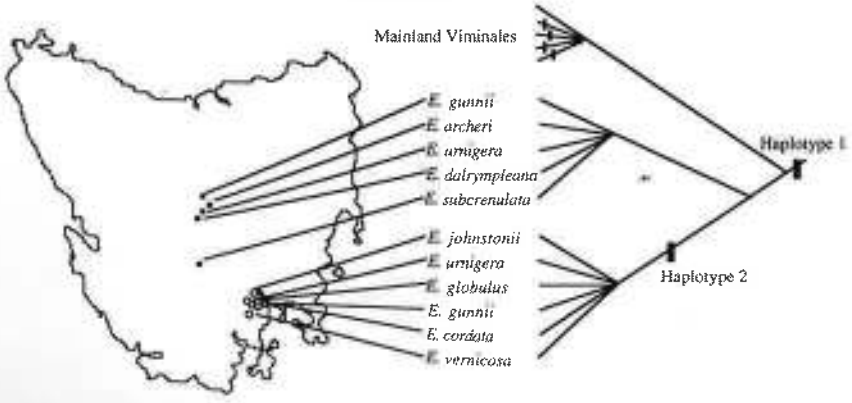
- develop molecular markers (simply inherited traits which distinguish underlying genetic differences) that can be used for fingerprinting, even at the seedling stage;
- develop DNA markers for selected elite trees in breeding programs using Marker-Assisted Selection (MAS);
- use DNA markers to study population biology and species relationships within *Eucalyptus*.

Outcomes

- A sparse linkage map (a representation of the distance between genes or markers on chromosomes) was constructed using an intra-provenance *E. globulus* F_1 cross. One Quantitative Trait Locus (QTL) was detected for growth, a crucial test of MAS in a closely related cross. The effect of this QTL changed with environment. This is the first discovery of a QTL by environment interaction in *Eucalyptus*.
- Molecular markers were used to reconstruct phylogenetic relationships between the subgenera of *Eucalyptus* and *Angophora*. This research was well received by the taxonomic community, and cited in three major reviews of *Eucalyptus* phylogeny.
- Chloroplast DNA polymorphisms were shared among many species of series *Viminales*, indicating that hybridisation may be more important than expected.
- DNA fingerprinting of a population of *E. risdonii* x *E. amygdalina* hybrids regenerating from lignotubers showed many individuals to be of clonal origin, and one clone was unexpectedly large, which led to a major re-assessment of the age of these mallee eucalypts.
- Genetic distance from Random Amplified Polymorphic DNA markers (RAPDs) was related to pedigree distance (genetic distance between parents). This result will prove useful to breeders selecting among trees of unknown relationship.

Goals

- Improve the *E. globulus* x *E. globulus* linkage map.
- Find molecular markers for rooting ability and deploy the clones in a field trial.
- Map genes which are expressed in cambial cells onto the *E. globulus* map in collaboration with S. Read, CRC-HFPS.
- Develop a bioassay to study resistance to *Mycosphaerella* infection in *E. globulus*.
- Complete an isozyme survey of *E. globulus*.
- Determine the genetic distance between the parents in the *E. globulus* proximity dependent crossing scheme.
- Develop microsatellite DNA markers.
- Continue the study of relationships in the series *Viminales* using nuclear genes.



Chloroplast DNAs of Tasmanian eucalypts appear to fall into two distinct haplotypes, corresponding to their geographic location. This may indicate the occurrence of complex interspecific hybridisation patterns within geographic regions.

Project 4 Genetic parameters

Leader

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Mr Paul Chambers

Mr Paul Tilyard

Ms Helena Nermut

Dr Wayne Tibbits

Background

This project provides the fundamental information on quantitative genetics necessary for effective exploitation of the potential of forestry species for breeding and assessment of breeding options. It specifically aims to:

- provide basic information on genetic variation and inheritance (genetic parameters) for traits of economic and biological importance;
- determine the reliability of genetic parameter and breeding value (value as a parent) predictions derived from open-pollinated progenies;
- provide the biological and genetic information necessary to assess the role of interspecific hybrids in eucalypt breeding;
- identify and provide specialised, pedigreed genetic material to support molecular and quantitative genetic studies.

Helena Nermut sorting E. globulus litter collected in litter-traps from a range of localities

Outcomes

- Genetic parameters have now been estimated for growth, survival, frost and *Mycosphaerella* resistance, pilodyn penetration and flowering time in *E. globulus* and *E. nitens*.
- Open-pollinated progenies have consistently provided poor estimates of genetic parameters, and breeding values for growth traits and age-trends in these parameters differ markedly from controlled crosses in the first four years of growth.
- Indirect measures of wood density using Pilodyn showed relatively large race effects (i.e. natural populations that have evolved distinct characteristics), were moderately heritable, showed little site x genotype interaction, but often adverse genetic correlations with growth.
- Multivariate mixed model procedures may overcome bias in genetic parameter estimates induced by thinning or size-dependent mortality.
- Combining the information from clonal trials and full-sib progeny tests in 'Mixed Models' markedly improved genetic parameter estimates.

Goals

- Continue studies on the genetic control and genotype x environment interactions for key traits in *E. globulus* and *E. nitens* base trials in Australia and overseas. Traits currently being investigated include growth, flowering intensity and time, vegetative phase change, pilodyn penetration, bark thickness and susceptibility to sawfly damage.
- Revise the racial classification of *E. globulus*.
- Detail the performance and genetics of interspecific F_1 and advanced generation *E. nitens* x *globulus* and *E. gunnii* x *globulus* hybrids.
- Complete studies of eucalypt hybrid-pest interactions.

Loading advanced generation hybrids (E. globulus x E. nitens) *for transfer to a North Eucalypt Technologies field site in Northern Tasmania*

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Project 5

Leader

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Staff

Mr Keith Churchill

Mr Scott Pepper

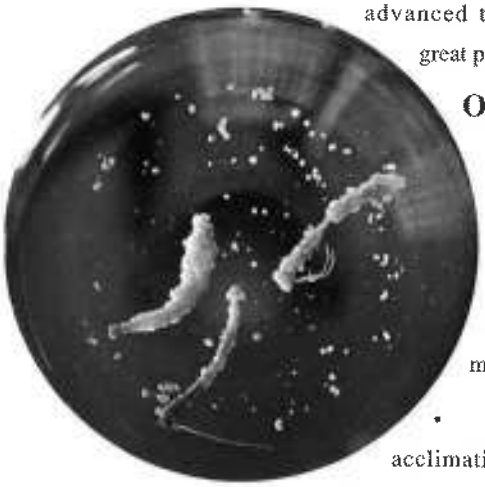
Ms Gillian Rasmussen

Vegetative propagation of selected genotypes

Background

There is great potential for the development of clonal forestry in temperate eucalypts. However, conventional propagation methods (stem cuttings) are usually not cost effective, and alternative techniques are being developed to overcome this problem. The aim of this project is to further develop techniques in tissue culture and somatic embryogenesis which will allow rapid deployment of new genetic selections.

An improved micropropagation procedure (IMP) has been developed. Somatic embryogenesis has advanced to the globular stage, and has great potential.



Globular somatic embryos of E. nitens *generated from hypocotyl tissue*

Outcomes

- IMP technology was transferred to one industry partner (North Eucalypt Technologies), and is currently being evaluated and compared with the existing micropropagation system.
- Advances in rooting and acclimation of clones arising from IMP allowed a simpler and cost-effective testing procedure to be developed for rooting ability. Plants arising from this procedure will be planted in the field in early spring.
- The genetic control of rooting ability was shown to be high with a heritability of around 0.4 and a proportion of dominance of 0.2.
- Somatic embryogenesis has been successfully induced to the globular stage in both *E. nitens* and *E. globulus*. This is the first report for both species. The induction, which takes place in liquid medium, is very efficient and somatic embryos can be multiplied. However reliable maturation (development of embryos from the globular stage up to a stage equivalent of a zygotic embryo in a ripe seed) is still to be achieved.

Goals

- Compare the zygotic and somatic embryogenesis process at the cellular (histological analysis) and molecular level (biochemical analysis of endogenous growth regulators) to assist in understanding the blockage in somatic embryo development.
- Find molecular markers for rooting ability in *E. globulus* (in collaboration with Project 3 and North Eucalypt Technologies).
- Complete studies on the heritability of rooting ability.

A screening experiment on rooting ability of E. globulus *cuttings*

Project 6

Leader

Prof Jim Reid

Staff

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Mr Craig Hardner

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Mr Dean Williams

Ms Ria Matysek

Breeding systems and development

Background

The aims of this project are to:

- develop an understanding of the control of flowering in *E. globulus* and *E. nitens*. In particular, identify the role of hormones in combination with the effects of environmental factors in promoting flowering;
- determine the role of the plant hormones abscisic acid, gibberellins (GA) and auxin (IAA) in seasonal variations in growth and development;
- investigate how inbreeding is influenced by the stand structure of the parent trees, and how inbreeding effects may affect the estimation of genetic parameters (inheritance), the prediction and capture of genetic gain from selection if made using inbred progeny, and the management of breeding populations;
- examine the factors influencing the level of outcrossing in *E. globulus* in order to better manage seed production in seed orchards.

E. globulus *in flower*

Outcomes

- Abscisic acid (ABA) levels in young shoots appeared to be correlated with the water potential. In contrast, GA_1 levels were relatively constant, except in mid-winter, probably due to feed-back regulation. IAA levels were positively correlated with growth rate .
- The effects of the gibberellin biosynthetic inhibitors paclobutrazol, prohexadione and CCC on flowering were compared but only a low flowering response was obtained.
- A tentative pathway for paclobutrazol catabolism has been formulated and microorganisms capable of metabolising paclobutrazol have been isolated from soils (Jackson *et al.* 1996).
- Two stages of differential selection against inbred progeny have been identified, within three months of planting (the establishment phase) and when the plantation is older than four years (after intense competition has developed). Failure to account for the higher mortality of inbreds will underestimate the impact of inbreeding.
- Estimates of heritability of open pollinated families were inflated up to an age of four years. However, this declined with age to converge with estimates from outcrosses thereafter.
- Isolated trees have lower outcrossing rates than trees in continuous stands, resulting in a bias to breeding values because of inbreeding depression. Hence OP families should be used with caution in eucalypt tree breeding programs.
- In *E. nitens* the levels of inbreeding depression and dominance variation for growth traits are similar to other eucalypt species and generally larger for flower production and bark thickness. However, these genetic effects are absent for Pilodyn penetration.

Goals

- Find alternatives to paclobutrazol as a promoter of reproductive activity and report on the best location for seed orchards to maximise seed production and reduce generation intervals.
- Investigate the genetic control of inbreeding depression and self fertility and the factors affecting outcrossing rates.
- Determine the effect of different levels of co-ancestry on seed set and early growth in *E. globulus*.
- Determine the genetic control of flowering in *E. nitens*.

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Soil and Stand Management Program

Introduction

The Soil and Stand Management program aims to develop silvicultural management and planning tools which will optimise the economic return to forest growers from their investments, while ensuring that management practices are sustainable over future rotations. In order to achieve this, research projects have been developed to examine forest growth and yield in relation to environmental factors, particularly temperature, the availability of water and nutrients and soil physical properties. These studies will allow description of the functioning of plantation ecosystems in quantitative terms and, using modelling procedures, simulate outcomes from alternative management systems.

Project 1

Plant production and water use

Leader

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Dr Greg Holz

Mr Bill Neilson

Mr Geoff Dean

Background

This project aims to improve cultural practices and productivity of plantations for pulpwood and sawn timber through an understanding of the physiological responses of eucalypts to environment and silvicultural practices. The photosynthetic, water-relations and water-use characteristics of eucalypts, particularly the key forestry species *E. globulus* and *E. nitens*, are measured in the context of the production of leaf area and biomass. The environmental variables investigated include water, temperature, light, macro- and micro-nutrients. The silvicultural practices of irrigation, pruning and thinning, vegetation management and fertiliser practice have each been shown to affect photosynthetic production and are the focus of several studies in the project.

Outcomes

- Increments in stem volume are significantly higher in *E. globulus* than *E. nitens* in the first few years of the growth cycle on frost-free sites.
- Maximum rates of growth are associated with total water use which is similar to pan evaporation.
- *E. globulus* has a higher water-use efficiency for wood production than *E. nitens* during the first few years of growth and is more suited to sites associated with moderate water stress.
- The effects of water stress on daily stomatal conductance can be accommodated by determining the ratio of conductance of stressed trees to that of irrigated trees as a function of the cumulative water stress integral over a preceding number of days.

Don White conducting biomass sampling to determine the relationships between leaf area and sapwood area

- The stomatal responses of *E. nitens* are best described using data for water status from the preceding 20 days, while that of *E. globulus* is best described using the preceding 8 days.
- The removal of live branches during green pruning on high quality sites results in changes in biomass partitioning in the remaining canopy. This suggests that trees can reallocate resources to compensate for loss of foliage. When pruning did not exceed 50% of the canopy length this reallocation was sufficient to prevent growth reduction. However, reallocation of resources was insufficient to compensate for 70% crown removal and a reduction in both height and diameter increment occurred.

- Competition for water from acacia regeneration among eucalypt plantations on high quality sites is minimal in older stands and is unlikely to decrease eucalypt productivity. However, large differences in standing volume of eucalypts with and without acacia competition suggests that intense competition for water or light can occur earlier in the rotation.

Goals

- Develop a simple scheme for scheduling irrigation in eucalypt plantations.
- Evaluate the impact of low temperature and frost on productivity of eucalypts.
- Fully describe the physiological impact of acacia as a weed of eucalypt plantations.
- Provide a physiological basis for fertiliser-induced micro-nutrient deficiencies.

Project 2 Dynamics of carbon and nutrients

Leader

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Staff

Mr Charles Turnbull

Dr Rabi Misra

Ms Ann LaSala

Mrs Linda Ballard

Mr Andrew Gibbons

Mr Martin Tyson

Background

The aims of the project are to:

- investigate the accumulation, allocation and cycling of carbon and nutrients in plantations of *E. nitens* and *E. globulus*, particularly in response to nutrient availability;
- determine the partitioning of biomass and nutrients to roots;
- identify specific nutrient deficiency or toxicity problems that become evident in plantations.

Tree growth in response to nutrition is being studied in five fertiliser trails established in 1992 and 1993 on representative but contrasting sites (in soils and climate) in collaboration with ANM Forest Management (ANM), North Eucalypt Technologies (NET) and Boral Timber (BT). In addition to fertiliser treatments, tree growth data are being analysed in relation to fertiliser treatment, and climatic and edaphic factors. These experiments also provide major field study sites for other projects in the program.

Outcomes

- A substantial response in tree growth to applied N plus P fertiliser occurred at only one site on a sandstone soil in north-east Tasmania (*E. globulus*, BT at Nabowla, 100-240 m elevation). Growth at this site without fertiliser has been poor and response to fertiliser has been significant from 10-34 months. Best tree growth occurred at Westfield (ANM, 430 m elevation) on a siltstone soil but a significant response to fertiliser was evident only at high rates (600:300 kg ha^{-1} N:P, *E. nitens*) and after 34 months. Tree growth on high altitude basalt soil has been poor and there has been no response to N plus P fertiliser (*E. nitens*, NET at Middlesex, 600 m elevation).
- A significant response to N alone (300 kg ha^{-1}) was observed on a dolerite soil (*E. nitens*, BT at Nunamara, 400 m elevation), above the basal dose of N and P at planting (Fig 2).
- The use of NP fertilisers to increase growth has affected trees adversely, and it appears that P is

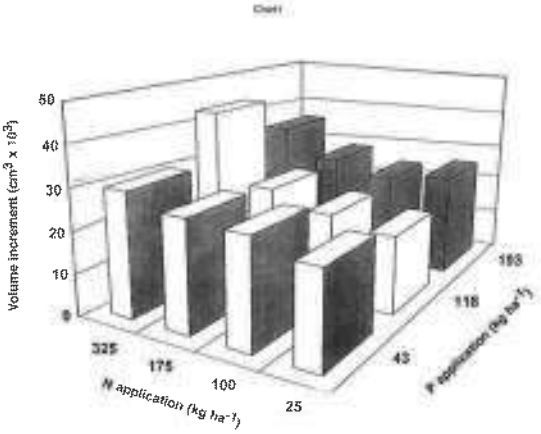

Figure 2 *Increase in volume (cm x 10^3) of three year old E. nitens in response to nitrogen and phosphorus fertiliser (kg ha^{-1}) on dolerite soils at Nunamara. There was no significant response to phosphorous and no interaction between N and P.*

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more detrimental than N. The link between stem deformity and copper deficiency found previously on ex-pasture sites has not been observed for these ex-forest sites.

- Allometric relationships have been derived (in association with Project 1) which will allow total and components of tree biomass to be estimated.
- The relationship between coarse root (>3 mm diameter) biomass and stem volume of *E. nitens* derived from trees aged 10 and 21 months have not changed with inclusion of data from trees aged 32 months. Increasing rate of N plus P fertiliser did not influence biomass density of roots in the medium (1-3 mm diameter) or fine (<1 mm diameter) size ranges at 32 months. Both N and P concentration in fine roots increased with increasing amounts of N plus P fertiliser.
- Trees in the highest fertiliser treatment at Westfield had accumulated a total above-ground biomass of 23 t ha-1 at 34 months, which contained 164 and 17 kg ha-1 of N and P respectively. The usefulness of different biomass components for prediction of response to nutrients is being investigated.

Charlie Turnbull and Ann LaSala measuring E. nitens in a CRC-North Eucalypt Technologies trial at Middlesex, Tasmania

Goals

- The major goal over the next year is to fully analyse tree growth and nutrient data for all the experiments in relation to site and fertilser treatments, and to present these results to the CRC industry partners.
- Estimate temporal variation in biomass and nutrient accumulation in root systems of single trees and determine the relevance of the results for carbon allocation.
- Evaluate effects of N and P fertilisers separately and in combination on stem shape (deformity) of *E. nitens* and *E. globulus* trees. Determine the significance of early stem deformity for solid wood production.

Project 3 Nutrient supply and acquisition

Leader

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Ms Paulina Teixeira

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Dr Greg Holz

Mr Chris Oliver

Ms Sandra Hetherington

Mr Peter Naughton

Ms Silvia Pongracic

Background

The aims of this project are to:

- determine nutrient supply characteristics of the major soil types on which eucalypt plantations are commonly grown;
- determine the factors controlling nutrient acquisition by tree roots, particularly nitrogen (N) and phosphorus (P);
- improve the management of nutrients, particularly fertiliser application, to increase the productivity and profitability of plantations.

Outcomes

- Tree growth data and N availability measurements from several Tasmanian sites indicate that N supply is often adequate to support high growth rates of *E. nitens* up to 2 or 3 years after planting (Fig 3), but trees on some soils may need fertilisation 'at-planting' with N as a spot to stimulate early development of the root system. In older plantations (3 to 6 years old) we have identified an opportunity to substantially increase growth rates on a variety of soils using N fertilisation.
- Although spot applications of P fertiliser will be needed on most ex-forest sites, P applications were not necessary to achieve the later-age response to added N.
- Field and pot studies indicate that eucalypts are more efficient than most other types of plants at taking up P in soils that have only low concentrations in the soil solution.
- Analyses of tree growth in several cultivation experiments has brought into question the widespread practice of ripping. If it was discontinued it could provide considerable cost savings without significant detrimental effects on wood production.
- Short-term laboratory studies with well aggregated soils have shown a progressive increase in root development of eucalypts with decreased soil strength (penetrometer resistance). Hence, (a) there does not appear to be a critical value of soil strength which will stop root elongation in these soils, and (b) cultivation is likely to favour

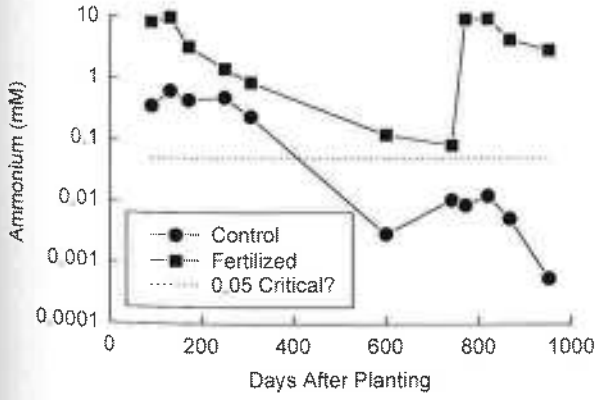

Figure 3 The effect of N fertiliser (applied on days 70 and 750) on the concentration of ammonium in soil solution (0-10 cm depth) in an E. nitens plantation during the first 3 years of growth.
Implications: *During the first 2 years, rates of N mineralisation were sufficient to meet the tree's requirements. Significant growth responses only occurred after the second application of fertiliser when concentrations of ammonium derived from N mineralisation dropped below 50 mM, a concentration which, from solution culture studies, is suggested as the minimum needed to maintain high rates of N uptake and growth.*

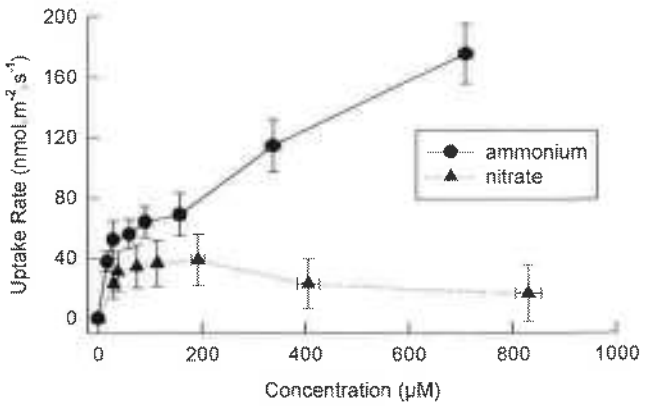

Figure 4 *The uptake of nitrate and ammonium by young E. nitens roots bathed in ammonium nitrate solution of different concentrations. Ammonia and nitrate were measured simultaneously using microelectrodes at the root tip. Bars are standard errors, n = 5.*

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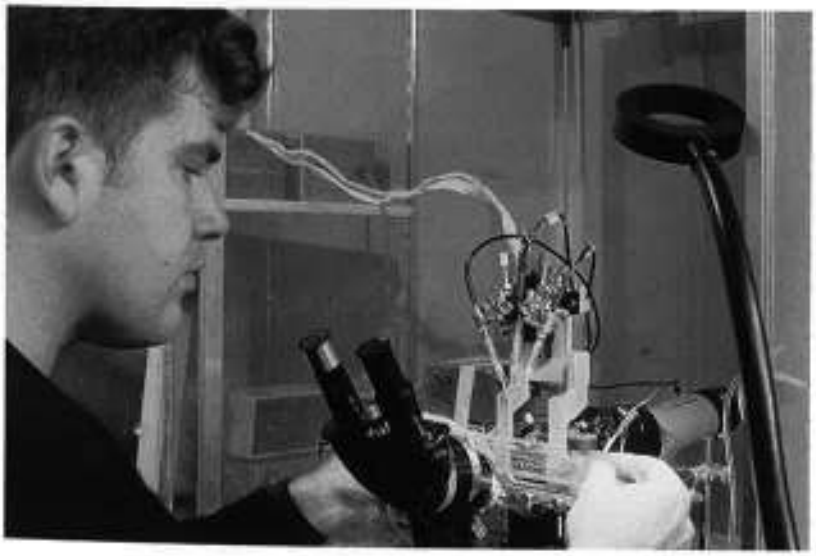
root growth by, among other factors, promoting root growth until the strength of the cultivated zone increases with settling and becomes similar to that of the uncultivated zone.

- Ammonium has been shown to be the preferred N source for *E. nitens* (Fig. 4).

Goals

- Quantify the changes in soil solution N and P that occur during the first 4 years of tree growth in typical plantations so that these concentrations can be evaluated as indicators of nutrient limitations to tree growth.
- Compare the proposed critical concentrations of soil solution P with those of more commonly used soil P analyses and evaluate the degree to which the method can be transferred to a range of soil-types.
- Identify a simple and useful index of N mineralisation.
- Describe root system development during the first 3 years in a rapidly growing *E. nitens* plantation.
- Define relationships between slope, rainfall intensity and erosion for several plantation soils.



Trevor Garnett adjusts microelectrodes for measuring nitrate and ammonium concentrations of root tips

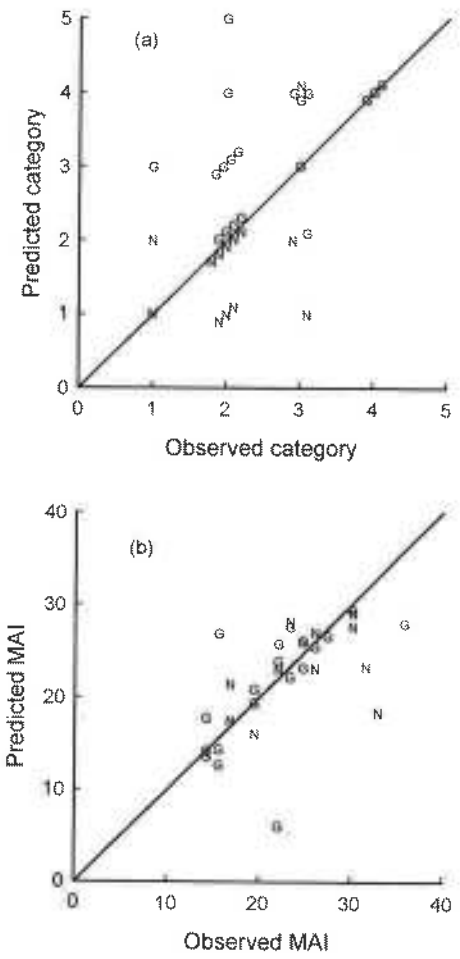


Figure 5 *Comparison of the predicted site productivities for 32 sites in NE and NW Tasmania obtained using: (a) the existing Forestry Tasmania system, and (b) the new SSM canopy production model. The new model predicts productivity more successfully. Species are* E. globulus *(G) and* E. nitens *(N). The lines are 1:1 relationships.*

Project 4

Leader

Dr Peter Sands

Staff

Ms Susan Lennon

Dr Mike Battaglia

Modelling plantation systems

Background

The project aims to produce process-based models that can be used as management tools for predicting plantation yield in response to environmental, site and silvicultural factors. As comprehensive process-based models of plantation growth and development are complex and require input data which are not readily available, the work of the project is focusing on simple models which combine the empirical and process-based approaches but require only readily available input data.

Outcomes

- A model developed earlier for estimating daily canopy production from standard meteorological data and parameters of the single-leaf light response is now being applied in a simple model of site productivity which also employs simple empirical relationships for leaf area index (LAI) after canopy closure. The site productivity model provides a sound basis for predicting site quality (Fig. 5).
- A review of forest growth models according to their intended use has been completed and provides guidelines for the structure of models for specific applications.
- A model for seed germination rate in response to soil temperature and water potential has been completed. It provides predictions of field germination in *E. delegatensis*.
- A simple technique for estimating parameters in S-system models has been developed.
- Stem sections obtained from *E. nitens* seedlings provide useful data on cambial activity in response to temperature and radiation.
- A workshop held in conjunction with the CSIRO Division of Forestry brought together people in industry, CSIRO and the University of New South Wales to enhance the development and application of models in a forestry context. It also provided an overview of work in progress and strengthened communication and collaboration between researchers and industry.

Goals

- Validate the canopy production model in combination with a simple water balance model using data from the CSIRO eucalypt plantation at Lewisham.
- Measure closed-canopy LAI at diverse sites and determine empirical relationships for closed-canopy LAI in response to environmental and site factors.
- Establish techniques for using ESOCLIM to generate realistic synthetic meteorological data.
- Complete development of the site productivity model and demonstrate its use to industry.
- Determine effects of light and temperature on cambial activity from stem sections of *E. nitens* seedlings.

Resource Protection Program

Introduction

Invertebrate research in the Resource Protection program has been directed toward reducing dependence on pesticides through the development of environmentally sensitive strategies for the effective management of major insect pests of native and plantation forestry. A major emphasis has been placed on the implementation and refinement of an Integrated Pest Management program for control of the *Eucalyptus* leaf beetle, *Chrysophtharta bimaculata*. Basic studies on the biology, behaviour and ecology of this beetle and other real and potential pest species have been undertaken to assist in the efficacy of control strategies for specific pests.

Similarly, detailed studies have been initiated on the basic life histories and habits of three major vertebrate browsers, possum, wallaby and pademelon, affecting natural regeneration and plantation seedlings. These studies are providing essential background data for the development of alternatives to poisons such as 1080 for managing damaging populations of vertebrates.

Project 1

Leader

Dr John Madden

Staff

Dr Anthony Clarke

Mr Bradley Howlett

Mr Mark Van den Berg

Mr Stephen Paterson

Leaf and tree factors influencing host tree location and attack by insects

Background

The aim of this project is to identify those physical and chemical factors which influence the behaviour of the adult *Eucalyptus* leaf beetle, *C. bimaculata*, in locating, feeding and oviposition on commercial eucalypt species and individual trees within species. A functional understanding of the specific qualities which affect tree susceptibility to attack is essential to the selection of trees less preferred or more resistant to insect attack. Research being conducted includes: the response of flying adult beetles to different coloured traps, phytochemistry of leaf oils and waxes, and responses of *C. bimaculata* adults and larvae to host plant leaf components in comparison with responses to leaf chemicals in agar-cellulose pellets and discs.

Outcomes

- The number of *C. bimaculata* adults caught on different coloured sticky traps was proportional to the percentage of reflection in the 520-560 nm range relative to the total spectral reflectance from 360-760 nm. The reflectance of leaves of species from the eucalypt subgenus *Monocalyptus* shifts through the 520-560 nm region as individual leaves grow and expand during spring-early summer. However, presence of a wax bloom on the majority of species from subgenus *Symphyomyrtus* effectively softens the reflectance of light from the leaves of most species with the notable exception of the new season growth of *E. nitens*.
- *C. bimaculata* adults prefer to feed and oviposit on species from the eucalypt subgenus *Monocalyptus*, but they can also attack the *Symphyomyrtus* species *E. nitens*. Chemical analyses of leaves indicates that the difference in levels of attack on the two subgenera is affected by the oil content of leaves. Oils are present in different relative proportions in the two subgenera but generally in smaller amounts in *Monocalyptus* species, with this subgenus having the monoterpene, phellandrene. *E. nitens* in contrast to most *Symphomyrtus* has very low leaf yields and also contains phellandrene.
- *Monocalyptus* oil yields increased with age while those of *Symphyomyrtus* declined.
- Leaf oil yields were found to differ significantly between genotypes within a species and were positively correlated with tree growth at the individual and family level.
- The susceptibility of *E. regnans* and *E. nitens* to attack by C. *bimaculata* is under genetic control with high heritability.

- Selection of appropriate oviposition sites by female beetles is the most critical factor influencing the subsequent development of larvae.

Goals

- Document changes in leaf colour and pigmentation, and verify phenological differences in the canopy reflectance of commercial eucalypt species through Landsat interpretation.
- Complete bioassay of leaf phytochemistry of commercial eucalypts.
- Publish results of the response of *C. bimaculata* and its major predators to colour traps

Project 2 Control of insect defoliators

Leaders

Dr Anthony Clarke

Dr Jane Elek

Staff

Dr John Madden

Dr Humphrey Elliott

Ms Sue Baker

Mr Steven Candy

Mr Alastair Hunt

Mr Vin Patel

Ms Nita Ramsden

Mr Mark Van den Berg

Background

This project aims to refine the Integrated Pest Management (IPM) strategy currently used to protect eucalypt plantations from defoliation by leaf beetles. The research is directed at:

- determination of the impact of the *Eucalyptus* leaf beetle, *Chrysophtharta bimaculata*, on growth of *E. nitens* and *E. regnans*;
- evaluation of the most effective and environmentally acceptable methods for controlling leaf beetles;
- increasing our understanding of the biology of *C. bimaculata* and its natural enemies.

Outcomes

- In the laboratory, *C. bimaculata* has been shown to have a higher average fecundity and longevity than previously reported.
- Smaller larval populations were developed on *E. nitens* trees that were adjacent to *E. regnans* than in pure *E. nitens* stands, which suggests *C. bimaculata* adults selectively oviposit on *E. regnans*. However, laboratory trials showed that *C. bimaculata* larvae feed more efficiently on *E. nitens*. This means that they eat less and grow faster on *E. nitens* than on *E. regnans*.
- The bioinsecticide, *Bacillus thuringiensis* (Btt), has been shown to have potential for controlling *C. bimaculata*. Using current spray application technology at 6 L ha^{-1}, Btt killed all first instar larvae, about 70% of second instar and fewer older larvae.
- In field trials, Btt had no effect on the population of predators and so spraying Btt is compatible with other biological control measures.

Goals

- Determine the minimum lethal dose and optimum droplet size of Btt for each larval stage and refine the timing of application and delivery systems of Btt sprays.
- Develop an insect impact model for *E. nitens* and incorporate this into the existing IPM strategy.
- Further investigate the potential of the pathogenic fungus, *Beauvaria*, and nematode species for controlling larval and adult *C. bimaculata* in the field.
- Continue research on the basic biology of *C. bimaculata* and its natural enemies.

Aggregation of Eucalyptus *leaf beetle,* Chrysophtharta bimaculata

RESEARCH

Project 3

Leader

Dr Clare McArthur

Staff

Mr James Bulinski

Ms Nadia Marsh

Ms Kathryn Patterson

Mr Stephen Turner

Dr David de Little

Wallaby in a feeding trial at the University of Tasmania

Vertebrate browsing in eucalypt plantations

Background

This project aims to develop methods to reduce the damage to seedlings in plantations caused by browsing vertebrates. Firstly it is necessary to develop an understanding of the ecology of the three principal browsing mammals Bennett's wallaby, pademelon and brushtailed possum to questions about; which animals are responsible, what damage they cause, under what conditions this varies, and why they cause the damage. This information can then be used to provide management options to reduce the damage. In this context, the project has the following main objectives:

- develop a risk-assessment model for predicting damage to plantations using broad-scale characteristics of the plantation and surrounding habitat;
- assess the importance of plantations as feeding areas and of eucalypt seedlings within plantations as a food source for the three main browser species;
- determine the influence of site preparation, plant composition, and browser species on damage to eucalypt seedlings;
- develop planting strategies to reduce damage in plantations, based on feeding preferences of browsers for common forestry species, provenances and cover crops.

Outcomes

- Some positive, linear correlations have been found between damage and relative abundance of pademelons and Bennett's wallabies as measured by scat counts.
- The relative preference between five seedlots of *E. nitens* has been determined for pademelons in captivity, and in the field in two plantations, one in which 1080 poison was layed and one unpoisoned. Field results under both conditions confirm the captive animal preference ranking, and indicate reduced damage under a poisoning regime. One seedlot was significantly more preferred than the others, and one seedlot was significantly less preferred.
- Preferences of brushtail possums consuming foliage, and preferences of possums and pademelons for seedlings, have been determined for some tree species. Possums rank foliage from the following species (from most preferred to least preferred): 1st *E. globulus* (nursery-grown), 2nd *E. globulus* (field-grown) and *E. nitens* (field grown), 3rd *E. delegatensis* (field), 4th *Acacia dealbata* (field), 5th *E. regnans* (field), 6th *A. melanoxylon* (field). Possums rank seedlings from the following species: 1st *E. nitens*, 2nd *E. regnans*, 3rd *A. melanoxylon*. Pademelons rank seedlings: 1st *A. melanoxylon*, 2nd *E. regnans* and *E. nitens*. Hence for these species, possums and pademelons show essentially the opposite preferences.
- Given the different preferences for seedlings demonstrated for possums and pademelons in captivity, the relative population sizes of the browser species feeding in plantations should be an important factor affecting the type and extent of damage to seedlings.

Goals

- Identify any correlation between extent of damage to *E. nitens* seedlings and that of the surrounding vegetation.
- Continue building relative preference list of plants for pademelons and possums.
- Start field trials on relative damage to seedlings in plantations with mixed-species and/or cover crops.

Possum selecting a eucalypt from a mixed seedling menu in a feeding trial at the University of Tasmania

- Compare relative feeding times spent in and out of plantations by the three browser species, and associated damage levels to seedlings.
- Compare the composition of the diets of the three browser species when feeding in plantations.
- Rank preference of possums for *E. globulus*, *E. gunnii* and hybrids, and determine any phenotypic variation due to environmental effects on these preferences.

Stephen Turner preparing food for captive possums in a feeding trial, University of Tasmania

Project 4

Leader

Dr Anthony Clarke

Staff

Dr Martin Steinbauer

Mr Zoltan Lukacs

Ms Tara Simmul

Dr David de Little

Ms Sandra Hetherington

Peter Volker

Dr Mick Statham

Mr Paul Dredge

Mr Peter Naughton

Autumn gum moth larvae

Biology of other forest insects

Background

The aim of this project is to investigate insects other than *Chrysophtharta* which are current or potential pests of native hardwoods. These include: the coreid bugs (genus *Amorbus* and *Acantholybas*), 'sap sucking' insects which attack the growing tips of eucalypts and cause tip-wilt and shrubbing; the autumn gum moth (*Mnesampela privata*) a defoliator which feeds on the glaucous juvenile foliage of blue-gums; and fireblight beetle (*Pygroides orphana*) also a defoliator which feeds on silver- and black-wattle. Results of ecological studies are used to: (i) assess the potential pest status of these insects in plantations and (ii) provide information valuable to the formulation of pest management strategies.

Outcomes

- Work on coreid biology has finished. This project made significant contributions to: the taxonomy of *Amorbus* and *Acantholybas*; understanding the biogeography of eucalypt feeding insects; and understanding host-choice in large, sap-feeding insects.
- The population phenology of *M. privata* has been monitored at sites in south-eastern Australia. The common name, autumn gum moth, is a misnomer, as both summer and autumn populations occur.
- Constant temperature development rates, longevity and diapause potential have been gathered for *M. privata*.
- An APA(I) award was granted to PhD candidate Tara Simmul to study the fireblight beetle, *P. orphana*. The grant is supported by the Tasmanian Forest Research Council.

Goals

- Complete ecological studies on *M. privata*.
- Start a research project on the fireblight beetle, *P. orphana*.
- Conduct an investigation of potential insects pests of *E. globulus* (other than those already investigated), particularly the gum-scale, *Eriococcus coriaceus*.

Education and Technology Transfer Program

Manager

Dr Neil Davidson

Staff

Ms Jane Burrell

Prof Jim Reid

Prof Robert Clark

Prof Robert Hill

Prof Robert Menary

Dr Robert Wiltshire

Ms Kristen Williams

Mr Ross Peacock

Mr Graham Wilkinson

Introduction

The Education and Technology Transfer program organises the intake of post-graduate and honours students and coordinates their supervision across the three research programs, and oversees the allocation of time of CRC research staff to undergraduate teaching in units where their expertise is most valuable. The program coordinates the transfer of technology from research programs to the industry partners, and organises exercises which raise public awareness of the expertise and activities of the Centre. The programs principal objectives are to:

- develop a national centre of excellence for post-graduate training with emphasis on training graduates relevant to the industry sector in the areas of tree genetics, forest protection, and stand management;
- rapidly transfer to the industry partners and other end-users the technology arising from research conducted at the Centre;
- raise public awareness of the CRC's objectives and the high quality and relevance of its research.

Outcomes

Education

- The Centre has 41 PhD, MSc and Honours students currently enrolled; 10 were attracted from industry, 10 are on scholarships with industry support (APA-I, FFIC, LWRDC), and a further 8 are on competitive national scholarships (APA, Science and Technology, AUSAID). Only 13 are supported solely by the CRC (see Table 2 for details).
- Supervision of post-graduate and honours students is widely distributed amongst CRC partner institutions with 20 of the 28 supervisors of honours, MSc and PhD projects being non University staff (see Table 3 for details). Dr N Davidson also coordinates a four-year undergraduate course, 'Forest Ecology', designed for students with an interest in forestry.
- 3 PhD and 2 honours graduates of the CRC have found employment in the forest industry this year (Don White, Mike Battaglia, Heidi Dungey, Joanne Dingle, Martin Tyson).
- There are six CRC scientists, who are not staff of University departments, contributing to University courses in fields allied to their research: Dr A Clarke has presented lectures in Agricultural Entomology, Dr R Misra in Soil Physics, Dr N Davidson in Physiological Plant Ecology, Dr M Battaglia in Quantitative Ecology, Dr P Smethurst in Soil and Nutrition and Dr B Potts in Genetics.
- There are 7 post-doctoral fellows currently working with the Centre: Dr Jean-Noël Ruaud in somatic embryogenesis; Dr Allie Muneri in wood science; Dr Dorothy Steane in molecular genetics; Dr Tony Clarke in entomology (Project Leader); Dr Clare McArthur in vertebrate browsing (Project Leader); Dr Wendy Wang in nitrogen mineralisation; and Dr Mark Hovenden on the effects of low temperature on photosynthesis.
- There were two visiting scientists; Dr Heather Keith (CSIRO Division of Forestry and Forest Products) who studied phosphorus uptake from forest soils, and Dr Robert Floyd (CSIRO Division of Entomology) who studied predation of eucalypts by autumn gum moth.

Technology transfer

- In the last year the program ran 15 seminars, 6 workshops, 2 short courses and a field day (for details see Table 4: Utilisation and Application of the Research, Commercialisation, Links with Users).

- Establishment of 'Hot off the seedbed' which presents to company partners a short summary of the implications/applications of each piece of scientific research in the Genetic Improvement program as it is completed.
- The publication of 69 research papers in refereed journals, 28 unrefereed articles and 6 theses.
- International consultancies were conducted in New Zealand and Chile by Nuno Borralho, and Heidi Dungey leaves for Chile on a three-year consultancy in July 1996. John Madden reviewed an ACIAR project in China.
- The production of a quarterly newsletter 'Overstorey', 9 issues of 'Hot off the seedbed', a Corporate Brochure, an Induction Handbook and Annual Report.

Public awareness

- Conducting a public display at Agfest with an attendance in excess of 2000 people.
- In the last year there have been 13 articles in newspapers and industry news sheets, and 5 items in the electronic media relating to the Centre (see Communication, Public Relations.
- The establishment of a world wide web page for the CRC.

CRC-THF display at Agfest, Tasmania 1996

Goals

Education

- Ensure existing MSc and PhD students complete their projects. As the CRC now has only two years to run, no new CRC scholarships will be advertised, and the number of research higher degree students enrolled (currently 41) will fall as students complete their degrees. Strong support and encouragement will be given to students to complete their degrees on time. On the other hand, if the proposal for a new CRC in Sustainable Production Forestry is successful, research higher degree student numbers will be maintained at current levels.
- Continue the involvement of partner staff in the supervision of student projects.
- Continue the involvement of CRC scientists, who are not teaching staff in University departments, in teaching at the undergraduate level.

Technology transfer

- Increase the rate of technology transfer. As research momentum and output has been building through the life of the CRC, technology transfer has received greater emphasis. The range of approaches to technology transfer has been increased and in the next two years will include visits by project staff to partners to discuss technology transfer, and a greater use of 'Hot off the seedbed' to present the implications/applications of research to company partners. This supports existing technology transfer exercises which include workshops, short courses, seminars and field days.

Public awareness

- Organise public displays and open days.
- Continue to gain coverage for the Centre in newspapers and partner news sheets, and present news releases to the electronic media.
- Organise the 1998 ANZAAS Conference on 'Sustainability of Temperate Ecosystems' and make a major contribution in the area of 'Sustainable forestry' (Prof J Reid is Chairman and Dr N Davidson is secretary of the Organising Committee).

Table 2a CRC Postgraduate Students 1995/96

No	Last Name	First Name	Degree	Topic	Funding
1	ADAMS	Paul	PhD	Sources of competition from weeds in plantations	LWRDC
2	BLACK	Paul	Hons	Effect of disturbance on patterns of dominance in Eucalyptus	Self supporting
3	BULINSKI	James	PhD	Effect of plantation design on feeding behaviour of wallaby	CRC
4	BUNDOCK	Peter	PhD	Genetic control of coppicing ability in E. globulus	APA
5	CANDY	Steve	PhD	Mathematical models to support IPM of leaf beetles	PFT employee & IFM
6	CHAMBERS	Paul	PhD	Quantitative genetics and the economic flow-ons from genetic gains	APA-I
7	DUNGEY	Heidi	PhD	The susceptibility of eucalypt hybrids to pests	Uni Res Schol
8	DUTKOWSKI	Greg	PhD	Improvement of mixed models for prediction of breeding values in forestry and application to breeding programs	Self supporting
9	GARNETT	Trevor	PhD	Kinetic parameters for uptake of nitrate and ammonium by eucalypt roots	CRC
10	GREAVES	Bruce	PhD	Age to age correlations in eucalypts	APA
11	HARDNER	Craig	PhD	Inbreeding in eucalypts	Uni Res Schol
12	HOWLETT	Bradley	PhD	Host location by Chrysophthorta bimaculata	FFIC
13	HUNT	Alastair	PhD	Predators of Chrysophthorta bimaculata	CRC
14	HUNT	Mark	PhD	Competition between understorey species and plantation eucalypts	CRC
15	KUBE	Peter	PhD	Breeding objectives and genetic control of traits for the production of sawlogs from plantation grown Eucalyptus aliens and E. globulus	FT employee
16	LADGES	Sven	PhD	Micronutrient deficiencies in eucalypts induced by excess application of N & P	CRC
17	LENNON	Susan	PhD	Modelling cambial growth	CRC
18	LOUGHHEAD	Eleanor	Hons	Molecular marker variation in the Eucalyptus gunnii aschers complex	Self supporting
19	LUKACS	Zoltan	PhD	Biology of the autumn gum moth	APA
20	MARSH	Nadia	PhD	Browsing of eucalypt seedlings by Eudemotens (Thylogale billardierii)	CRC
21	McGRANAHAM	Michelle	PhD	Genetic control of propagation ability in Pinus radiata and strategies for their use in breeding programs	APA
22	MEDHURST	Jane	PhD	Thinning of Eucalyptus nitens stands	FFIC
23	MENDHAM	Daniel	PhD	Process based predictions of nutrient limitations to plants	APA-I
24	MITCHELL	Alexandra	PhD	Reproductive biology and breeding systems for E. globulus	CRC
25	MORONI	Martin	PhD	Nitrogen mineralisation	APA-I
26	PEACOCK	Ross	MSc	Regeneration after cable logging	Dept Plan NSW employee
27	PINKARD	Libby	PhD	The effect of pruning on productivity and resource allocation in E. nitens	FFIC
28	RICHTER	Michele	PhD	Mechanisms of drought tolerance in eucalypts	CRC
29	SIMMUL	Tara	PhD	Biology of the fire bright beetle	APA-I
30	STEINBAUER	Martin	PhD	Biology of Tasmanian coreid bugs	APA
31	TEIXEIRA	Paulina	MSc	Soil structure and erosion in eucalypt plantations	CRC
32	VOLKER	Peter	PhD	Estimation of genetic parameters for eucalypt hybrids	ANM employee
33	WARDLAW	Tim	PhD	Armillaria butt and root rot of eucalypts	FT employee
34	WARREN	Charles	Hons	Long term effects of phosphinothricin on growth of Eucalyptus	Self supporting
35	WEI	Xianming	PhD	Efficiency of selection in eucalypts	AIDAB
36	WESTPHALEN	Grant	MSc	Indicator species for sustainability in native forest systems	CRC
37	WHITE	Don	PhD	Water relations of E. aliens and E. globulus under cyclical drought	CRC
38	WILKINSON	Graham	MSc	Genetic variation in E. obliqua	FT employee
39	WILLIAMS	Dean	PhD	Reproductive biology of Eucalyptus	CRC
40	WILLIAMS	Kristen	PhD	Modelling Eucalyptus distribution	DPI-Forestry
41	WILSON	Steve	PhD	Early growth and survival of eucalypt seedlings	APA-I (TFRC)

Table 2b CRC Postgraduate Students 1995/96 continued

No	Last Name	First Name	Scientific Supervisors	CRC Program	Field	PT/ FT Time	Start	Finish
1	ADAMS	Paul	Dr C Beadle, Dr P Smethurst	Soil and Stand Management	Weed biology	Full time	1996	1999
2	BLACK	Paul	Dr N Davidson, Dr M Brown	Soil and Stand Management	Eucalypt ecology	Full time	1996	1996
3	BULINSKI	James	Dr C McArthur	Resource Protection	Vertebrate browsing	Full time	1994	1997
4	BUNDOCK	Peter	Dr R Vaillancourt	Genetic Improvement	Eucalypt genetics	Full time	1993	1998
5	CANDY	Steve	Dr J Madden, Dr H Elliott	Resource Protection	Entomology	Part time	1993	1999
6	CHAMBERS	Paul	Dr N Borralho	Genetic Improvement	Quantitative genetics	Full time	1995	1998
7	DUNGEY	Heidi	Dr B Potts, Prof J Reid	Genetic Improvement	Eucalypt genetics	Full time	1992	1995
8	DUTKOWSKI	Greg	Dr N Borralho, Dr A Gilmour	Genetic Improvement	Tree breeding	Part-time	1996	2003
9	GARNETT	Trevor	Dr P Smethurst, Dr N Davidson	Soil & Stand Management	Tree nutrition	Full time	1993	1996
10	GREAVES	Bruce	Ms C Raymond, Dr B Potts, Dr N Borralho	Genetic Improvement	Eucalypt genetics	Full time	1993	1997
11	HARDNER	Craig	Dr B Potts, Dr N Borralho	Genetic Improvement	Eucalypt genetics	Full time	1993	1996
12	HOWLETT	Bradley	Dr J Madden, Dr A Clarke, Dr P McQuillan	Resource Protection	Entomology	Full time	1993	1997
13	HUNT	Alastair	Dr A Clarke, Dr J Madden	Resource Protection	Entomology	Full time	1993	1998
14	HUNT	Mark	Dr N Davidson, Dr C Beadle	Soil & Stand Management	Eucalypt ecology	Full time	1994	1997
15	KUBE	Peter	Dr N Borralho, Ms C Raymond	Genetic Improvement	Tree Breeding	Part-time	1996	2003
16	LADGES	Sven	Prof R Menary, Dr C Beadle	Soil and Stand Management	Tree nutrition	Full time	1995	1999
17	LENNON	Susan	Dr P Sands, Dr M Battaglia, Prof J Reid	Soil & Stand Management	Modelling	Full time	1995	1998
18	LOUGHHEAD	Eleanor	Dr R Vaillancourt	Genetic Improvement	Molecular biology	Full time	1996	1997
19	LUKACS	Zoltan	Dr A Clarke, Dr J Madden, Dr R Floyd	Resource Protection	Entomology	Full time	1994	1997
20	MARSH	Nadia	Dr C McArthur	Resource Protection	Vertebrate browsing	Full time	1993	1996
21	McGRANAHAM	Michelle	Dr N Borralho	Genetic Improvement	Forest Genetics	Full time	1996	1999
22	MEDHURST	Jane	Dr C Beadle, Dr N Davidson	Soil and Stand Management	Tree physiology	Full time	1996	1999
23	MENDHAM	Daniel	Dr P Smethurst, Prof B Menary, Dr G Holz	Soil & Stand Management	Soil nutrition	Fulltime	1995	1998
24	MITCHELL	Alexandra	Dr B Potts, Dr R Vaillancourt	Genetic Improvement	Eucalypt genetics	Full time	1995	1998
25	MORONI	Martin	Dr P Smethurst, Prof B Menary	Soil & Stand Management	Soil nutrition	Full time	1995	1998
26	PEACOCK	Ross	Dr N Davidson, Dr M Brown, Prof R Hill	Soil & Stand Management	Forest ecology	Part time	1994	1998
27	PINKARD	Libby	Dr C Beadle, Dr N Davidson	Soil & Stand Management	Eucalypt physiology	Full time	1994	1997
28	RICHTER	Michele	Dr N Davidson, Dr C Beadle	Soil & Stand Management	Eucalypt physiology	Full time	1996	1998
29	SIMMUL	Tara	Dr A Clarke	Resource Protection	Insect ecology	Full time	1996	1999
30	STEINBAUER	Martin	Dr A Clarke, Dr J Madden	Resource Protection	Entomology	Full time	1992	1995
31	TEIXEIRA	Paulina	Dr R Misra, Mr R Cromar	Soil & Stand Management	Soil structure and erosion	Full time	1993	1995
32	VOLKER	Peter	Dr B Potts, Dr N Borralho	Genetic Improvement	Eucalypt genetics	Part time	1992	1996
33	WARDLAW	Tim	Dr C Mohammed, Dr G Kile	Resource Protection	Pathology	Part time	1994	2000
34	WARREN	Charles	Dr N Davidson, Dr C Beadle	Soil and Stand Management	Tree physiology	Full time	1996	1996
35	WEI	Xianming	Dr N Borralho	Genetic Improvement	Quantitative genetics	Full time	1994	1997
36	WESTPHALEN	Grant	Dr M Brown, Dr N Davidson	Soil and Stand Management	Plant ecology	Full time	1996	1998
37	WHITE	Don	Dr C Beadle, Dr N Davidson	Soil & Stand Management	Eucalypt physiology	Full time	1993	1996
38	WILKINSON	Graham	Prof J Reid	Education	Eucalypt genetics	Part time	1989	1996
39	WILLIAMS	Dean	Prof J Reid & Dr B Potts	Genetic Improvement	Reproductive Biology	Full time	1996	1999
40	WILLIAMS	Kristen	Prof J Reid, Dr M Austin, Dr M Brown	Education	Eucalypt ecology	Part time	1991	1995
41	WILSON	Steve	Prof R Clarke, Mr P Volker	Soil & Stand Management	Eucalypt ecology	Full time	1993	1996

Table 3 Summary of student enrolments in the CRC

Postgraduate Students

Number of Students

Full/Part Time:	Full time	33
	Part time	8
Degree:	Grad Dip with Hons	0
	BSc Honours	2
	BAgrSc Honours	0
	MSc	4
	PhD	35
CRC Program:	Genetic Improvement	13
	Soil & Stand Management	17
	Resource Protection	9
	Education	2

Supervisor:

Dr M Austin	1	Dr N Davidson	10	Dr G Kile	1	Dr B Potts	6
Dr M Battaglia	1	Dr D de Little	1	Dr M Line*	1	Ms C Raymond	2
Dr C Beadle	8	Dr H Elliott	1	Dr J Madden*	5	Prof J Reid*	6
Dr N Borralho	8	Dr R Floyd	1	Dr C McArthur	2	Dr P Sands	1
Dr M Brown	4	Dr A Gilmour	1	Dr P McQuillan	1	Dr P Smethurst	1
Prof R Clark*	1	Prof R Hill*	1	Dr R Misra	1	Dr R Vaillancourt	3
Dr A Clarke	5	Dr G Holz	1	Prof R Menary	3	Mr P Volker	1

Funding:	CRC (Honours Scholarship)	2
	CRC (PhD/MSc Scholarship)	13
	Univ Research Scholarship with CRC top up	2
	APA with CRC top up	5
	APRA - Industry	5
	FFIC	3
	AIDAB	1
	DPI - Forestry	1
	Employed in forest industry	6
	LWRDC	1
	Self-supporting	2

* University Department Staff

Utilisation and Application of Research

Strategy for Technology Transfer

One of the principal objectives of the Education and Technology Transfer program is to transfer the technology rapidly to the industrial partners and other end users. This involves the following steps:

1. *Involvement of industrial partners in planning research projects and running experiments*

Most CRC research is conducted using company trials, or trials established on company land so companies are involved at the outset with the planning and implementation of research projects and have ownership of them. Research plans for these experiments are lodged with the companies, and these include an agreed protocol for the research. The company partners allocate staff time (in-kind contributions) to CRC research projects so effective interaction can occur. Ultimately, the Industry Research Committee of the CRC retains an overview of these research projects and can support, reject or modify any research program.

Neil Davidson (CRC) and Peter Naughton (Boral Timber) discuss performance of clonal plantations.

2. *Early transfer of results*

The early transfer of results starts with informal interactions (phone, fax, E-mail and visits to company sites). In the Genetic Improvement program the first stage in formal transfer involves faxing a summary of the implication/application of research on an A4 page entitled 'Hot off the seedbed'. Company responses then determine whether the next form of presentation of the information will be a seminar, workshop, short course or field day. Where an individual company shows particular interest this presentation may be conducted at the company operations. Where interest is more general there may be visits to each company by research staff or a course or workshop run at the CRC. The next stage in transfer is a technical report or unrefereed paper, which is followed by a refereed journal paper.

3. *Development of training courses in modern forestry techniques for company staff*

The Resource Protection program has conducted 2 technical workshops on Forest Protection (in November 1995 and May 1996) which have attracted approximately 20 participants each.

Technology Transfer also occurs at the post-graduate research level. There are 10 company staff enrolled in PhD and MSc studies. Seven are conducting their research while still employed; Mr Tim Wardlaw (Forest Pathologist, Forestry Tasmania), Mr Steve Candy (Statistician, Forestry Tasmania), Mr Peter Kube (Tree Breeder, Forestry Tasmania), Mr Peter Volker (Silvicultural Superintendent, ANM), Mr Don White (Research Scientist, CSIRO), Mr Graham Wilkinson (Chief Forest Practices Officer, Forestry Tasmania), Mr Ross Peacock (Research Scientist, Dept. Planning, NSW). Three resigned their positions to conduct research but intend returning to industry: Mr Greg Dutkowski, (Research Manager, Bunnings), Mr Paul Adams (S.A. Dept. Primary Industry), Ms Jane Medhurst (Forestry Tasmania). There are 10 of our students on scholarships supported by industry: Paul Adams (LWRDC) on weed competition with eucalypts; Bradley Howlett (FFIC) on host location by *C. himaculata*; Jane Medhurst (FFIC) on thinning of

E. nitens stands; Libby Pinkard (FFIC) on the effect of pruning on *E. nitens*; Paul Chambers (APA-I) selection strategies for mechanical pulping; Daniel Mendham (APA-I) on prediction of nutrient limitations; Martin Moroni (APA-I) on nitrogen mineralisation; Tara Simmul (APA-I) on the biology of fire blight beetle; Steve Wilson (APA-I) on survival of eucalypt seedlings; and Kristen Williams (DPI) on modelling of eucalypt distributions.

During the life of the CRC 10 of our students have been employed in the forest industry. This is rapidly increasing, with 3 PhD and 2 honours graduates of the CRC finding such employment in 1995/96 (Don White, Mike Battaglia, Heidi Dungey, Joanne Dingle, Martin Tyson).

Major Outcomes

- During the first five years of the Centre, we estimate Technology Transfer activities reached approximately 11,000 people through a major international conference, 75 seminars, 20 workshops, four symposia, five short courses, six field days or field tours. During 1995/96, 15 seminars, 6 workshops, 2 short courses and a field day were conducted (for details see Table 4, below). Table 5 presents Technology Transfer activities proposed for 1996/97.
- Publication of 157 refereed and 167 unrefereed papers and completion of 29 theses during the life of the CRC. The publication of 69 research papers in refereed journals, 28 unrefereed articles and comletion of 6 theses in 1995/96 (see Publications).
- In the last five years there have been 22 articles in newspapers and industry news sheets, and 11 items in the electronic media relating to the Centre. There have been 13 articles in newspapers and industry news sheets, and 5 items in the electronic media relating to the Centre during 1995/96 (see Communication, Public Relations).

Peter Gore (CRC) visited Bunnings Treefarms (WA) to give a two-day workshop on controlled pollination techniques.

- Public good research conducted by the CRC is presented in Table 6.
- In each of the research programs of the CRC several research projects have led to the production of technology which has been transferred or is being transferred to the company partners (see Table 7).
- There are a wide range of end users of the technology developed by the CRC including small and medium sized enterprises (SMEs) and contracting organisations (see Table 8).

Table 4 Technology Transfer Activities

The following table summarises CRC-THF's technology transfer for 1995/96.

Month	*Function*	*Topic*	*Reach*	*Pgm.*	*Time* (days)
July	Workshop	Joint CRC-THF/Melbourne Univ./ ANU/Amcor workshop on soil and plant nutrition	30	SSM	3
Sept.	Technical publication	Four articles in CSIRO newsletter 'Onwood'	2000	GI SSM	
Oct.	Workshop	'Forest growth modelling', conducted in association with CSIRO	30	SSM	3
Oct.	'Overstorey'	Issue of newsletter	150	ETT	
Nov.	Workshop (technical)	'Forest protection' (at North Forest Products)	20	RP	2
Nov.	Workshop	'Reproductive biology of eucalypts and application to breeding' (in WA)	30	GI	4
Nov.	Technical news sheet	First issue of technical news sheet 'Hot off the seedbed' (faxed to all partner organisations)	20	GI	
Nov.	Workshop	'A model of plantation growth' (at North Eucalypt Technologies)	8	SSM	1
Dec.	'Overstorey'	Issue of newsletter	150	ETT	
Dec.	'Hot off the seedbed'	Implications of research faxed to partners (QTL mapping)	40	GI	
Dec.	'Hot off the seedbed'	Implications of research faxed to partners (chloroplast DNA)	40	GI	
Dec.	'Hot off the seedbed'	Implications of research faxed to partners (pulping ssp *pseudoglobulus*	40	GI	
Jan.	Workshop	'A model of plantation growth' (at ANM)	5	SSM	1
Jan.	'Hot off the seedbed'	Implications of research faxed to partners (flowering times of *E. globulus*)	40	GI	
Feb.	'Hot off the seedbed'	Implications of research faxed to partners (accounting for thinning when estimating genetic parameters)	40	GI	
Feb.	'Hot off the seedbed'	Implications of research faxed to partners (survival in tree breeding)	40	GI	
Nov.	Workshop	'A model of plantation growth' (at Forestry Tasmania)	6	SSM	1
Mar.	Technical publication	Two articles in CSIRO newsletter 'Onwood'	2000	GI	
Mar.	Field day	Field day at Forestry Tasmania	31	ETT	1
Mar.	'Hot off the seedbed'	Implications of research faxed to partners (somatic embryogenesis)	40	GI	
Apr.	'Overstorey'	Issue of newsletter	150	ETT	
Apr.	Corporate Brochure	Centre capability document	2000	ETT	
May	'Hot off the seedbed'	Implications of research faxed to partners (stand density and outcrossing)	40	GI	
May	'Overstorey'	Issue of newsletter	150	ETT	

Table 5 Technology Transfer Activities Proposed for 1996/97

Month	*Function*	*Topic*	*Reach*	*Pgm.*	*Time (days)*
July	Seminar	'The Search for New Technology in Australian Forestry' Royal Society of Tasmania	150	ETT	1
Aug.	Workshop (technical)	'Water use and water relations' (at CRC)	20	RP	2
Aug.	'Overstorey'	4 issues of the newsletter	150	ETT	
July	'Hot off the seedbed'	Implications of research faxed to partners. (At least 12 for the year)	40	GI	
Nov.	Field Day	Field day at Boral Timber	30	ETT	2
May	Display	CRC display at Treefest	2000	ETT	4
Aug.	Workshops*	Workshops will be held for each company, on site	20	all programs	2
Aug.	Visits	Research staff will visit company operations (1 week)	10	all programs	2

**Workshops: 'Selecting for wood density', 'Modelling for site productivity,' 'Forest protection', 'Site preparation for plantations'*

Table 6 Examples of public good research conducted by the CRC

Genetic Improvement Program

- Extensive taxonomic molecular and quantitative studies undertaken on *E. globulus* populations allowed identification of 13 races within *E. globulus* and provides a framework for the conservation of the genetic resources of the species.
- Major advances have been made in somatic embryogenesis of eucalypts at the CRC. The techniques developed may well be applied in the future to genetically engineered eucalypt material at the cellular level.
- Taxonomic revision of genus *Eucalyptus* has occurred in the light of molecular genetics research conducted at the CRC.
- The hybrid breeding project has produced F_2 and advanced generation hybrids between *E. globulus* and both *E. nitens* and *E. gunnii*. These could lead to the development of synthetic lines to exploit marginal sites.
- Identification of the gibberellin biosynthetic pathway in eucalypts

Soil and Stand Management Program

- Excavators conserve topsoil during clearing, maintaining site productivity and sustainability of forest practice.
- Water use of plantations has been partitioned into layers so models can more accurately predict species response to climatic variables, enabling prediction of soil-water balance.
- Kinetics of NO^3- and NH^4+ uptake by eucalypt roots is work pioneered at the Centre.
- Effect of temperature on photosynthesis, temperature acclimation and depression of photosynthesis after frost. This will be used in models of plantation productivity and to determine location of plantations at high altitude.

Resource Protection Program

- A survey of the leaf volatile oils and waxes in eucalypts has allowed identification of biochemical markers at the species, series and subgeneric level which provides a framework for the study of eucalypt-pest interactions.
- The taxonomy of the coreid bugs (sap sucking insects) has been revised and the ecology elucidated (7 publications) for a group of potential insect pests.

Table 7 Technology transferred or in the process of being transferred

Genetic Improvement Program

- Wood density identified as an important characteristic in pulping costs.
  - breeding objectives adjusted (1995)
- Pilodyn measurements have allowed estimates of basic density.
  - included in breeding programs (1995)
- Provenance of *E. globulus* with desirable high density identified.
  - used by seed collectors (1995)
- Collaboration has been developed with the STBA (Southern Tree Breeding Association)
  - provides end users other than CRC partners with access to results of CRC genetics projects (1994-1996+)
- National genetic evaluation of *E. globulus* spp. *globulus* (with STBA) using new statistical methods (BLUP) has provided tree breeders with the first direct comparison of the breeding values for around 50 000 trees.
  - basis for a national breeding program (1994)
- Reduction in growth due to inbreeding for *E. globulus*.
  - incorporated into breeding programs (1995)
- Hormonal control of flowering in *Eucalyptus*.
  - paclobutrazol used in seed orchards (1993)
- Flowering times of *E. globulus* families determined.
  - used in crossing programs and seed orchard design (1994)

Soil and Stand Management Program

- On most ex-forest sites tested, mineralisation rates are sufficient to maintain concentrations of N that can sustain high growth rates during the first two years.
  - application of urea at year three
  - urea is quickly converted to ammonium, preferred N source for E. nitens *(1996)*
- P requirements for eucalypts are low, but on most sites tested, application of P at planting improved growth.
  - spot application of P at planting (1995)
- Copper deficiency implicated in gross stem deformities in *E. nitens* plantations established on highly fertile ex-pasture sites which receive additional N and P fertiliser.
  - no fertiliser application on fertile ex-pasture sites (1994)
- Use excavators to form windrows as less topsoil and organic matter is removed. This also provides a larger area for planting, a more uniform stand and increases tree growth (at year 7).
  - excavators recommended for clearing (1993)
- Ripping at establishment is generally not required, while surface cultivation (mounding) is required prior to planting to maximise plantation growth.
  - ripping not required (1995)
- Good pre-planting weed control on native forest sites eliminated need for expensive post-planting applications of atrazine.
  - employment of good pre-planting weed control (1993)
- *E. globulus* is more tolerant than *E. nitens* of moderate water stress during the growing cycle.
  -planting of E. globulus *on sites subject to moderate water stress (1996)*
- Pruning of up to 50% of the crown of *E. nitens* had no significant effect on height growth.
  - pruning of E. nitens *to obtain solid wood products (1996)*
- Simple models of biomass partitioning and canopy assimilation, and relationships between leaf area index and site factors have been derived.
  - potential to predict site productivity for plantations in a form (MAI) likely to be useful to forest managers (1996)

Resource Protection Program

- Development (with Forestry Tasmania) of an Integrated Pest Management Program.
  - control of defoliating insects (1992-1996+)
- Trap trees of *E. regnans* to control insect numbers in adjacent plantations of *E. nitens*.
  - used by North Forests (1996)
- Differences between provenances of *E. nitens* in susceptibility to browsing by pademelon.
  - potential for use in breeding programs (1996)

Table 8 End users of CRC technology

End user	Research Program
ANM	all programs
North Forests Products	all programs
Amcor Plantations*	all programs
Bunnings Treefarms*	Genetic Improvement and Soil and Stand Management
Boral Timber Tasmania*	all programs
Forestry Tasmania	all programs
CSIRO	all programs
University of Tasmania	all programs
Public good research	all programs
STBA membership:	
ANM	as above
North Forests Products	as above
Amcor	as above
Bunnings Treefarms	as above
Forestry Tasmania	as above
Primary Industries (SA) Forestry	Genetic Improvement
Kimberley-Clark Australia	Genetic Improvement
A.E. O'Connor Pty Ltd*	Genetic Improvement

* Small to medium sized enterprise (SME)

Contracts conducted

Personnel	Contracting organisation	Date	Project
Dr N Borralho	P.T. Inda Kat Pulp and Paper Corporation (10 days)	July 1995	Selection modelling and breeding strategies in *Acacia mangium*
Dr N Borralho	P.T. Indah Kiat Pulp and Paper Corporation	Apr. 1996 (3 days)	Selection modelling in *Acacia mangium*
Dr N Borralho	Soporcel Ltd	Sept. 1995 (15 days)	Strategic elements for Soporcel breeding program
Dr N Borralho	North Forest Products	Sept. 1995 (10 days)	Gains from alternative deployment options
Dr N Borralho	Tasman Forests	Jan. 1996 (6 days)	Prediction of breeding values in *P. radiata* clones
Dr N Borralho	Cooperative de Mejoramiento Genetico Foristal, Universidad Austral de Chile, and Facultad de Ciencias Forestales	Feb. 1996 (14 days)	Breeding and selection for *P. radiata*
Dr J Madden	Australian Centre for International Agricultural Research (ACIAR)	May 1996 (14 days)	Review of ACIAR project in China

Staffing and Administration

Staffing

During 1995/96 some major changes to the staffing of the CRC occurred.

At its meeting on March 14 1996, the Board of the CRC endorsed the appointment of David de Little as Deputy Director of the Centre. Dr de Little is Manager of Eucalypt Research at North Eucalypt Technologies (an enterprise of North Forest Products) and has been involved with the Centre since its inception. Dr de Little contributed approximately 10% of his time to Centre activities in 1995/96. However, since his appointment as Deputy Director Dr de Little's contribution to the Centre has risen to 25%.

Michael Battaglia, the recipient of an ARC fellowship at the University of Tasmania in 1994, was appointed to a research scientist position at CSIRO Forestry and Forest Products in Hobart, and is now involved as a modeller on a CRC project.

Mark Hovenden was appointed as a postdoctoral fellow in June 1996 to investigate the effects of low temperature and photoinhibition on growth and photosynthesis in plantation eucalypts.

In March 1996, Greg Dutkowski was appointed to the position of Tree Breeder with the Genetic Improvement program. Dutkowski, formerly of Bunnings Treefarms, is also undertaking PhD studies through the CRC.

During the year under review, Dorothy Steane received the annual award from the Linnean Society for the best thesis in plant science in the United Kingdom. She is currently working on the molecular basis for phylogenetic relationships in *Eucalyptus*.

In line with a recommendation from the Third Year Review, the position of Business Manager was created and Jan Lynch was appointed to this position in September 1995.

Technical appointments made during 1995/96 were: Martin Tyson, working with Robin Cromer in the area of nutrient partitioning, and with Chris Beadle in the area of canopy processes; Stuart Skabo, assisting René Vaillancourt in his work on molecular genetics; Scott Pepper, working with Jean-Noël Ruaud in the area of embryogenesis; Stephen Turner working with Clare McArthur on vertebrate browsing; Jason Lawson working with Carolyn Raymond on wood properties; and Helena Nermut working with Brad Potts on eucalypt genetic. Paul Tilyard replaced Peter Gore as the technician working with Brad Potts in genetic parameters

New students starting with the Centre this year include: 10 PhD students - Paul Adams, Greg Dutkowski, Peter Kube, Sven Ladiges, Michelle McGranaham, Jane Medhurst, Daniel Mendham, Martin Moroni, Tara Simmul, Dean Williams; one Masters student, Grant Westphalen and 3 Honours students, Paul Black, Eleanor Loughhead and Charles Warren.

Dorothy Steane (photo courtesy of the 'Examiner' newspaper)

Administration

The number of meetings held by the Board and other Committees during 1995/96 were as follows:

Board of Management	4
Industry Research Committee	3
Scientific Review Committee	0 *
Management Committee	13

*A scientific review was conducted by an external review panel in June 1996 and an additional internal review in 1995/96 was seen as unnecessary.

A revised Strategic Plan for the Centre was developed in 1995 and used to develop the objectives and strategies for a Business Plan. The Business Plan documented the major research, marketing, financial and training objectives for the CRC, and developed strategies for the achievement of these objectives prior to the end of June 1998. Both documents were distributed to all staff, students and industry partners. The Key Objectives for the Centre were defined in the Business Plan as -

Research Objectives

- Improve the efficiency and effectiveness of the applied research and development of industry partners through fostering and facilitating cooperative research.
- Produce research outcomes which improve the competitiveness of industry partners, as well as being of interest to a wider range of stakeholders.
- Ensure the long-term viability of Australia's forest industry through high quality, relevant research in sustainable plantation forestry.

Marketing Objectives

- Communicate the economic benefits of the Centre's research and technology transfer programs amongst all stakeholders.
- Ensure industry captures the benefits of research through effective technology transfer.

Financial Objectives

- Diversify the Centre's funding base.
- Be successful in achieving funding for a new CRC in the 1996 application round.
- Management of research outcomes to maximise opportunities from the development of intellectual property.

Training Objective

- Provide relevant education and training that meets the skill formation needs of industry partners and national forestry objectives.

A 'Handbook for Staff and Students' was developed and distributed during the year, to assist new staff and students, as well as being a resource for existing staff and students. The Handbook details contact points, administrative guidelines and a range of issues applicable to those who are involved with the CRC.

A major reworking of intellectual property documentation was undertaken during the year. Intellectual property statements for all research projects have been developed, in consultation with industry partners, to ensure appropriate records of both proprietary and Centre intellectual property are maintained and reviewed.

Fifth Year Review

The Fifth Year Review panel from left to right: Dr Mike Carson, Prof Roger Sands and Mr Ian Whyte

As a first round CRC, the Centre was required to undertake a Fifth Year Review. Stage One of this Review took place over the period June 24-25 1996, with Stage Two due to occur from September 3-5 1996.

The Stage One Review Panel consisted of:

- Dr Mike Carson (Chairman), Manager - Biotechnology Division, New Zealand Forest Research Institute
- Professor Roger Sands, Head - School of Forestry, University of Canterbury, New Zealand
- Mr Ian Whyte, Chief Executive, Forest Industries Association of Tasmania.

The CRC's Visitor, Dr Peter Nelson, participated in an advisory/resource capacity, and was in attendance during the two days of the Stage One Review.

Stage One of the Fifth Year Review was a scientific technical review of the Centre's projects. It was an independent review focusing on the quality of the Centre's research activities and their contribution to technology transfer, taking into account aspects of utilisation and commercialisation.

The report of the Stage One Review Panel will be presented soon to the Board for their comment, and will then form part of the Stage Two Review Report.

Table 9 Specified personnel in the CRC

Name	Title	Employing Agency	Proportion of time in the CRC
Professor James Reid	Director	University of Tasmania	0.5
Dr David de Little	Deputy Director	North Forest Products	0.1*
Dr Nuno Borralho	Manager, Genetic Improvement program	University of Tasmania	1.0
Mr Robin Cromer	Manager, Soil and Stand Management program	CSIRO Forestry and Forest Products	0.5
Dr John Madden	Manager, Resource Protection program	University of Tasmania	0.4
Dr Neil Davidson	Manager, Education and Technology Transfer program	University of Tasmania	1.0

**Since Dr de Little's appointment as Deputy Director his contribution to the CRC has risen to 0.25.*

Publications

Genetic Improvement

Refereed publications

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Public Relations

Genetic Improvement

Television

'Super trees' in plantation forestry (Nuno Borralho), 1995 ABC

Discussion of research achievement (Dorothy Steane), 1996 ABC

Print

Outstanding research achievement of Director Prof Jim Reid, 1995 *The Mercury*

Outstanding individual research achievement of Dr Dorothy Steane, 1996 *The Mercury, The Examiner, Unitas*

Somatic embryogenesis (Jean-Noël Ruaud) *Onwood*

New statistical models to determine breeding values in plantation eucalypts (Nuno Borralho) *Onwood*

Soil and Stand Management

Radio

The potential of irrigated plantations (Chris Beadle), 1995 ABC

The effect of pruning on tree growth (Libby Pinkard, Jane Medhurst), 1995 ABC

Print

Modelling plantation productivity (Peter Sands) 1995 *Onwood*

Effect of frost on photosynthesis of plantations (Neil Davidson) 1995 *Onwood*

Effect of pruning on tree growth (Chris Beadle) 1995 *Onwood*

Comparative water relations of *Eucalyptus nitens* and *E. globulus* (Don White) 1995 *Onwood*

Sustainable productivity from eucalypt plantations (Robin Cromer) 1995 *Australian Forest Grower.*

Resource Protection

Television

Leaf beetle damage to eucalypt forest (Jane Elek and Tony Clarke), 1995

Print

New discoveries of Martin Steinbauer, 1995 *Unitas*

Education

For details on workshops, short courses, seminars and field days conducted by the Education and Technology Transfer Program see Utilisation, Application of Research, Table 4 p38.

Print

Effects of Federal budget cuts on University funding and CRCs, 1996 *The Mercury*

Grants and Awards

Title of Grant/Award	Reason for Award	Length of Award	Name of Recipient	Amount Involved	Any anticipated award/grant
Forests and Forests Industry Council	Postgraduate scholarship	Three years	CL Beadle	$96,000	
Land and Water Resources Research & Development Corporation	Postgraduate student, research assistant	Three years	Drs N Mendham (Agricultural Science), P Smethurst and C Beadle	$214,557	
BARC	Salaries	Twelve months	C McArthur	1. $6279 2. $9350	
North Forest Products	Salaries	Six months	C McArthur	$6000	
Boral Timber	Salaries	Six months	C McArthur	$3500	
North Forest Products	Equipment	na	C McArthur	$12000	
FAO	CRC Visitor	Eight months	Fang Dong Li	$6000	
Intensive Forest Management Program	Study alternative methods of insect control	Three - four years	JL Madden	$236,000	$100,000 through FWPRDC
Portuguese National Council for Industrial & Technological Research	Postgraduate scholarship	Twelve months	PC Teixeira	$26,000	
ARC - APA(I) and the Tasmanian Forest Research Council	Postgraduate scholarship	Three years	AR Clarke, T Simmul	$87,921	
APA(I)	Postgraduate scholarship	Three years	NB Borralho	$118,500	

Performance Against Indicators

The CRC Commonwealth Agreement contained specific indicators against which performance of the CRC was to be judged. These indicators were agreed to formally by both the Commonwealth and the CRC. Outlined below are the indicators (in italics) and a brief outline of the performance of the CRC against these indicators after five years.

Generic Indicators

Important generic performance indicators will be the number of publications in international, refereed journals, the participation of visiting scientists and the ability to attract external funds

Publications:

The total number of publications is over 350 with half this total in refereed national or international journals or monographs, with a substantial number of the remainder as major papers in conference proceedings (mostly refereed) (Table 10). The output has grown substantially with over a four-fold increase from the first full year of operation (1992) to 1995 (Table 11).

Table 10 Publications by program and type, 1991-1996

Program	Journal Papers & Book Chapters	Conference Proceedings	Conference Presentations & Technical Reports	Theses	Total
GI	51	44	51	16	162
SSM	74	24	25	6	128
RP	32	2	21	3	58
ETT	0	0	0	4	4
Total	157	70	97	29	352

This shows the substantial synergy created by the Centre since publications in 1992 largely reflect the productivity of the individual components that came together to form the Centre.

Visiting Scientists

The Centre has attracted a distinguished list of international and national visitors to work in the Centre under its visiting scientists scheme (Table 12). In addition, many shorter visits have occurred including: Dr Peter Dye (CSIR, South Africa); Dr Robert Teskey (University of Georgia, USA); Dr Ephraim Epstein (Israel); Mr Fernando Baeza Melendez (former Governor of the Mexican State of Chihuahua); Dr Zhang Shaoang (Beijing Forestry University, China); Dr Claudio Balocchi (Universidad Austral de Chile); Prof Nayerah Rastin (University of Göttingen, Germany); Dr Zang Daoqun (Chinese Academy of Forestry); Dr Stephen Read (School of Forestry, University of Melbourne); Dr Philip Moody (Qld Department of Primary Industriy); Mr Li Fang Dong and Mr Wang Bao Ping (FAO Tainees from Paulownia Research Centre, China); plus touring groups of foresters from Brazil, Chile, USA, Indonesia and China. International and national scientists have given numerous seminars during the CRC seminar series each year.

External funding:

External funding by CRC staff totalled $2,082,754 from 1991/92 to 1995/96. 1995/96 funds totalled $719,246. Of this amount, $84,100 was received directly by the Centre for external consultancies, technical and student support, and $45,000 was received from partner organisations for specific CRC project activities. The balance was received in the form of ARC grants/post-graduate awards of $456,836 across the three research programs, as well as grants from the European Research Community, FAO, and IFMP, and these funds (i.e. the balance) are held

Table 11 Publications by type and year (note: 1996 figures include articles published, in press or submitted)

	1991	1992	1993	1994	1995	1996
Journal papers and book chapters	3	13	25	25	22	69
Conference proceedings	0	2	11	10	35	12
Conference presentations and technical reports	1	6	12	29	33	16
Theses	3	2	6	10	7	1
Total	7	23	54	74	97	98

Table 12 Visiting Scientists

Dr Gary Hodge	University of Florida	6 months
Dr Eberhard Voit	Medical University of South Carolina	10 months
Dr Myron Zalucki	University of Queensland	3 months
Prof Alan Berryman	Washington State University	1 month
Dr Peter Kanowski	University of Oxford	3 months
Dr Heather Keith	CSIRO Division of Forestry, Canberra	6 months
Dr Robert Floyd	CSIRO Division of Entomology	2 months
Prof Peter Davies	Cornell University, New York	9 months

Table 13 Staff and post-graduate student numbers recruited in each year of CRC operations (note: data does not include CRC-funded administrative staff, in 1995/96).

Year	Research staff	Postgrad. students	Technical staff	All staff
1991/92	4	16	3.75	23.75
1992/93	5	15	9	29
1993/94	1	17	4.5	22.5
1994/95	3	3	3	9
1995/96	2	12	6	20
Planned No.	9	11*	10	30
Current No.	12.5	10	11.8	34.3

* CRC-funded students only.

separately to general CRC accounts. Staff are also part of the project 'Breeding objectives and selection criteria to maximise the economic value of sawn timber' funded by an FWPDRC grant totalling $880,122. This grant is not included in the total external funding since the funding is received through the QFRI.

Establishment of the Centre

If possible employ up to half the new staff for the Centre in 1991/92 and the rest in 1992/93

There were some delays involved in the commencement of key professional staff, due to the time taken for relocation from positions overseas and the granting of visas by the Australian Government. However, post-graduate students were attracted rapidly in advance of the timetable which enabled this indicator to be met (i.e. that there were to be 30 CRC-funded staff recruited in the first year).

Management of the Centre

Complete establishment of administrative services and systems at the time the CSIRO Division of Forestry moves to the University campus in March/April 1992

This indicator was met with the administrative staff and services all in place by the time of occupation of the new CSIRO/CRC building.

Genetic Improvement

Production of reliable estimates of heritabilities and correlations for commercially desirable tree characters and of genetic gains in each generation. Determination of the optimum age for selection of elite lines and the development of breeding plans. Estimates of heritabilities and correlations for important traits will be possible within three years. Assessment of genetic gain, selection age and development of breeding plans is dependent on estimates of heritabilities and correlations

The last few years have seen a dramatic improvement in our knowledge of heritabilities and genetic correlations for key traits in *E. globulus*, *E. nitens* and *E. regnans*. Published estimates of genetic parameters for growth, wood density and other traits prior to the start of the CRC were very limited (to our knowledge there were only eight papers published in total with two of them including wood properties). They were also based on only a few provenances from the whole range of the natural distribution.

Research carried out by the CRC-THF, often in collaboration with industry partners and breeding organisations, has produced over 25 papers or technical reports on the genetic control of *E. globulus* and *E. nitens*, including the analysis of large *E. globulus* and *E. nitens* base populations, across Australia, for growth (diameter and height), flowering (precocity and peak) and wood density. Work done at the CRC-THF also includes the first estimates from full-pedigree material for *E. globulus* and *E. nitens*, both in Australia and overseas (Portugal). This information has been used in breeding programs in Australia. A cooperative breeding strategy, for both *E. globulus* and *E. nitens*, was developed by the CRC-THF, in collaboration with the STBA and industry partners, with the program now underway. Selections carried out in these programs are based on the estimated genetic parameters.

As most parameter estimates published for *Eucalyptus* are derived from open-pollinated progeny from base populations, considerable work has been done in improving such estimates. We have made major advances in understanding the reliability of such estimates as well as their age-trends and the impact of site and mortality. We have developed approaches to improving genetic parameter estimates derived from OP progeny (Borralho and Potts 1996) and provided indications of reliability for specific traits by directly comparing OP and controlled cross parameter estimates for growth.

Selection rules have been defined for current breeding programs. The studies include a detailed economic model of eucalypt plantations for kraft pulp production. Results demonstrating the large benefits of cooperative breeding were pivotal to the development of a cooperative breeding scheme by the STBA.

Show that hybrid seed can be produced successfully and used in field plantings. F_1 hybrid seed will

continue to be planted and F_2 seed could be available for planting within two years

Interspecific F_1 hybrid seed has been produced in large quantities, barriers to its production identified, and growth of F_1 hybrids monitored. F_2 and backcross hybrid seed was produced for *E. gunnii* x *E. globulus* and *E. nitens* x *E. globulus* and trials established in 1994 and 1995 respectively.

Develop a system to vegetatively propagate elite material from breeding programs, successfully establish field plantings and reduce production costs. This is an ongoing activity but it is hoped to establish the first reasonable sized field plantings within three years

Significant progress on a cost-effective vegetative propagation system has been made. The improved micropropagation system (IMP) halves the number of steps required compared with previous systems. IMP has been tested successfully in one industry laboratory. It was found to be a useful system for small-scale research projects such as the screening of rooting ability across genotypes. However, original objectives changed significantly, as a result of the third year review and a more recent workshop with industry partners. The industry partners also agreed to put more emphasis on the somatic embryogenesis project. Research done at the CRC-THF indicated:

- While the program was not able to reliably clone recalcitrant *E. globulus* and *E. nitens* clones, rooting ability was found to be under strong genetic control, with enough genetic variation to enable the identification of good rooters within any given family. Rooted cuttings from this experiment are going to be planted in the field as a demonstration trial.
- Screening methods for rooting ability, both *in vitro* or as cuttings, have been made robust and simple. These results allow the development of a workable cloning strategy for temperate *Eucalyptus*, producing a large number of progeny from outstanding families, and subsequently screening within these families for rooting ability.
- Somatic embryogenesis has been successfully induced in both *E. nitens* and *E. globulus*. The high proportion of genotypes displaying competency with somatic embryogenesis (around 80% whatever the family) does not narrow the genetic variation within progenies. Furthermore, within one genotype, up to hundreds of somatic embryos can be obtained, indicating the great potential of this method for genetic engineering purposes. However, the somatic embryos do not develop beyond the globular stage. Achieving full development of the somatic embryos up to the germination stage will be our major challenge for the coming years.

Determine the reduction time for seed production of elite material and the role played by the gibberellins in the flowering process. The gibberellin biosynthesis pathway in eucalypts should be elucidated within two years

The gibberellin biosynthetic pathway has been determined as the early 13-hydroxylation pathway, with GA_1 being the active hormone. By chemical and cultural means the seed to seed generation time has been reduced to 2.5 years for *E. globulus* from the 5-10 years found in plantations. While a substantially reduced level of GA_1 (less than 0.1 ng.g FW^{-1}) is required to allow flowering, it is not the only factor involved in the promotion of flowering. Cold is also required and it does not act via the reduction in GA_1 levels.

Develop techniques for fingerprinting eucalypts using DNA markers. The University has initiated work in this area and it will be possible to establish procedures for differentiation at the broad taxonomic level within two years and develop detailed genomic RFLPs for individual species by the end of five years

Genomic and organellar DNA markers (RFLP and PCR based) were developed and their usefulness demonstrated at different taxonomic levels: across the whole of the genus *Eucalyptus*; between closely related species; within species such as *E. globulus*, and in fingerprinting man-made and natural clones. In addition, a linkage map in an interspecific F_2 of *Eucalyptus* was the first such map produced in the

genus. We obtained good evidence for the first case of QTL x environment interaction in *Eucalyptus*. The feasibility of finding QTLs in *Eucalyptus* was demonstrated, which is the first step towards the realisation of MAS.

Soil and Stand Management

Development of silvicultural practices for the judicious management of soils and stands for the short- and long-term management of plantation forests

The following guidelines have been developed for several aspects of silvicultural management of soils and stands in plantations.

Inter-rotation management:

- Top-soil and organic matter should be conserved during clearing for plantation establishment, and can best be achieved using excavators rather than bulldozers.
- Ripping of most soils is not justified, but mound or surface ploughing should be used on all soils except those that are very well structured.
- Good preplanting weed control is recommended because it can reduce the need for expensive post-planting weed control on ex-native forest sites.
- The planting of *E. globulus* rather than *E. nitens* is recommended on low elevation sites where moderate water stress is experienced as part of the growing cycle.

Intra-rotation management:

- Fertilisation strategies can be devised for N and P at specific sites. These strategies include expectations of the N and P requirements of the plantations (including weeds and trees), the soils ability to satisfy these needs, and consideration of empirical responses observed at many sites.
- P fertiliser will be needed at planting on all ex-native forest sites; N should also be added (as monoammonium phosphate, or urea with triple superphosphate). No further requirement for P is likely to be needed, but further urea applications will benefit most three- to six-year-old plantations on ex-native forest sites.
- Fertilising soon after planting on highly fertile ex-pasture sites should be avoided because of the potential to induce deformations. Later-age applications of N may also be unnecessary.
- Control of weeds in thinned stands is also recommended because it maximises the growth response of the remaining trees.
- Recovery of the crown after green pruning is rapid, so early pruning followed by thinning can be applied successfully to *E. nitens* plantations to produce clearwood.

Development of process-based models to predict wood yields under a wide range of silvicultural regimes

A number of key outcomes have been achieved which are listed below under four headings.

Reviews:

- A review of existing forest growth models indicated that the appropriate accuracy, scale, types of inputs and range of outputs were suitable for key forest management questions.
- A review of existing models of cambial activity highlighted the possibility of modelling cambial activity of eucalypts as a means to predict pulpwood quality, and has provided the direction for a new PhD project in this area.
- Current forest modelling activity in Australia was the focus of a major seminar and workshop, ForMod95, which has strengthened collaboration and promoted communication between researchers and industry.

Evaluations:

- An evaluation of an existing and widely used process-based model (Forest-BGC) was carried out and the model found to be of limited suitability for forest management purposes.
- An existing empirical model for predicting site quality showed it to be a conservative but biased predictor of site quality for eucalypt plantations.
- Existing datasets suitable for forest growth

modelling were evaluated and several selected for collation and use by researchers throughout Australia.

Models have been developed that:

- simulate the light environment of eucalypt canopies;
- predict above-ground biomass partitioning in response to biomechanical constraints on stem-function;
- predict eucalypt seed germination under conditions of variable temperature and soil-water potential;
- estimate daily canopy photosynthesis using readily available meteorological and physiological data;
- predict site quality for eucalypt plantations using only simple and readily obtained site descriptors;
- predict nutrient uptake kinetics;
- predict forest growth where processes such as biomass and nutrient partitioning are poorly understood by utilising the S-system approach to modelling complex systems.

These models have been applied to:

- explain the response of forests to thinning and highlight the role of competition for water between trees and understorey species in reducing the expected thinning response;
- illustrate the importance of considering photosynthetic acclimation to temperature when simulating forest productivity;
- predict the mean annual increment of *E. globulus* plantations significantly better than does the existing prediction system;
- resolve a long-standing international controversy about nutrient uptake kinetics.

Resource Protection

Determination of the factors that predispose trees to attack by defoliating insects and mammals. It will be possible to establish the relative importance of phenology and colour in host attraction within two years and this information can then be assessed for utilisation in breeding programs

Tree resistance to the *Eucalyptus* leaf-beetle, *Chrysophtharta bimaculata*, is best considered to be due to antixenotic factors (factors which decrease tree favourability for feeding and/or oviposition), rather than antibiotic factors (factors which negatively influence beetle growth and survival following feeding on the tree). In the field, leaf colour (the amount of red in flush) is correlated with *C. bimaculata* oviposition and subsequent damage. It is likely, however, that colour is a correlate, rather than the causative factor of oviposition choice. Early and rapid tree growth have also been shown to lead to lesser amounts of insect damage. Ongoing work is suggesting that choice between trees may simply be related to the amount of soft, expanding foliage carried by the tree at the time of attack; with trees with more flush preferred.

The development of biological control techniques to minimise the damage caused. Enhanced biological control for native insect pests has not been tried in Australia before and it is not possible to provide more quantitative indicators

An integrated pest management (IPM) strategy to control leaf-beetles has been developed and uses currently available control methods (primarily synthetic pyrethroids) in the most economically efficient and environmentally sensitive way to reduce pest populations, while maintaining populations of beneficial insects. Large-scale field trials of the biotic insecticide, *Bacillus thuringiensis* (Btt), have been carried out and ongoing research is aimed at developing better application technology. Laboratory trials have also demonstrated that a number of fungal and bacterial entomopathogens can rapidly kill adult and larval leaf beetles and a new research project has been designed to further develop their use. Artificial manipulation of native predator and parasitoid species has been investigated, but in the light of new findings is now considered to be an impractical control option.

Assessment of the feasibility of breeding insect tolerant genotypes of Eucalyptus spp. *CSIRO Division of Forestry has been working in this area for two years. Future direction and strategy depends on confirming that results are repeatable from season to season and this will take at least three years*

It has been demonstrated that the resistance of *E. regnans* and *E. nitens* to insect attack is a heritable trait within family lines. A wide range of resistance classes (from highly susceptible to resistant) have been shown to occur across families. With this information it is now possible to say that breeding for insect resistant genotypes is feasible. The commercial feasibility of incorporating resistance into breeding programs has yet to be approached, but is a new research initiative being considered for the new CRC.

Development of substances which inhibit or eliminate browsing by vertebrates. Given current knowledge of preferred and non-preferred genotype of plantation stock, it is probable key compounds determining palatability of foliage to browsing by vertebrates and invertebrates are likely to be similar, and it should be possible to determine and test these within three years

This performance indicator at the start of the CRC was based on the current, limited knowledge available from a similar browsing/forestry situation in Victoria. Subsequent research in Tasmania within the Vertebrate Browsing project in the CRC has shown that the situation is not directly transferable to the browsing species in Tasmania. Consequently, the aims of the project have been altered substantially within the last three years. These aims are now being addressed, and the annual goals set from 1994/95 onwards have largely been achieved on time.

Education

The number of post-graduate students trained in areas specified.

We reached the target of 25 post-graduate and honours students that was set in the CRC Joint Venture Agreement within the first two years of the Centre's operation. In 1991/92 there were 16 honours and post-graduate students. The total increased to 28 in 1993, 33 in 1994, 37 in 1995 and 41 in 1996. The students attracted to conduct PhD projects at the CRC were of the highest standard (a great majority with first class honours), and many recruited from interstate.

The number of students enrolled in special courses

Special courses designed to train company operational staff commenced in 1994 with two workshops 'Basic Experimental Design' and 'Basic Quantitative Genetics' (November 1994). These were well attended and have been followed by workshops on 'Forest Protection' (November 1995, May 1996) and 'Water Use' (August 1996). Each workshop has attracted 20 or more participants, drawn from North Forest Products, ANM, Amcor, Bunnings, Forestry Tasmania, CSIRO Forestry and Forest Products and the University of Tasmania.

A special four-year undergraduate course in Forest Ecology, which provides university students with the background to continue in the forest industry, attracts 12-15 students a year.

The Graduate Diploma of Science (Forest Processes) is offered through the Plant Science Department and two students have graduated through this course, but we have found most undergraduates with high academic achievement prefer to enrol in honours.

The quality and numbers of post-doctoral fellows attracted.

During the life of the CRC there have been nine post-doctoral fellows working in the research programs.

In the Resource Protection program, Dr Tony Clarke has played a key role, leading research in projects 2 and 4 on the control of insect defoliators and the biology of other insects pests of *Eucalyptus*. Dr Clare McArthur who was appointed in 1995, has also played a key research role in developing the vertebrate browsing project.

In the Genetic Improvement program, Dr Greg Jordan was appointed post-doctoral fellow in 1991 to conduct a combined analysis of the base populations of *E. globulus*. Dr Omar Hasan was post-doctoral fellow from 1992 to 1994 and identified and quantified gibberellins, auxins and abscisic acid in the cambial tissue of *E. globulus* with the aim of determining their

effect on wood properties. Dr Jean-Noël Ruaud was appointed in August 1994 on a project investigating the use of somatic embryogenesis in vegetative propagation and is now playing a key role leading the tissue culture project. Dr Allie Muneri who was appointed in January 1995 has made a major contribution to the new area of wood science in project 2. Dr Dorothy Steane who was appointed as a molecular geneticist in project 3 in February 1995, soon after her thesis was completed at Oxford University, recently received the annual award from the Linnean Society for the best thesis in plant science in the United Kingdom. She is currently working on the molecular basis for phylogenetic relationships in *Eucalyptus*.

In Soil and Stand Management, Dr Michael Battaglia, who was appointed post-doctoral fellow from May 1993 to June 1994, researched the effect of temperature-acclimation and chilling injury on the photosynthesis of *E. nitens* and *E. globulus* (project 1). In 1996, he was appointed to a research scientist position at CSIRO Forestry and Forest Products in Hobart, and now works with the CRC in another capacity. Dr Wendy Wang worked for two years from July 1994 on the important topic of nitrogen mineralisation in soils. Dr Mark Hovenden, who was appointed in June 1996, is investigating the effects of low temperature and photoinhibition on growth and photosynthesis in plantation eucalypts.

Two of the CRC's post-doctoral fellows, Dr G Jordan and Dr M Battaglia were successful in securing three-year ARC fellowships at the University of Tasmania commencing July 1994. National competition for these fellowships is intense, with only ten per cent of applicants successful.

The acceptance by the forestry community of students on completion of their studies

During the life of the CRC 10 postgraduate and Honours students have been employed in the forestry industry. Further, ten scientific staff from industry are currently enrolled in PhD or MSc courses at the CRC. (For details see Utilisation and Application of Research, point 3)

Technology transfer

The degree of adoption of research results by industry

Studies conducted in each of the three research programs at the CRC for Temperate Hardwood Forestry have led to commercially useful results which are being adopted by the forest industry.

(For details see Utilisation and Application of Research, Table 7).

The quality and relevance of technical publications targeted to user groups.

During the life of the CRC, the three research programs have produced 157 refereed publications, 167 unrefereed publications and 29 Honours and PhD theses. All of these are of direct or indirect relevance to plantation forestry and most are published in journals of international standing. Copies of these publications are circulated amongst user groups. A short summary of the implications of the research is also sent to each of the industrial partners in our one-page news sheet entitled 'Hot off the seedbed'.

The number of seminars, field days, short courses and workshops organised

We have run 75 seminars, 20 workshops, four symposia, five short courses and six field days or field tours in the first five years of the Centre. We estimate our various exercises in technology transfer have reached 11,700 people.

Organise one public seminar on the potential role of hardwood plantations in Australian wood supply within twelve months of Centre establishment

A series of seminars on 'The Role and Potential of Eucalypt Plantations in Australia's Wood Supply' was held in Hobart on 16 June 1992 and attracted 150 participants.

Organise first short course in the second year of the Centre

Two short courses were held in the second year of the Centre:

- 'Tree Improvement for Future Plantations' – a one-day workshop run by Ms C Raymond

(Genetic Improvement program) and Dr P Kriedemann, 12 October 1992 (12 participants).

- 'Establishing Eucalypt Plantations' – held on 5-6 April 1993 for forest growers and organised by Dr C Beadle (Soil and Stand Management program). This was a one-day workshop with presentations by representatives from each of the forestry companies plus a field day and was attended by 50 participants.

Budget

Notes to and forming part of the accounts for 1995/96

Summary of significant accounting policies

All funds under the Cooperative Research Centre's control are administered through the University of Tasmania's Financial Management System (FMS).

The principal accounting policies adopted in preparing the accounts of the unincorporated entity are detailed hereunder.

(a) Basis of accounting and principles of consolidation

The cash accounts have been prepared on the basis of historic costs. Cost in respect to the cash contributions and expenditure is the cash sum exchanged in the financial year determined from transactions recorded on the FMS.

In-kind amounts are the economic values of goods and services declared by each of the joint venture partners and accepted by the entity as being valid.

(b) Interest

Interest is calculated and paid by the University based on the monthly cash balances being held on the FMS on behalf of the entity.

(c) Assets and depreciation

Plant and equipment assets are recorded on the University's asset register in the name of the entity as they are acquired. Their entire cost is expensed in the year of purchase and depreciation is not provided for.

Capital expenditure relates to costs associated with buildings. These costs are also expensed and depreciation is not provided for.

The capital contribution of $150,000 by the University of Tasmania in 1994/95 is part of the provision of new laboratories and accommodation for CRC staff and students in molecular biology. The extension was completed in 1995/96 with a further contribution of $240,000 to capital costs being made by the University.

(d) Employee entitlements

Provision has been made for pro-rata entitlements to annual and long service leave.

(e) Partner contributions

Budget estimates of contributions are taken from the original Commonwealth Agreement and actual figures are provided by the partners.

(f) Allocation from Commonwealth Grant

The CRC received five grant payments during the year 1995/96 (consisting of an outstanding payment from 1994/95 plus the scheduled quarterly payments for 1995/96).

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INDEPENDENT AUDIT REPORT
TO THE MEMBERS OF THE COOPERATIVE RESEARCH CENTRES COMMITTEE REPRESENTING THE COMMONWEALTH IN RESPECT OF

COOPERATIVE RESEARCH CENTRE FOR TEMPERATE HARDWOOD FORESTRY

Scope

We have audited the attached financial information of the Cooperative Research Centre for the Temperate Hardwood Forestry as set out in Tables 1 to 4 of the Annual Report for the year ended 30 June 1996 as required by clause 14(1)(f) of the Commonwealth Agreement. The Directors of the Cooperative Research Centre are responsible for the preparation and presentation of the financial information contained therein, and have determined that the basis of accounting as described in Note 1 is appropriate to meet the needs of the Members of the Cooperative Research Centres Committee. We have conducted an independent audit of the financial information in order to express an opinion to the Members of the Cooperative Research Centres Committee on its preparation and presentation and to report on the matters identified below in relation to the sources and applications of the Cooperative Research Centre for Temperate Hardwood Forestry funding. No opinion is expressed as to whether the basis of accounting as described in Note 1 is appropriate to the needs of the Members of the Cooperative Research Centres Committee.

The financial information has been prepared for distribution to Members of the Co-operative Research Centres Committee and for the purpose of fulfilling the requirements of the Commonwealth Agreement. We disclaim any assumption of responsibility for any reliance on this report or on the financial information to which it relates to any person other than the Members of the Cooperative Research Centres Committee, or for any purpose other than that for which it was prepared.

Our audit has been conducted in accordance with Australian Auditing Standards. Our procedures included examination, on a test basis, of evidence supporting the amounts and other disclosures in the financial information. These procedures have been undertaken to provide reasonable assurance that the Cooperative Research Centre for Temperate Hardwood Forestry has complied with Clauses 4, 5(1), 5(2), 5(3), 9(1), 9(5) and 12(2) of the Commonwealth Agreement and to form an opinion as to whether in all material respects, the financial information presents fairly the sources and applications of funding in accordance with the basis of accounting described in Note 1. These policies do not require the application of all Accounting Standards and Urgent Issues Group Consensus Views.

The audit opinion expressed in this report has been formed on the above basis and reports on compliance with the following matters:

1. The multipliers adopted by the Centre to value in-kind contributions other than salary costs have a sound and reasonable basis. The Researcher's Contributions for the year has been provided at least to the value for that year committed in accordance with the Budget and the total value of all contributions for the year under report equalled or exceeded the amount of grant paid during the year. [Clause 4].

2. The Researcher has used the grant and the Researcher's contributions for the Activities of the Centre and not for any other purpose. [Clause 5(1)].

3. The Researcher's allocations of the budgetary resources between Heads of Expenditure has not been lower or higher than the allocation in the budget by $100,000 or 20% (whichever is the greater amount) without prior approval by the Committee. [Clause 5(2)].

4. Capital Items acquired from the Grant and Researcher's Contributions are vested as provided in the Joint Venture Agreement. [Clause 5(3)].

5. Intellectual Property in all Contract Material is vested as provided in the Joint Venture Agreement and no Intellectual Property has been assigned or licensed without the prior approval of the Committee [Clause 9(1), 9(5)].

6. Proper accounting standards and controls have been exercised in respect of the Grant and Researcher's Contributions and income and expenditure in relation to the Activities of the Centre have been recorded separately from other transactions of the Researcher. [Clause 12(2)].

Qualification

The Cooperative Research Centre for Temperate Hardwood Forestry has not complied with the following requirements of the Commonwealth Agreement:

Clause 4

The contributions by particular Researcher's for the year under report have not been provided to at least the value for that year committed in the budget. The Researcher's who breached the clause are:

Researcher	Amount Committed $ 000	Amount Provided $ 000
Boral	163.0	28.8
Bunnings Treefarms	169.1	78.3

Qualified Audit Opinion

In our opinion the attached financial information presents fairly, in accordance with the basis of accounting described in Note 1, the sources and applications of the Cooperative Research Centre for Temperate Hardwood Forestry funding for the year ended 30 June 1996 and except for the non-compliance detailed above, the Cooperative Research Centre for Temperate Hardwood Forestry has complied with the required clauses of the Commonwealth Agreement.

Price Waterhouse
Chartered Accountants

Steven A Hernyk
Partner

Hobart

31 July 1996

IN-KIND CONTRIBUTIONS FROM PARTNERS ($000's) TABLE 1

EXPENDITURE

PARTNER	ACTUAL								PROJECTED		GRAND TOTAL
	1991/92	1992/93	1993/94	1994/95	1995/96 Actual	1995/96 Budget	Cumulative to date Actual	Cumulative to date Budget	1996/97	1997/98	
CSIRO FORESTRY and FOREST PRODUCTS											
SALARIES	531.4	610.9	613.6	573.3	600.0	566.8	2,929.2	2,725.1	578.2	589.8	4,097.2
CAPITAL											
OTHER	900.4	1,033.9	1,042.5	909.7	879.2	895.1	4,765.7	4,537.2	889.4	883.8	6,538.9
TOTAL	1,431.8	1,644.8	1,656.1	1,483.0	1,479.2	1,461.9	7,694.9	7,262.3	1,467.6	1,473.6	10,636.1
UNIVERSITY OF TASMANIA											
SALARIES	468.4	407.7	330.6	372.8	432.0	503.0	2,031.5	3,535.0	503.0	503.0	3,037.5
CAPITAL	40.0			150.0	240.0	200.0	430.0	240.0			430.0
OTHER	648.7	636.6	553.5	656.0	767.7	727.6	3,262.5	2,873.6	827.5	827.5	4,917.5
TOTAL	1,177.1	1,044.3	884.1	1,178.8	1,439.7	1,430.6	5,724.0	6,648.6	1,330.5	1,330.5	8,385.0
ANM FOREST MANAGEMENT											
SALARIES	21.0	26.0	38.0	45.4	41.0	93.0	171.4	197.0	93.0	93.0	357.4
CAPITAL											
OTHER	28.0	62.0	98.0	59.0	117.0	37.0	364.0	453.0	37.0	37.0	438.0
TOTAL	49.0	88.0	136.0	104.4	158.0	130.0	535.4	650.0	130.0	130.0	795.4
NORTH FOREST PRODUCTS											
SALARIES	84.0	59.3	70.6	109.8	156.7	170.0	460.4	426.0	170.0	170.0	800.4
CAPITAL											
OTHER	107.0	103.7	125.4	122.0	221.4	76.0	679.5	804.0	76.0	76.0	831.5
TOTAL	171.0	163.0	196.0	231.8	378.1	246.0	1,139.9	1,230.0	246.0	246.0	1,631.9

IN-KIND CONTRIBUTIONS FROM PARTNERS ($000's) TABLE 1 CONT

EXPENDITURE

PARTNER	ACTUAL								PROJECTED		GRAND TOTAL
	1991/92	1992/93	1993/94	1994/95	1995/96 Actual	1995/96 Budget	Cumulative to date Actual	Cumulative to date Budget	1996/97	1997/98	
BORAL TIMBER TASMANIA											
SALARIES	39.6	24.2	24.9	3.6	13.8	123.0	106.1	327.0	123.0	123.0	352.1
CAPITAL											
OTHER	50.2	42.6	26.7	4.8	15.0	40.0	139.3	488.0	40.0	40.0	219.3
TOTAL	89.8	66.8	51.6	8.4	28.8	163.0	245.4	815.0	163.0	163.0	571.4
FORESTRY TASMANIA											
SALARIES	47.2	57.3	69.0	77.2	75.4	73.0	326.1	185.0	73.0	73.0	472.1
CAPITAL											
OTHER	61.0	64.6	78.1	79.5	85.5	24.0	368.7	300.0	24.0	24.0	416.7
TOTAL	108.2	121.9	147.1	156.7	160.9	97.0	694.8	485.0	97.0	97.0	888.8
AMCOR PLANTATIONS											
SALARIES		118.1	118.6	79.5	90.2	118.0	406.4	472.0	118.0	118.0	642.4
CAPITAL											
OTHER		81.0	60.6	96.3	124.2	60.0	362.1	240.0	60.0	60.0	482.1
TOTAL		199.1	179.2	175.8	214.4	178.0	768.5	712.0	178.0	178.0	1,124.5
BUNNINGS TREEFARMS											
SALARIES					44.4	86.1	44.4	86.1	86.1	86.1	216.6
CAPITAL											
OTHER					33.9	83.0	33.9	83.0	83.0	83.0	199.9
TOTAL		0.0	0.0	0.0	78.3	169.1	78.3	169.1	169.1	169.1	416.5
TOTAL IN-KIND CONTRIBUTIONS											
SALARIES	1,191.6	1,303.5	1,265.3	1,261.6	1,453.5	1,732.9	6,475.5	7,953.2	1,744.3	1,755.9	9,975.7
CAPITAL	40.0			150.0	240.0	200.0	430.0	240.0			430.0
OTHER	1,795.3	2,024.4	1,984.8	1,927.3	2,243.9	1,942.7	9,975.7	9,778.8	2,036.9	2,031.3	14,043.9
GRAND TOTAL IN-KIND	3,026.9	3,327.9	3,250.1	3,338.9	3,937.4	3,875.6	16,881.2	17,972.0	3,781.2	3,787.2	24,449.6

CASH CONTRIBUTIONS ($000's)

TABLE 2

PARTNERS	ACTUAL 1991/92	1992/93	1993/94	1994/95	1995/96 Actual	1995/96 Budget	Cumulative to date Actual	Cumulative to date Budget	PROJECTED 1996/97	1997/98	GRAND TOTAL
A CSIRO Forestry & Forest Products											
B University of Tasmania	500.0						500.0	500.0			500.0
C Forestry Tasmania											
D North Forest Products					12.7		12.7				12.7
E ANM Forest Management		20.0	20.0	25.0	25.0		90.0		20.0	20.0	130.0
F Boral Timber Tasmania											
G Amcor Plantations					7.3		7.3				7.3
H Bunnings Treefarms											
TOTAL CASH FROM PARTICIPANTS	500.0	20.0	20.0	25.0	45.0		610.0	500.0	20.0	20.0	650.0
INTEREST	10.5	68.6	25.0	60.9	55.6	26.4	220.6		50.0	20.0	290.6
OTHER EXTERNAL FUNDS			1.8	121.0	84.1	30	206.9		20	20	246.9
FUNDING FROM THE CRC GRANT	948.6	1,448.5	1,723.5	1,320.2	2,226.3	1,786.2	7,667.1	7,150.2	1,786.2	1,786.2	11,239.5
TOTAL CRC CASH CONTRIBUTION	1,459.1	1,537.1	1,770.3	1,527.1	2,411.0	1,842.6	8,704.6	7,650.2	1,876.2	1,846.2	12,427.0
Cash carried over from previous year		1,163.4	876.1	951.0	741.4	741.4			989.8	499.0	
Less unspent balance	1,163.4	876.1	951.0	741.4	989.8	408.9			499.0		
TOTAL CASH EXPENDITURE	295.7	1,824.4	1,695.4	1,746.7	2,162.5	2,175.1	7,714.7		2,367.0	2,345.2	12,426.9
ALLOCATION OF CASH EXPENDITURE BETWEEN HEADS OF EXPENDITURE											
SALARIES	118.8	636.1	1,079.6	1,150.2	1,461.1	1,439.8	4,445.8		1,545.7	1,618.9	7,610.4
CAPITAL		500.0	62.0	0.0	20.0		582.0				582.0
OTHER	176.9	688.3	543.8	596.5	681.4	735.3	2,686.9		821.3	726.3	4,234.5

Note: Capital expenditure of $20,000 in 1995/96 was for "Lachat" equipment.

SUMMARY OF RESOURCES APPLIED TO ACTIVITIES OF CENTRE ($000's)

TABLE 3

ALL PROGRAMS

EXPENDITURE

	ACTUAL 1991/92	1992/93	1993/94	1994/95	1995/96 Actual	1995/96 Budget	Cumulative to date Actual	Cumulative to date Budget	PROJECTED 1996/97	1997/98	GRAND TOTAL
GRAND TOTAL (IN-KIND)	3,026.9	3,327.9	3,250.1	3,338.9	3,937.4	3,875.6	16,881.2	17,972.0	3,781.2	3,787.2	24,449.6
GRAND TOTAL (CASH EXPENDITURE)	795.7	1,324.4	1,685.4	1,746.7	2,162.5	2,175.1	7,714.7	7,539.1	2,300.5	2,278.8	12,294.0
TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE	3,822.6	4,652.3	4,935.5	5,085.6	6,099.9	6,050.7	24,595.9	25,511.1	6,081.7	6,066.0	36,743.6

ALLOCATION OF TOTAL RESOURCES APPLIED TO ACTIVITIES OF CENTRE BETWEEN HEADS OF EXPENDITURE

TOTAL SALARIES (CASH AND IN-KIND)	1,310.5	1,939.6	2,345.0	2,411.8	2,914.0	3,172.7	10,921.5	12,165.0	3,290.0	3,374.8	17,586.3
TOTAL CAPITAL (CASH AND IN-KIND)	540.0	0.0	62.0	150.0	260.0	200.0	1,012.0	740.0	0.0	0.0	1,012.0
TOTAL OTHER (CASH AND IN-KIND)	1,972.1	2,712.7	2,528.5	2,523.8	2,925.9	2,678.0	12,662.4	12,606.1	2,791.7	2,691.2	18,145.3

Allocation of resources between categories of activities (1995/96) TABLE 4

PROGRAM	RESOURCE USAGE			
	Cash $000's	In-kind $000's	Staff Contributed	Staff funded by CRC
Research	1,899.1	3,744.5	11.8	12.0
Education	70.4	110.2	0.2	0.5
Commercialisation/ Tech Transfer				
Administration	193.0	82.7	0.5	
TOTAL	2,162.5	3,937.4	12.5	12.5

ATTACHMENT C

RESEARCH STAFF RESOURCES (1995/96)

Employer		Main activity	Total % time	% spent on Research Program			Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC Administration
				Gen	*SSM*	*Prot*				
ANM										
VOLKER, P		R	20	20			20			
HETHERINGTON, S		R	35		15	20	35			
Total			55	20	15	20	55			
Amcor Plantations										
PONGRACIC, S		R	35	20	10	5	35			
WHITEMAN, P		R	25	10	10	5	25			
Total			60	30	20	10	60			
Bunninga Treefarms										
BREIDAHL, R		R	5	5			5			
SHEDLEY, C		R	8	8			8			
DUTKOWSKI, G		R	17	17			17			
MCARTHUR, G		A	5				0			5
Total			35	30	0	0	30			5
North Forest Products										
TIBBITS, W		R	4	4			4			
RASMUSSEN, G		R	10	10			10			
HOLZ, G		R	17		17		17			
DE LITTLE, D		R	10			10	10			
OLIVER,C		R	60		60		60			
DEAN, G		R	5	5			5			
POWELL, M		R	14	14			14			
FRENCH, J		R	3	3			3			
JAMIESON, A		A	8							8
Total			131	36	77	10	123			8
Boral Timber Tasmania										
NAUGHTON, P		R	10		10		10			
Total			10	0	10	0	10			
Forestry Tasmania										
ELEK, J		R	40			40	40			
KUBE, P		R	20	20			20			
ELLIOTT, H		R	10			10	10			
Total			70	20		50	70			

Employer		Main activity	Total % time	% spent on Research Program			Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC Administration
CRC funded				*Gen*	*SSM*	*Prot*				
CLARKE, A	Uni Tas	R	100			100	100			
McARTHUR, C	Uni Tas	R	100			100	100			
DAVIDSON, N	Uni Tas	R	100		50		50	50		
SMETHURST, P	CSIRO	R	100		100		100			
MISRA, R	Uni Tas	R	100		100		100			
HOVENDEN, M	Uni Tas	R	100		100		100			
WANG, X	Uni Tas	R	100		100		100			
POTTS, B	Uni Tas	R	75	75			75			
BORRALHO, N	Uni Tas	R	75	75			75			
MUNERI, A	Uni Tas	R	100	100			100			
RUAUD, J-N	CSIRO	R	100	100			100			
DUTKOWSKI,G	Uni Tas	R	100	100			100			
STEANE, D	Uni Tas	R	100	100			100			
Total			1250	550	450	200	1200	50		

RESEARCH STAFF RESOURCES (1995/96)

Attachment C

Employer		Main activity	Total % time	% spent on Research Program			Total on Research	% spent on Education	% Spent on Commercialisation Program	% spent on CRC Administration
CSIRO Forestry & Forest Products				*Gen*	*SSM*	*Prot*				
SANDS, P		R	80		80		80			
RAYMOND, C		R	100	100			100			
BATTAGLIA,M		R	100		100		100			
BEADLE, C		R	70		70		70			
TURNBULL, C		R	70		70		70			
HARTNEY, V		R	70	70			70			
CROMER, R		R	50		50		50			
MUMMERY, D		R	50		50		50			
Total			590	170	420		590			
University of Tasmania										
REID, J		R	50	20			20			30
VAILLANCOURT, R		R	45	45			45			
BORRALHO, N		R	25	25			25			
POTTS,B		R	25	25			25			
MADDEN, J		R	40			40	40			
HILL, R		R	10		10		10			
GORST, J		R	10	10			10			
MENARY, R		R	10	10			10			
WILTSHIRE, R		R	20		20		20			
CLARK, R		R	10		10		10			
LINE, M		R	10		10		10			
BROWN, P		R	10		10		10			
NEWMAN,I		R	5		5		5			
MENDHAM, N		R	5		5		5			
WHITE, R		A	10				0			10
UNWIN, G		E	25					25		
Total			310	135	70	40	245	25		40

SUMMARY OF CONTRIBUTIONS IN PERSON YEARS (100% = 1 person year)

	Total equiv. person years	Person years spent on Research program			Total on Research	Person years spent on Education Program	Person years spent on Commercialisation Program	Person years spent on CRC Administration
		Gen	*SSM*	*Prot*				
Total Contributed	12.6	4.4	6.1	1.3	11.8	0.2		0.5
Total funded by CRC	12.5	5.5	4.5	2.0	12.0	0.5		
Grand total	25.1	9.9	10.6	3.3	23.8	0.7		0.5
Proportion of total professional (%) staff resources in each activity	100.0	39.5	42.4	13.2	95.1	2.8		2.1

SUPPORT STAFF

Contributed	
Organisation	Number of staff (person years)
ANM	0.0
Amcor Plantations	1.0
North Forest Products	0.4
Boral Timber	0.2
Bunnings Treefarms	0.5
Forestry Tasmania	1.1
CSIRO	4.7
University of Tasmania	1.5
Total	9.4

CRC Funded (by employing organisation)	
Organisation	Number of staff (person years)
CSIRO	0.8
University of Tasmania	13.3
Total	14.1

BORAL TIMBER TASMANIA

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Naughton, P	Scientist	SSM	10								
Badkin, P	Technician	SSM	20								
			Total Salary	31.1	19.0	19.7	2.9	10.8	8.0	8.0	99.5
	Direct On-Costs		*% tot salary*								
	Payroll tax		7.0		1.4	1.4	0.2	0.8			
	Superannuation		5.5		1.1	1.1	0.2	0.6			
	Workers Compensation		5.0		1.0	1.0	0.1	0.5			
	Leave Loading		8.0		1.6	1.6	0.2	0.9			
	Long Service Leave		2.0		0.1	0.1	0.0	0.2			
	Other										
			27.5								
			Total On-Costs	8.5	5.2	5.2	0.7	3.0	2.2	2.2	27.0
			Total Salaries & On-Costs	39.6	24.2	24.9	3.6	13.8	10.2	10.2	126.5

CAPITAL

			Total Capital								

OTHER

	% of Total Salaries & On-Costs							
Head Office Overheads	12.0	4.8	3.9	3.0	0.5	1.7	1.0	1.0	
Office Support	30.0	19.1	23.5	12.1	1.1	4.1	2.4	2.4	
Operational	30.0	26.3	15.2	11.6	1.1	4.1	2.4	2.4	
Vehicle costs	7.0				0.3	1.0	0.6	0.6	
Trial maintenance	8.0				0.3	1.1	0.6	0.6	
Experiments	20.0				1.5	2.8	1.6	1.6	
Land rent	2.0					0.2	0.2	0.2	
		Total Other	50.2	42.6	26.7	4.8	15.0	8.8	8.8	156.9
		TOTAL IN-KIND CONTRIBUTION	89.8	66.8	51.6	8.4	28.8	19.0	19.0	283.4

UNIVERSITY OF TASMANIA

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Reid J	Scientist	Gen	50								
Vaillancourt R	Scientist	Gen	45								
Borralho N	Scientist	Gen	25								
Potts B	Scientist	Gen	25								
Gorst J	Scientist	Gen	10								
Menary R	Scientist	Gen	10								
Cummings I	Technician	Gen	40								
Haig G	Technician	Gen	20								
Smolenski A	Technician	Gen	30								
Dungey H	Student	Gen	100								
Xianming Wei	Student	Gen	100								
Wiltshire R	Scientist	SSM	20								
Clark R	Scientist	SSM	10								
Hill R	Scientist	SSM	10								
Line M	Scientist	SSM	10								
Brown P	Scientist	SSM	10								
Newnam I	Scientist	SSM	5								
Mendham N	Scientist	SSM	5								
Madden J	Scientist	RPP	40								
Rumbold B	Technician	RPP	5								
Unwin G	Scientist	ETT	25								
White R	Scientist	Admin	10								
Johnson G	General	Admin	10								
			Total Salary	324.1	270.5	168.9	225.3	246.7	280.8	286.4	1,802.7

Direct On-Costs	*% total salary*								
Payroll tax	7.0	22.7	18.9	11.8	11.0	17.3			
Superannuation	17.0	55.1	46.0	28.7	26.7	41.9			
Workers Compensation	0.8	3.2	2.7	1.7	1.6	2.0			
Leave Loading	1.3	4.5	3.8	2.4	2.2	3.2			
Long Service Leave	3.2	10.3	8.6	5.4	5.0	7.9			
Outside study-Academics		68.5	57.2	28.0	26.6	40.4			
HECS student contributions				83.7	74.4	72.6			
	Total On-Costs	164.3	137.2	161.7	147.5	185.3	0.0		
	Total Salaries & On-Costs	488.4	407.7	330.6	372.8	432.0	503.0	503.0	3,037.5

CAPITAL

Modifications to Plant Science Building	40.0							
New building/equipment				150.0	240.0			
Total Capital	40.0			150.0	240.0	0.0		430.0

OTHER

	% of Total Salaries & On-Costs								
Academic services	25.0	122.1	101.9	82.6	93.2	108.0			
General uni services	41.0	200.3	167.2	135.5	152.9	177.1			
Dept'l office support	10.0	48.8	40.8	33.0	37.3	43.2			
Laboratory rent	32.0	156.3	130.5	105.8	119.3	138.2			
Office space	8.0	39.1	32.6	26.4	29.8	34.6			
Central Science Lab			80.0	83.2	134.8	88.0			
Management Agency		82.0	83.6	87.0	88.7	176.6			
	Total Other	648.6	636.6	553.5	656.0	767.7	827.5	827.5	4,917.4
	TOTAL IN-KIND CONTRIBUTION	1,177.0	1,044.3	884.1	1,178.8	1,439.7	1,330.5	1,330.5	8,384.9

NORTH FOREST PRODUCTS

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
de Little D	Scientist	RPP	10								
Holz G	Scientist	SSM	17								
Oliver C	Technician	SSM	60								
Tibbits W	Scientist	Gen	4								
Powell M	Scientist	Gen	14								
Rasmussen G	Scientist	Gen	10								
Dean G	Scientist	Gen	5								
French J	Scientist	Gen	3								
Joyce K	Technician	Gen									
Burgess D	Technician	Gen									
Hingston T	Technician	Gen									
Denny W	Technician	Gen									
Jamieson A	Manager	Admin	8								
Walker B	Secretary	Admin									
			Total Salary	58.0	53.7	64.1	86.1	122.9	67.9	67.9	520.6
	Direct On-Costs		*% of total salary*								
	Payroll tax										
	Superannuation										
	Workers Compensation										
	Leave Loading										
	Long Service Leave										
	Other										
			Total On-Costs	6.0	5.6	6.5	23.7	33.8	7.3	7.3	90.2
			Total Salaries & On-Costs	64.0	59.3	70.6	109.8	156.7	75.2	75.2	610.8

CAPITAL

			Total Capital								

OTHER

	% of Total Salaries & On-Costs							
Head Office Overheads	21.0	22.1	17.3	11.3	6.3	17.3	17.3	112.6
Office Support	18.0	6.4	4.2	7.0	3.4	4.2	4.2	47.4
Office hire	20.0	15.8	18.1	23.0		18.1	18.1	112.8
Operational		59.6	85.8	80.7		85.8	85.8	397.7
Experiments	8.0							8.0
Other	40.0				211.7			251.7
Total Other	107.0	103.7	125.4	122.0	221.4	125.4	125.4	930.3
TOTAL IN-KIND CONTRIBUTION	171.0	163.0	196.0	231.8	378.1	200.6	200.6	1,541.1

AMCOR PLANTATIONS

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Whiteman P	Scientist	Gen	10								
Pongracic S	Scientist	Gen	20								
Krygsman M	Technician	Gen	40								
Appleton R	Technician	Gen	15								
Pye C	Technician	Gen	20								
Whiteman P	Scientist	SSM	10								
Pongracic S	Scientist	SSM	10								
Krygsman M	Technician	SSM	20								
Appleton R	Technician	SSM	5								
Whiteman P	Scientist	RPP	5								
Pongracic S	Scientist	RPP	5								
			Total Salary		51.3	51.8	63.7	69.3	70.7	72.1	378.9
	Direct On-Costs		*% of total salary*								
	Payroll tax										
	Superannuation										
	Workers Compensation										
	Leave Loading										
	Long Service Leave										
	Other										
			Total On-Costs		66.8	66.8	15.8	20.9	21.3	21.7	213.3
			Total Salaries & On-Costs		118.1	118.6	79.5	90.2	92.0	93.8	592.2

CAPITAL

			Total Capital								

OTHER

	% Total Salaries & On-Costs							
Head Office Overheads				25.9	39.0	39.8	40.6	145.3
Operational				70.4	85.2	86.9	88.6	331.1
Total Other		81.0	60.6	96.3	124.2	126.7	129.2	618.0
TOTAL IN-KIND CONTRIBUTION		199.1	179.2	175.8	214.4	218.7	223.0	1,210.2

CSIRO Forestry & Forest Products

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Raymond, Ms C	Scientist	Gen	100								
Hartney, Mr V	Scientist	Gen	70								
Churchill, Mr K	Technician	Gen	100								
Svensson, Mr J	Technician	Gen	70								
Baiiaglia, Mr M	Scientist	SSM	100								
Sands, Dr P	Scientist	SSM	80								
Beadle, Dr C	Scientist	SSM	70								
Turnbull, Mr C	Scientist	SSM	70								
Mummery, Mr D	Scientist	SSM	50								
Cromer, Mr R	Scientist	SSM	50								
Lasala, Ms A	Technician	SSM	100								
Cherry, Ms M	Technician	SSM	100								
Hand, Mr F	Technician	SSM	100								
			Total Salary	421.2	484.2	492.4	453.2	474.3	483.7	493.4	3,302.4
	Direct On-Costs		*% of total Salary*								
	Productivity Benefit		3.0	12.6	14.5	14.8	13.6	14.2	14.5	14.8	
	Superannuation		18.6	70.3	80.8	82.1	84.3	88.2	90.0	91.8	
	Workers Compensation		0.9			4.5	4.1	4.3	4.4	4.4	
	Leave Loading		1.5	6.3	7.2	7.4	6.8	7.1	7.3	7.4	
	Long Service Leave		2.5	10.5	12.1	12.4	11.3	11.9	12.1	12.3	
	Other			10.5	12.1	0.0					
			Total On-Costs	110.2	126.7	121.2	120.1	125.7	128.2	130.8	862.8
			Total Salaries & On-Costs	531.4	610.9	613.6	573.3	600.0	611.9	624.2	4,165.2
CAPITAL											
			Total Capital								
OTHER			*% of Total Salaries & On-Costs*								
	Divisional Administration/Support			510.3	586.4	589.0	498.8	459.4	466.2	473.2	3,583.3
	Institute Overheads		6.6	47.8	55.0	55.3	68.8	39.6	40.4	41.2	348.1
	Corporate Overheads		17.5	127.6	146.5	147.3	114.7	105.0	107.1	109.2	857.4
	Amortised capital costs		37.0	196.7	226.0	227.0	212.1	222.0	226.4	230.9	1,541.1
	Direct Operating Allocation			18.0	20.0	23.9	15.4	53.2	20.0	20.0	170.5
			Total Other	900.4	1,033.9	1,042.5	909.7	879.2	860.1	874.5	6,500.3
			TOTAL IN-KIND CONTRIBUTION	1,431.8	1,644.8	1,656.1	1,483.0	1,479.2	1,472.0	1,498.7	10,665.6

FORESTRY TASMANIA

Remised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Elliott, H	Chief, Divn of Silviculture	RPP	10								
Elek, J	Research Forester	RPP	40								
Bashford, R	Technician	RPP	10								
Baker, S	Technician	RPP	50								
Ramsden, N	Technician	RPP	50								
Kube, P	Research Forester	Gen	20								
			Total Salary	39.6	47.5	57.5	64.4	62.9	69.2	76.1	417.2
	Direct on-costs		*% tot.salary*								
	Superannuation		5.0	1.2	2.4	2.9	3.2	3.1	3.4	3.8	20.0
	Workers Compensation		3.5	1.8	2.1	2.1	2.3	2.2	2.4	2.7	15.6
	Leave Loading		12.0	0.6	0.6	0.7	0.8	0.8	0.9	1.0	5.4
	Long Service Leave		3.1	1.2	1.4	1.8	2.0	2.0	2.1	2.4	12.9
	Other		7.0	2.8	3.3	4.0	4.5	4.4	4.8	5.3	29.1
			Total On-Costs	7.6	9.8	11.5	12.8	12.5	13.6	15.2	83.0
			Total Salaries & On-Costs	47.2	57.3	69.0	77.2	75.4	82.8	91.3	500.2

CAPITAL

			Total Capital								

OTHER

	% of Total Salaries & On -Costs							
Head Office Overheads	34.6	14.8	16.4	19.6	22.3	21.4	23.5	25.9	143.9
Office Support(inc equipment,admin)	22.7	9.7	10.7	13.1	14.6	14.5	16.0	17.5	96.1
Corporate Overheads	18.2	7.7	8.6	10.4	11.7	11.3	12.4	13.7	75.8
Operational	48.0	28.8	28.9	35.0	30.9	38.3	42.1	46.3	250.3
	Total Other	61.0	64.6	78.1	79.5	85.5	94.1	103.5	566.1
TOTAL IN-KIND CONTRIBUTION		108.2	121.9	147.1	156.7	160.9	176.9	194.8	1,066.3

ANM FOREST MANAGEMENT

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Volker, P	Scientist	Gen	20								
Hetherington, S	Scientist	SSM	15								
Hetherington, S	Scientist	RPP	20								
			Total Salary	17.0	21.0	29.0	34.4	31.0			
	Direct On-Costs		*% total salary*								
	Payroll tax										
	Superannuation										
	Workers Compensation										
	Leave Loading										
	Long Service Leave										
	Other										
			Total On-Costs	4.0	5.0	9.0	11.0	10.0			
			Total Salaries & On-Costs	21.0	26.0	38.0	45.4	41.0	93.0	93.0	357.4

CAPITAL

			Total Capital								

OTHER

	% of Total Salaries & On -Costs							
Office support		11.0	9.0	10.0	10.0	10.0		
Vehicle costs		7.0	6.0	7.0	11.0	5.0		
Trial maintenance			22.0	53.0	8.0	54.0		
Experiments (land rent)		10.0	25.0	28.0	30.0	48.0		
	Total Other	28.0	62.0	98.0	59.0	117.0	37.0	37.0	438.0
TOTAL IN-KIND CONTRIBUTION		49.0	88.0	136.0	104.4	158.0	130.0	130.0	795.4

BUNNINGS TREEFARMS

Itemised List of In-Kind Contributions (in $'000's)

SALARIES

Name	*Designation*	*Program*	*% time CRC*	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	TOTAL
Dutkowski, G	Scientist	Gen	17								
Shedley, C	Scientist	Gen	8								
Breidahl, R	Scientist	Gen	5								
Pilbeam, D	Technician	Gen	4								
Groom, D	Technician	Gen	7								
Mathieson, S	Technician	Gen	4								
Sims,V	Technician	Gen	6								
Booth, M	Technician	Gen	6								
Jansen,Y	Technician	Gen	6								
Casual Staff	Technician	Gen	4								
Woodard,J	Administration	Admin	5								
McArthur,G	Manager	Admin	5								
			Total Salary					37.6			37.6
	Direct On-Costs		*% tot. salary*								
	Payroll tax		6.0					2.3			
	Superannuation		6.0					2.3			
	Workers Compensation		2.8					1.1			
	Leave Loading		1.3					0.5			
	Long Service Leave		1.7					0.6			
	Other										
			Total On-Costs					6.8			6.8
			Total Salaries & On-Costs					44.4	86.1	86.1	216.6

CAPITAL

			Total Capital								

OTHER

	% of Total Salaries & On-Costs							
Head Office Overheads					14.4	70.0	70.0	
Operational					19.5	13.0	13.0	
			Total Other		33.9	83.0	83.0	199.9
			TOTAL IN-KIND CONTRIBUTION		78.3	169.1	169.1	416.5

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